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Keraudren Extension 3D Marine Seismic Survey Environment Plan

PROJECT / FACILITY	Keraudren Extension 3D Marine Seismic Survey
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ACRONYMS

Abbreviation	Description
°C	Degrees Celsius
3D	3 Dimensional
AAM	Active Acoustic Monitoring
AASM	Airgun Array Source Model
ABARRES	Australian Bureau of Agricultural and Resource Economics and Sciences
ACN	Australian Company Number
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AHO	Australian Hydrographic Office
AIMS	Australian Institute of Marine Science
AIS	Automatic Identification System
ALARP	As Low as Reasonably Practicable
AMOSC	Australian Marine Oil Spill Centre
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
ANSI	American National Standards Institute
APASA	Asia-Pacific Applied Sciences Associates
ASBTIA	Australian Southern Bluefin Tuna Industry Association
BIAs	Biologically Important Areas
BOD	Biological Oxygen Demand
BOSSMAZ	Blended-Over-Streamer-Source-Multi-Azimuth
CAES	Catch and Effort System
CAMBA	China Australia Migratory Bird Agreement
CCI	Chamber of Commerce and Industry
CD	Conservation Dependent
CE	Critically Endangered
CEO	Chief Executive Officer
CH_4	Methane
CM	Control Measure
CMID	Common Marine Inspection Audit

Abbreviation	Description
CO_2	Carbon Dioxide
cP	centipoise
CPUE	Catch-per-unit-effort
CSIRO	Australian Commonwealth Scientific and Industrial Research Organisation
CTDs	Conductivity, Temperature, Depth meters
DAFF	Department of Agriculture, Fisheries and Forestry
DAHs	Dissolved Aromatic Hydrocarbons
dB	Decibels
DBCA	Department of Biodiversity, Conservation and Attractions
DAWR	Department of Agriculture and Water Resources (Commonwealth)
DBCA	Department of Biodiversity, Conservation and Attractions (WA)
DCA	Department of Communications and the Arts (Commonwealth)
DER	Department of Environmental Regulation (Waste Management Branch)
DIIS	Department of Industry, Innovation and Science
DMAC	Diving Medical Advisory Committee
DMP	Department of Mines and Petroleum (WA) – now Department of Mines, Industry Regulation and Safety
DoD	Department of Defence (WA)
DoEE	Department of Energy and Environment (Commonwealth)
DoF	Department of Fisheries (WA) – now Department of Primary Industry and Regional Development
DoNP	Director of National Parks
DoT	Department of Transport (WA)
DPaW	Department of Parks and Wildlife (WA) – now DBCA
DPIRD	Department of Primary Industries and Regional Development
DPLH (Hedland)	Department of Planning, Land and Heritage (Hedland)
DSV	Dive Support Vessel
E	Endangered
EF&LS	Exmouth Freight & Logistics Services
EFL	Electric Flying Leads
EMBA	Environment that May Be Affected
EP	Environment Plan
EPA	Environmental Protection Authority
EPBC	Environment Protection and Biodiversity Conservation

Abbreviation	Description
EPO	Environmental Performance Outcome
EPOs	Environmental Performance Outcomes
EPSs	Environmental Performance Standards
ESD	Ecologically Sustainable Development
FPSO	Floating Production Storage and Offloading
FRC	Fast Rescue Craft
g/cm^3	Gram per cubic centimetre
g/m^2	Gram per square metre
GHG	Greenhouse Gas
HF	High-Frequency
HFO	Heavy Fuel Oil
hrs	Hours
HSE	Health Safety and Environment
HSEMS	Health, Safety and Environment Management System
Hz	Hertz
IAPP	International Air Pollution Prevention
IBA	Important Bird Area
ICPC	International Cable Protection Committee
ICT	Incident Control Team
IFO	Intermediate Fuel Oil
IKU	Marine Diesel analogue from the SINTEF Oil Weathering Model
ISV	Installation Support Vessel
IMCA	International Marine Contractors Association
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMDG	International Maritime Dangerous Goods
IMS	Invasive Marine Species
IMT	Incident Management Team
in^3	Cubic inch
IOGP	International Association of Oil and Gas Producers
ISPP	International Sewage Pollution Prevention
ITOPF	International Tanker Owners Pollution Federation Ltd
IUCN	International Union for Conservation of Nature
JAMBA	Japan Australia Migratory Bird Agreement

Abbreviation	Description
JASURAUS	Underwater cable system
JRCC	Joint Rescue Coordination Centre
JSA	Job Safety Analysis
KEF	Key Ecological Feature
kHz	Kilo hertz
km	Kilometre
km/hr	Kilometres per hour
km^2	Square kilometres
KPI	Key Performance Indicator
L	Litre
LAT	Lowest Astronomical Tide
LMS	Listed Migratory Species
LTS	Listed Threatened Species
m	Metres
M	Migratory
m/h	Metres per hour
m/s	Metres per second
m^3	Cubic metres
MARPOL	International Convention for the Prevention of Pollution from Ships
Max	Maximum
MAZ	Multi Azimuth
MDO/MGO	Marine Diesel Oil/Marine Gas Oil
MF	Mid-Frequency
MFO	Marine Fauna Observer
mins	Minutes
mm	Millimetres
MMA	Marine Management Area
MME	Australian National Plan for Maritime Environmental Emergencies
MMF	Mackerel Managed Fishery
MMO	Marine Mammal Observer
MNES	Matters of National Environmental Significance
MoC	Management of Change
MOD	Maximum over depth

Abbreviation	Description
MODU	Mobile Offshore Drilling Unity
MoU	Memorandum of Understanding
MP	Marine Park
MSS	Marine Seismic Survey
MTWA	Marine Tourism WA
N/A	Not Applicable
N_2O	Nitrous Oxide
ND	No Data
NEBA	Net Environmental Benefit Analysis
NGO	Non-government organisation
nm	Nautical Mile
NMFS	National Marine Fisheries Service (US)
NMSC	(Australian) National Marine Safety Committee
NOPTA	National Offshore Petroleum Titles Administrator
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOx	Oxides of Nitrogen
NWA	North West Alliance
NWCS	North West Cable System
NWS	North West Shelf
OCNS	Offshore Chemical Notification Scheme
ODS	Ozone Depleting Substance
OPEP	Oil Pollution Emergency Plan
OPGGS (E) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
OPP	Offshore Project Proposal
OSRL	Oil Spill Response Limited
OSRT	Oil Spill Response Team / Oiled Shoreline Response Team
OVID	Offshore Vessel Inspection Document
OWM	Oil Weathering Model
OWRP	Oiled Wildlife Response Plan
PAH	Polycyclic Aromatic Hydrocarbon
PAM	Passive Acoustic Monitoring
PFTIMF	Pilbara Fish Trawl Interim Managed Fishery
PGS	PGS Pty Ltd

Abbreviation	Description
PHGFC	Port Hedland Game Fishing Club
PHVMR	Port Hedland Volunteer Marine Rescue
PHYC	Port Hedland Yacht Club
PK	Peak
PMS	Planned Maintenance System
PMST	Protected Matters Search Tool
PPA	Pearl Producers Association
ppb	Parts per billion
ppm	Parts per million
PROWRP	Pilbara Regional Oiled Wildlife Response Plan
psi	Pounds per square inch
PTS	Permanent threshold shift
R95%	The range to the given sound level after the 5% farthest points were excluded
RL	Received levels
R_{max}	The maximum range to the given sound level over all azimuths
RMS	root mean square
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
SBRUVS	Stereo baited remote underwater video system
ROV	Remote Operated Vehicle
SDS	Safety Data Sheet
SEL	Sound Exposure Level measured as dB re 1 $\mu Pa^{2} \cdot s$
SIMOPs	Simultaneous Operations
SINTEF	Norwegian applied research organisation
SL	Source level
SMPEP	Shipboard Marine Pollution Emergency Plan
SOLAS	Safety of Life at Sea
SOPEP	Shipboard Oil Pollution Emergency Plan
SOx	Oxides of Sulphur
SPRAT	Species Profile and Threats database
TACC	Total allowable commercial catch
TBC	To be confirmed
TTS	Temporary threshold shift
VI	Varanus Island

Abbreviation	Description
VOO	Vessel of Opportunity
V	Vulnerable
VSP	Vertical seismic profiling
WA	Western Australia
WAF	Water Accommodated Fraction
WAFIC	Western Australian Fishing Industry Council
WAOWRP	WA Oiled Wildlife Response Plan
WDCS	Whale and Dolphin Conservation Society

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Appendix B – Values and Sensitivities of the Marine and Coastal Environment

Appendix C – EPBC Act Protected Matters Search Reports (Operational Area and EMBA) and Aboriginal Heritage Inquiry System Searches

Appendix D – RPS (2019) Ancient Coastline KEF Fish and Pearl Oyster Habitat Survey Report

Appendix E – FishCube Data

Appendix F – Stakeholder Consultation

Appendix G – Santos Risk Matrix and Consequence Table

Appendix H – JASCO Keraudren Extension 3D Marine Seismic Survey Acoustic Modelling

Appendix I – Noise Impacts Technical Appendix

Appendix J – Hydrocarbon Pathways and Thresholds

0. EP Summary

An Environment Plan (EP) summary has been prepared from material provided in this EP. This summarises the items listed in **Table 0-1**, as required by Regulation 11(4) of the Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.

Table 0-1: EP Summary Table

EP Summary Material Requirement	Relevant EP Section
Details of the titleholders nominated liaison person for the activity	**Section 1.4**, page 23
The location of the activity	**Section 2.3**, page 27
A description of the activity	**Section 2**, pages 26 - 34
A description of the receiving environment	**Section 3**, pages 35 - 125
Consultation already undertaken and plans for ongoing consultation	**Section 4**, pages 126 - 156
Details of the environmental impacts and risks	**Section 6 and 7**, pages 162 - 409
The control measures for the activity	**Section 8.6**, pages 414 - 436
The arrangements for ongoing monitoring of the titleholder's environmental performance	**Section 8**, pages 410 - 433
Response arrangements in the oil pollution emergency plan	**Section 8.11**, page 439 (EP); and **Section 4**, pages 38 – 40 (OPEP)

1. Introduction

Santos WA Northwest Pty Ltd (Santos) completed the Keraudren 3-Dimensional (3D) Marine Seismic Survey (MSS) between May and July 2019. The survey acquired 2,140 square kilometres (km^2) of 3D seismic data but achieved coverage of only 65% of the planned exploration component of the survey. The survey was not completed as planned due to the late arrival of the seismic survey vessel and the termination of the survey due to the onset of peak humpback whale migration.

As the objectives of the survey were not fully met, additional 3D seismic data acquisition is required to complete the original program as proposed by Santos. Additionally, subsequent to acceptance of the Keraudren 3D MSS, further geological studies have identified the requirement for the acquisition of additional 3D seismic data to the north-east of the originally planned survey area. This Environment Plan (EP) provides for the acquisition of a new survey, the Keraudren Extension 3D MSS, over these two areas.

1.1 Background

Recent exploration drilling undertaken by Santos in the Bedout Sub-basin has identified hydrocarbons within several new reservoirs. These results have highlighted the potential to extend prospectivity to a larger area than previously recognised. In order to evaluate this potential, Santos needs to acquire a new 3D MSS.

Santos' Bedout permits expire in August 2021 and while they can be renewed, 50% of the permit area must be relinquished at that time. The incorporation of the Keraudren Extension 3D MSS data into regional geologic models will be key to developing a clearer understanding of the area's prospectivity and will form the basis of the relinquishment strategy. As such, it is important that as much of the survey as possible be acquired during the 2020 acquisition season.

New seismic data coverage is proposed largely over areas not currently covered by 3D seismic survey data; however, there is some overlap with vintage 3D data. The current 2D seismic data in the survey area provides only a sparse coverage and poor data quality, which is insufficient to define potential exploration drilling opportunities. Where new acquisition is proposed over areas with existing 3D seismic data coverage, modern acquisition techniques are expected to provide improved data quality allowing for more efficient exploration for hydrocarbon resources.

1.2 Activity Overview

Santos plans to conduct the Keraudren Extension 3D MSS in the Bedout Sub-basin within exploration permit areas WA-435-P, WA-436-P, WA-437-P and WA-438-P, and surrounding waters. The seismic survey vessel will tow a seismic source array and a series of streamers across the survey area. During the survey, the seismic source will emit pulses of high-intensity, low-frequency sound. Sound will reflect from the underlying rock layers beneath the seabed, and the reflected sound will be recorded by the towed streamers.

The Keraudren Extension 3D MSS may be acquired in stages. The exact area to be acquired in each stage will be determined based on operational and timing factors. To allow for flexibility due to vessel availability, approval timings, budget cycles, environmental sensitivities and other factors, a period of three years (2020 to 2022) is proposed in which to complete the survey. It is Santos' intention to acquire the full survey within two of the three years.

1.3 Purpose of this Environment Plan

The Keraudren Extension 3D MSS EP has been prepared in accordance with the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations) for assessment and acceptance by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). This EP details the environmental impacts and risks associated with the Keraudren Extension 3D

MSS, the defined Petroleum Activity (or 'Activity') and demonstrates how these will be reduced to as low as reasonably practicable (ALARP) and to an acceptable level.

The EP provides an implementation strategy that will be used to measure and report on environmental performance during planned activities and unplanned events. The environmental management of the Activity described in the EP complies with the Santos Environmental Management Policy (QE-91-IQ-00047_REV 5) (**Figure 1-1**) and with all relevant legislation. This EP documents relevant stakeholder consultation performed during the planning of the Activity.

This EP will be valid from the date that it is accepted by NOPSEMA, until 31st December 2022.

1.4 Titleholder

OPGGS(E)R 2009 Requirements
Regulation 15. Details of titleholder and liaison person.
(1) The environment plan must include the following details for the titleholder: a) name; b) business address; c) telephone number (if any); d) fax number (if any); e) email address (if any); and f) if the titleholder is a body corporate that has an Australian Company Number (ACN) (within the meaning of the *Corporations Act 2001*). (2) The environment plan must also include the following details for the titleholder's nominated liaison person: a) name; b) business address; c) telephone number (if any); d) fax number (if any); and e) email address (if any).

1.4.1 Details of Titleholder

Santos WA Northwest Pty Ltd (Santos) will undertake the Petroleum Activity (within exploration permits WA-435-P, WA-436-P, WA-437-P and WA-438-P and surrounding waters). Santos WA Oil Southwest Pty Ltd and Santos WA Northwest Pty Ltd are 100% owned subsidiaries of Santos Energy Limited. Titleholder details are provided in **Table 1-1**.

Table 1-1: Titleholder details

Titleholder	ACN/ABN	% Interest				Address
		WA-435-P	WA-437-P	WA-436-P	WA-438-P	
Santos WA Southwest Pty Limited	**ACN** 050 611 688 **ABN** 63 050 611 688	20	20	30	30	Business Address: Level 7, 100 St Georges Terrace, Perth, Western Australia 6000 Telephone number: (08) 6218 7100 Fax number: (08) 6218 7200 Email address: Offshore.environment.admin@santos.com
Santos WA Northwest Pty Ltd	**ACN** 009 140 854 **ABN** 58 009 140 854	60	60	40	40	
Carnarvon Petroleum Ltd	**ACN** 002 688 851 **ABN** 60 002 688 851	20	20	30	30	Business Address: 2/76 Kings Park Rd, West Perth, Western Australia 6005 Telephone number: (08) 9321 2665 Fax number: (08) 9321 8867 Email address: admin@cvn.com.au

1.4.2 Details for Santos' Nominated Liaison Person

Details for Santos' Nominated Liaison Person for the Activity are as follows:

Name: Michael Giles (Geophysical Manager)

Business address: Level 7, 100 St Georges Terrace, Perth, WA 6000

Telephone number: (08) 6218 7100

Email address: Offshore.environment.admin@santos.com

Additional information about Santos and its operations can be obtained from the website at: www.santos.com.

1.4.3 Notification Procedure in the Event of Changed Details

If there is a change in the titleholder, the titleholder's nominated liaison person or a change in the contact details for the titleholder or liaison person, Santos will notify NOPSEMA in writing and provide the updated details.

1.5 Environmental Management Framework

OPGGS(E)R 2009 Requirements
Regulation 13. Environmental assessment.
Requirements (4) The environment plan must: a) describe the requirements, including legislative requirements, that apply to the Activity and are relevant to the environmental management of the Activity; and b) demonstrate how those requirements will be met.
Regulation 16. Other information in the environment plan.
The environment plan must contain the following: a) a statement of the operator's corporate environmental policy.

1.5.1 Environmental Management Policy

The Activity will be conducted in accordance with the Santos Environmental Management Policy (QE-91-IQ-00047_REV 5) (**Figure 1-1**) and relevant legislative requirements presented within **Appendix A,** inclusive of references to the relevant EP sections where the legislation may prescribe or control how the Activity is undertaken. **Sections 6, 7** and **8** of this EP detail and evaluate impacts and risks from planned activities and unplanned events, provide control measures, set environmental performance outcomes and standards, and provide the strategy for ensuring environmental performance is achieved, as outlined within the EP.

1.5.2 International Legislation

Australia is signatory to numerous international conventions and agreements that obligate the Commonwealth government to prevent pollution and protect specified habitats, flora and fauna. Those that are relevant to the Activity are detailed in **Appendix A.**

1.5.3 Commonwealth Legislation

All activities conducted under the EP will comply with legislative requirements established under relevant Commonwealth legislation, and in line with applicable best practice guidelines and management procedures. These are further detailed in **Appendix A**.

Environmental Management

Policy

Our commitment

We share the community's concern for the proper care and custody of our environment for present and future generations. At Santos protecting the environment and valuing cultural heritage are an integral part of the way we do business.

Our objective is to implement best environmental practices wherever practical to do so. We are committed to demonstrating leadership in environmental management and ensuring that our actions are performed in a manner which has acceptable impact on the land, sea and air.

We will comply with all applicable environmental legislation and regulations relevant to our business.

We will promote continuous improvement in energy efficiency, greenhouse gas emission reduction and innovation to reduce our carbon footprint and energy use.

Our actions

Wherever we operate we will:

+ Maintain open community and government consultation regarding our activities and our environmental performance
+ Educate, train and encourage our workforce to conduct activities in an environmentally responsible manner
+ Identify, assess and control risks to the environment and the surrounding community in order to manage the potential for unacceptable pollution and impacts
+ Develop and implement systems to manage all activities which have the potential to affect the surrounding natural environment
+ Measure our environmental performance and set targets for continual improvement; and
+ Conduct monitoring of the surrounding natural environment thereby contributing to knowledge of natural systems and enabling any impacts to be detected.

Governance

This policy has been reviewed and endorsed by the Santos WA Energy Holdings Board of Directors and management who foresee benefits in, and take responsibility for, its successful implementation.

By accepting employment with Santos, each employee and contractor acknowledges that they are responsible for the application of this policy.

K. T. Gallagher

Kevin Gallagher
Managing Director & CEO

APPROVED 28 November 2018 QE-91-IQ-00047_REV 5

Figure 1-1: Santos Environmental Management Policy

2. Activity Description

OPGGS(E)R 2009 Requirements
Regulation 13. Environmental assessment.
Description of the Activity: (1) The environment plan must contain a comprehensive description of the Activity including the following: a) the location or locations of the Activity; b) general details of the construction and layout of any facility; c) an outline of the operational details of the Activity (for example, seismic surveys, exploration drilling or production) and proposed timetables; and d) any additional information relevant to consideration of environmental impacts and risks of the Activity. Note: An environment plan will not be capable of being accepted by the Regulator if an activity or part of the Activity, other than arrangements for environmental monitoring or for responding to an emergency, will be undertaken in any part of a declared World Heritage property – see regulation 10A.

2.1 Activity Overview

Santos plan to conduct the Keraudren Extension 3D MSS in the Bedout Sub-basin within exploration permit areas WA-435-P, WA-436-P, WA-437-P and WA-438-P and surrounding waters.

During the survey, a seismic survey vessel will tow a seismic source array and a series of streamers within the operational area of the survey, as defined in **Section 2.3**. The seismic source will emit pulses of low-frequency sound which will reflect from the underlying rock layers beneath the seabed, and the reflected sound (seismic data) will be recorded by the towed streamers.

The seismic survey vessel will be supported by other marine vessel and helicopter operations.

2.2 Terminology

To aid interpretation of the Activity description and impact assessment sections, **Table 2-1** defines key terminology used.

Table 2-1: Key terminology

Term	Explanation
Activity	The Keraudren Extension 3D MSS, including all supporting activities.
Racetrack	The method by which sail lines are traversed to acquire the seismic survey data, comprising circuits that resemble a simple racetrack.
Seismic source	Comprises a configuration of multiple seismic source elements (“airguns”) which discharge seismic pulses necessary to achieve the survey objectives.
Seismic source interval	Interval between individual seismic pulses, sometimes referred to as “source point interval”.
Seismic survey vessel	Vessel towing the seismic source arrays and streamers.
Streamers	A series of cables towed underwater behind the seismic survey vessel. The streamers accommodate hydrophones which record seismic reflections.
Support vessel	Vessel undertaking support functions such as assisting with the management of on the water communications with other third-party vessels, refuelling and resupply. Support vessel includes a ‘chase boat’.

Full power zone	Refer to **Table 2-2**
Ramp up zone	Refer to **Table 2-2**
Operational area	Refer to **Table 2-2**
Survey area	Comprises the 'full power zone' and 'ramp-up zone'.

2.3 Location and Operational Area

There are three areas defined for the Activity based on the output of the seismic source. These are: (i) the "full power zone"; (ii) the "ramp-up zone"; and (iii) the encompassing "operational" area. **Figure 2-1** shows these areas and a description and coordinates for each area is provided in **Table 2-2**.

The operational area is located entirely within Commonwealth waters. Water depths range between approximately 40 meters (m) and 250 m (below mean sea level). The operational area is located approximately 45 kilometres (km) from the nearest land (Bedout Island), 56 km from the nearest mainland coastline and 141 km from Port Hedland.

2.4 Activity Duration and Timing

The survey is estimated to take 132 days to complete in total. This is the estimated number of days that the seismic survey vessel would theoretically need to acquire the seismic data and conduct survey line changes. The estimated survey duration does not provide for potential delays caused by slow vessel speeds, strong ocean currents, weather downtime, standby (e.g. caused by whale sightings) and equipment failure or other delays relative to the acquisition plan, as these are factors that are difficult to predict. An additional 30 days of contingency time within the operational area has been provided as part of the environmental assessment. Therefore, including contingency time, the survey is estimated to take up to approximately 162 days to complete. However, should additional contingency time be required within the operational area to complete the survey objectives then Santos will assess the situation in accordance with the Santos Management of Change Procedure (refer to **Section 8.10**).

The seismic survey may be acquired in stages between 2020 and 2022. This may result in the decision to continue the survey beyond 162 days within the operational area if considered to be acceptable and ALARP. The exact area to be acquired in each stage will be determined by operational and timing factors. The timing of the survey is dependent upon vessel availability, weather conditions, the receipt of the required statutory approvals and the control measures within this EP. During any year that a survey stage is undertaken, it will be undertaken within a window between 1 February and 31 July.

Santos

Table 2-2: Proposed Keraudren Extension 3D MSS areas of operation and coordinates

Operational Area		Ramp-up Zone		Full Power Zone	
The operational area defines the area within which the seismic survey vessel will operate during the normal conduct of the Petroleum Activity[1]. It includes the full power and ramp-up zones, but also a working buffer beyond these zones. The operations to be conducted within this area include active acquisition within the full power zone, source emissions within the ramp-up zone, line changes, general equipment maintenance and other miscellaneous activities. Within the operational area, the seismic source or individual source elements within the array may be infrequently discharged at or less than full capacity for testing (e.g. bubble tests) or maintenance purposes. Testing typically takes just minutes or a few hours to complete and is required to ensure seismic source integrity, both in terms of measured output and timing of firing.		This is a zone that surrounds the full power zone. Typically, this zone will be used to incrementally build the power of the seismic source from non-operation to full capacity, for the purpose of soft starts. Additionally, this zone may also be used for occasional source testing at, or below, full capacity.		This is the area within which the seismic source will be operated in full acquisition mode to achieve the geophysical objectives of the survey. Within this zone, the normal mode of operation is to systematically traverse the pre-determined sail lines, discharging the source at full capacity. However, the source may also be used at less than full capacity within this zone.	
Water depth: ~40 m to 250 m		Water depth: ~40 m to 185 m		Water depth: ~40 m to 168 m	
Area: 20,160 km^2		Area: 2,610 km^2		Area: 8,620 km^2	
		Total Area: 11,230 km^2 (Ramp-up + Full Power Zones)			
Longitude	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Latitude**
18° 26' 32.738" S	118° 26' 4.740" E	18° 10' 57.888" S	118° 51' 45.140" E	18° 15' 15.614" S	118° 56' 13.557" E
18° 5' 18.564" S	118° 40' 25.232" E	18° 10' 30.586" S	119° 42' 24.332" E	18° 14' 43.455" S	119° 38' 25.121" E
17° 57' 7.051" S	119° 3' 1.378" E	18° 44' 44.964" S	119° 42' 38.024" E	18° 43' 55.800" S	119° 38' 47.487" E
17° 56' 44.087" S	119° 11' 2.402" E	18° 50' 39.171" S	119° 52' 29.602" E	18° 49' 11.844" S	119° 48' 7.049" E
17° 58' 32.902" S	119° 31' 53.285" E	19° 7' 9.723" S	119° 44' 4.967" E	19° 5' 57.520" S	119° 40' 3.690" E
18° 2' 52.093" S	119° 39' 58.421" E	19° 25' 56.147" S	119° 42' 3.685" E	19° 21' 59.811" S	119° 37' 46.341" E
18° 17' 20.155" S	120° 0' 0.000" E	19° 6' 46.482" S	119° 6' 11.190" E	19° 7' 58.198" S	119° 10' 40.660" E
19° 10' 31.098" S	120° 0' 0.000" E	19° 4' 14.839" S	119° 7' 42.438" E	19° 5' 8.669" S	119° 12' 10.778" E
19° 24' 31.689" S	119° 56' 39.463" E	18° 46' 34.167" S	118° 33' 50.647" E	18° 47' 35.461" S	118° 38' 55.856" E
19° 26' 42.291" S	119° 49' 41.819" E	18° 36' 1.731" S	118° 40' 15.131" E	18° 38' 47.154" S	118° 44' 2.985" E
19° 26' 40.134" S	119° 42' 23.081" E	18° 38' 12.267" S	118° 44' 36.644" E	18° 41' 22.444" S	118° 49' 2.241" E
19° 7' 30.768" S	119° 6' 11.750" E	18° 34' 53.713" S	118° 52' 8.215" E	18° 38' 12.487" S	118° 56' 33.063" E
18° 48' 31.035" S	118° 30' 27.033" E				
18° 37' 56.772" S	118° 22' 18.078" E				

[1] Note, at any time during the survey, the seismic survey vessel may depart the operational area if, in the opinion of the vessel master, the safety of the vessel and crew is at risk e.g. in the event of severe sea/weather conditions restricting manoeuvring capabilities. In this instance, the seismic survey vessel may have its seismic equipment deployed in the water but will not be permitted to discharge the seismic source. Likewise, during mobilisation and demobilisation to the operational area the seismic vessel may have its seismic equipment deployed in water, as permitted under maritime law, but will not be permitted to discharge a seismic source.

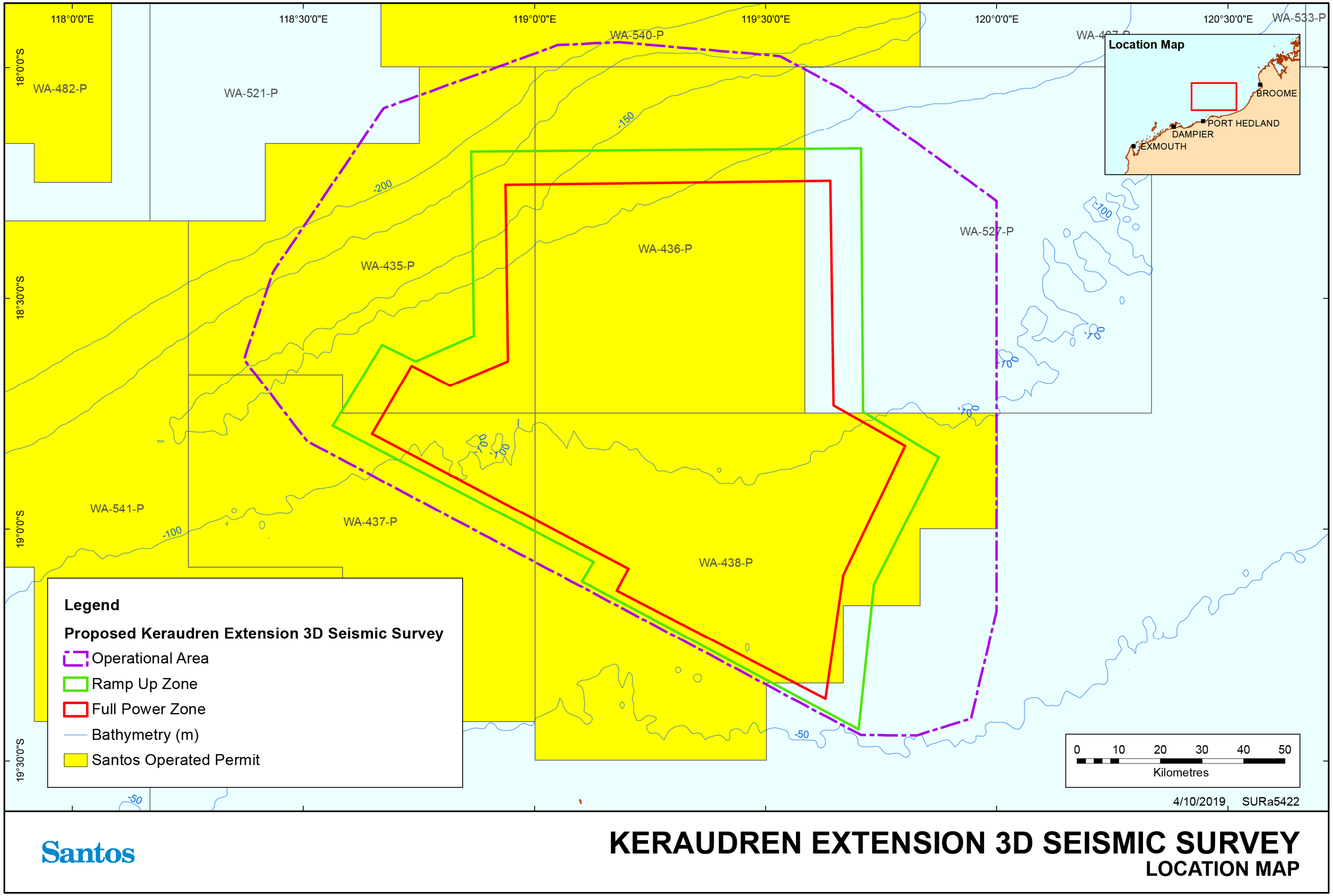

Figure 2-1: Location of full power zone, ramp-up zone and operational area

2.5 Acquisition Parameters

During the proposed seismic acquisition, the seismic survey vessel will traverse a series of pre-determined sail lines within the ramp-up and full power zone at a speed of approximately 4.5 knots (8.3 kilometres per hour (km/hr)). The seismic survey vessel will turn to make line changes within the operational area. The sail lines will be spaced approximately 450 m apart. The seismic survey vessel will typically complete the lines in a 'racetrack' (or loop) formation, whereby a line is completed and the vessel turns to survey a parallel line offset by several kilometres, before turning again to survey a line adjacent to but offset by 450 m from the first line. The racetrack formation is continued with the seismic survey vessel gradually moving across the full power zone.

The seismic source will be towed behind the seismic survey vessel and at a depth of approximately 7 m below sea level. The seismic source will be suspended centrally above the spread of streamers, which will be towed at approximately 20 m depth. The seismic source will either be a 'dual source' or a triple source. Dual source has two full identical arrays that are discharged alternately at a 12.5m spacing (each source discharged every 25m). Triple source has three identical sources with a single source alternately discharging at 8.33m, which results in each individual source discharging every 25m.

A summary of the survey parameters is provided in **Table 2-3.**

2.5.1 Survey Line Plan Options

This EP allows for two different line plan options, involving different survey azimuths (line orientations). Option 1 (**Figure 2-2**) provides for acquisition along lines orientated at 120/300 degrees, principally covering exploration permit areas WA-435-P, WA-437-P and WA-438-P, and at 90/270 degrees over permit area WA-436-P. Option 1 includes approximately 5 km of survey overlap to account for the different acquisition azimuths. Option 2 (**Figure 2-3**) provides for the survey to be acquired entirely along lines orientated at 120/300 degrees.

A summary of the different survey parameters for each option is provided in **Table 2-3**.

2.5.2 Staged Acquisition

Based on an estimated 162 days to acquire the required seismic data, it may be possible to achieve this within a February to July timeframe in a single year. It is more likely, however, that the seismic acquisition will be staged across a maximum of 3 years. The exact area to be acquired in each stage will be determined based on operational and timing factors, and in consultation with stakeholders.

If staging is required, then each survey stage will need to 'overlap' with the previous stage in order to tie-in the acquired seismic data. The approximate overlaps would be 900 m (two sail lines) between each stage of parallel acquisition).

Table 2-3: Acquisition parameters

Parameter	Seismic Survey Parameters	
	Common Parameters	
Volume of seismic source	Max. 3,500 cubic inches (in^3)	
Operating pressure	2,000 psi	
Seismic source depth	Approx. 7 m	
Vessel speed	Approx. 4.5 knots (8.33 km/hr)	
Seismic source interval	Either 8.3 m (triple source) or 12.5 m (dual source)	
Seismic streamer length	Approx. 9,100 m	
Total seismic streamer spread width	825m at head, 990 m at tail (nominal)	
Seismic streamer depth	Nominally 20 m, always >10m above seabed.	
Sail line spacing	450 m	
	Option 1	**Option 2**
Survey azimuth (line orientation)	Partially 120/300 degrees, and 90 / 270 degrees	Entirely 120/300 degrees
Acquisition Area (within full power zone)	7,070 km^2	6,831 km^2
Average sail line time to traverse	Approx. 8 hours (hrs) 20minutes (mins)	Approx. 9 hrs 20 mins
Sail line turn time	Approx. 3 hrs 10 mins	Approx. 3 hrs 02 mins
Total expected duration (includes contingency)	162 days	151 days

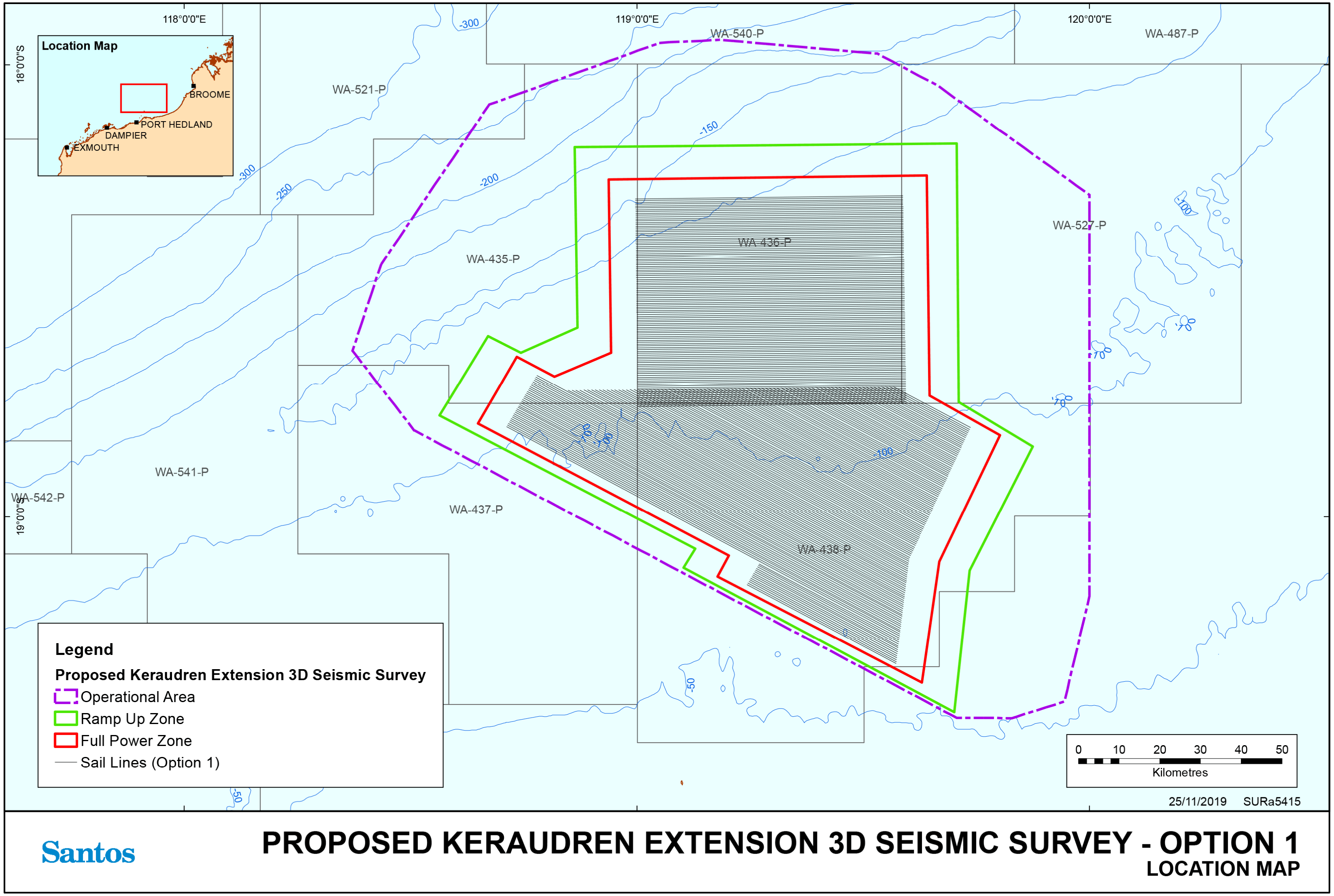

Figure 2-2: Keraudren Extension 3D MSS – Option 1 Survey Design

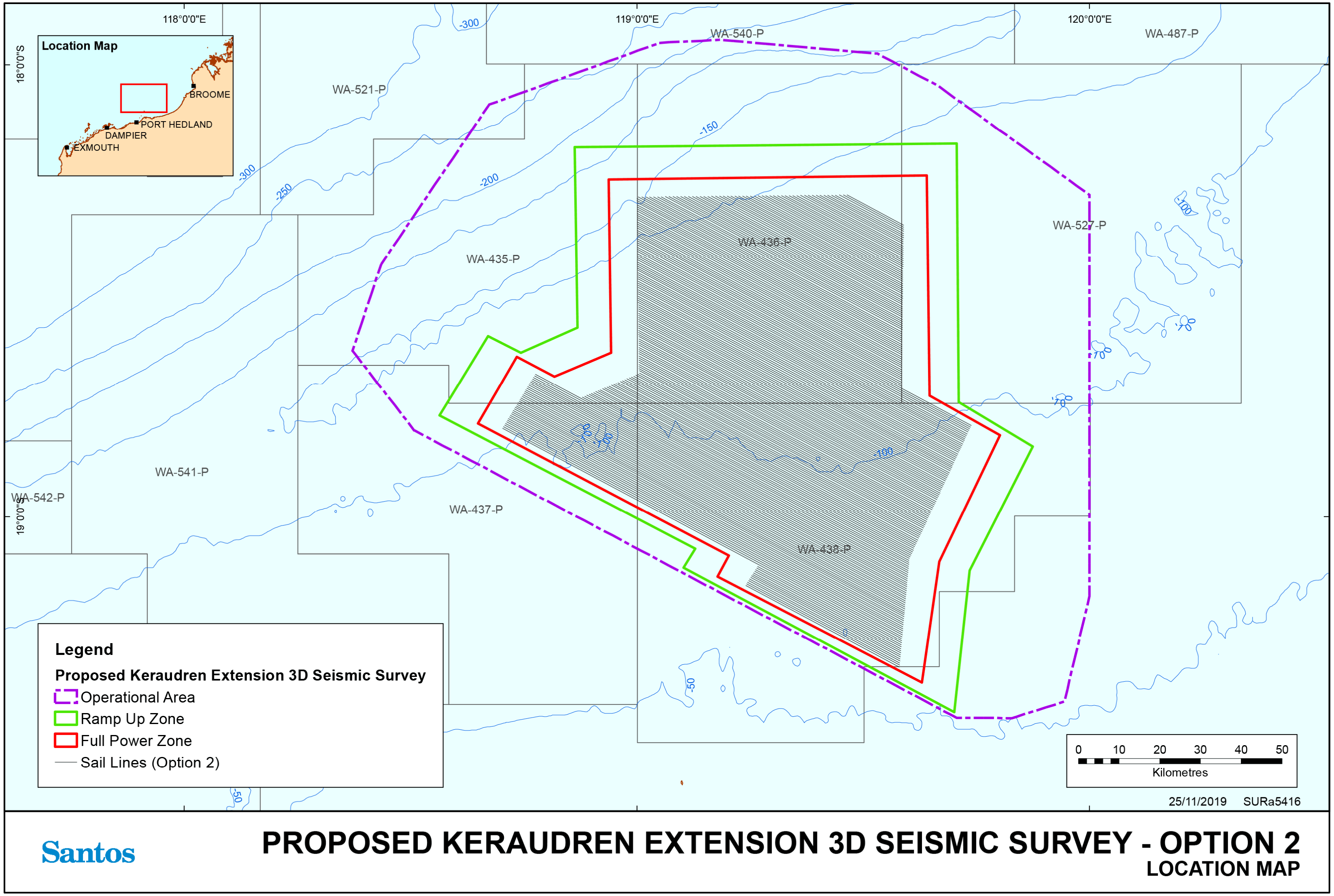

Figure 2-3: Keraudren Extension 3D MSS – Option 2 Survey Design

2.6 Support Vessels

Up to two dedicated support vessels (one being a chase vessel) will accompany the seismic survey vessel to provide logistical, safety and equipment management duties. At least one vessel will be rigged and capable of towing the seismic survey vessel in the case of an emergency. The vessels will also mobilise to and from the mainland to undertake re-supply, refuelling and other support functions for the Activity. The support vessels may be required to leave the operational area to respond to unplanned events such as retrieval of accidentally over boarded floating objects, or communicating with a third-party vessel, or for other logistical and safety reasons.

The seismic survey vessel will have an on-board workboat, which may be launched from the seismic survey vessel to assist with equipment deployment and retrieval, or to carry out streamer maintenance activities. The seismic survey vessel will also have a fast rescue craft (FRC) on-board.

2.7 Aircraft

Aircraft maybe used for crew changes, critical equipment supply, surveillance and emergency response uses. Aircraft includes helicopters and drones.

3. Description of the Environment

OPGGS(E)R 2009 Requirements
Regulation 13. Environmental assessment.
Description of the environment (2) The environment plan must: a) describe the existing environment that may be affected by the Activity; and b) include details of the particular relevant values and sensitivities (if any) of that environment.

3.1 Environment that May Be Affected (EMBA)

This section summarises the key physical, biological, socio-economic and cultural characteristics of the existing environment that may be affected (EMBA), both from planned activities and unplanned events associated with the Activity. The description of the environment applies to two areas:

- The operational area as described in **Table 2-2**; and
- The EMBA, shown in **Figure 3-1**.

Most planned activities and unplanned events associated with the Activity may affect the environment up to a few hundred metres from the marine vessel or aircraft. However, underwater acoustic emissions from seismic sources will, and a large unplanned vessel hydrocarbon spill would, extend substantially beyond a few hundred metres.

3.1.1 Underwater Acoustic Emissions EMBA

Numerical acoustic modelling shows that noise levels exceeding predefined impact thresholds (refer to **Section 6.2**) do not exceed the boundary of the unplanned vessel hydrocarbon spill EMBA, as described below. Therefore, the unplanned hydrocarbon spill EMBA represents the overall EMBA for activities conducted under this EP.

3.1.2 Unplanned Vessel Hydrocarbon Spill EMBA

Credible unplanned vessel hydrocarbon spill scenarios that have been considered for the EMBA and assessed in **Section 7** of this EP are outlined in **Table 3-1**. Stochastic hydrocarbon dispersion and fate modelling applied to the largest credible hydrocarbon spill scenario, as summarised in **Section 7.1**, was undertaken to inform the EMBA. The EMBA has, therefore, been based on the largest credible hydrocarbon spill scenario – the release of 1,065 cubic meters (m^3) of marine diesel oil / marine gas oil (MDO / MGO). The spill trajectories from two modelled release locations have been combined and their extents interpolated to other locations within the operational area to form a single EMBA. The EMBA is illustrated in **Figure 3-1**.

While the EMBA represents the largest possible spatial extent that could be affected by the worst-case hydrocarbon spill event, it is important to understand that the stochastic modelling considers 120 different simulations for any one spill event (with two events modelled in total). Simplistically, each simulation considers a different combination of metocean conditions over time. An actual spill event is more likely to be represented by only one of the simulations and hence, have a much smaller spatial footprint. An example of a single simulation modelled (i.e. a deterministic model) for this Activity is illustrated in **Figure 3-1** to demonstrate a more realistic spatial extent for any hydrocarbon phase of the worst-case spill scenario (i.e. a deterministic EMBA). This single simulation was selected from the 240 modelled simulations (i.e. 120 simulations at each of the two modelled locations) to indicate the worst-case spill in relation to potential for shoreline contact.

Table 3-1: Summary of largest credible unplanned vessel hydrocarbon spill scenarios

Event	Hydrocarbon Type	Modelled Spill Volume	Comment	Section
Hydrocarbon spill (MDO/MGO) from vessel collision – surface release	MDO/MGO	1,065 m^3	Modelled spill volume based on the predicted largest fuel tank on a seismic and support vessel.	**7.1**
Hydrocarbon spill (MDO/MGO) during refuelling	MDO/MGO	37.5 m^3	Spill volume based on 15 minutes of flow at a pumping rate of 150 m^3/hr.	**7.2**

3.2 Environmental Values and Sensitivities

A comprehensive description of the environmental values and sensitivities of the existing environment within the EMBA (as required by Regulation 13(3) of the OPGGS(E)R), is provided for in Santos' *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062). It is a compilation of environmental values and sensitivities including physical, biological, social, economic and cultural features within the marine and coastal environment that are relevant to all of Santos' activities, not specifically to this EP. A copy of the document is provided in **Appendix B**.

Specific to this EP, the Department of the Environment and Energy (DoEE) Protected Matters Search Tool (PMST) associated with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) was used to determine potential receptors such as Matters of National Environmental Significance (MNES) within the operational area and the EMBA. The results of these searches are provided in **Appendix C.**

A summary of the information derived from the Protected Matters Search, Bioregional Plans and the identified Fauna Recovery Plans of relevance to the operational area and the EMBA is provided in this section.

3.2.1 Bioregions

Based on the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) Version 4.0, the operational area overlaps the North West Shelf Province and Northwest Transition (**Figure 3-2**). The EMBA overlaps these two provinces as well as the Northwest Province and the Timor Province.

The presence of marine and coastal habitats within the operational area and EMBA is summarised in **Table 3-2** and a detailed description of these habitats with reference to the IMCRA provincial bioregions is provided in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062).

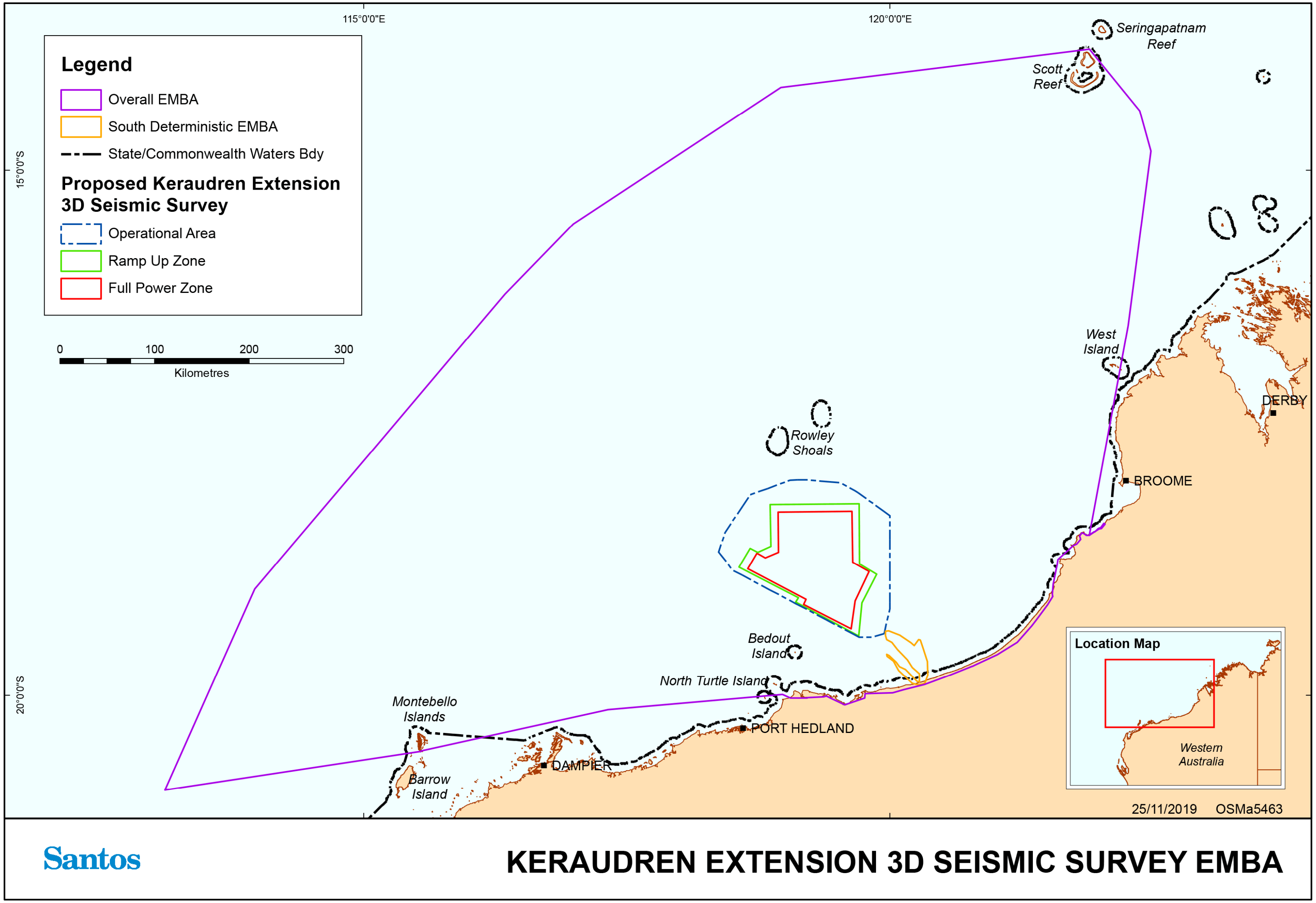

Figure 3-1: EMBA from planned activities and unplanned events

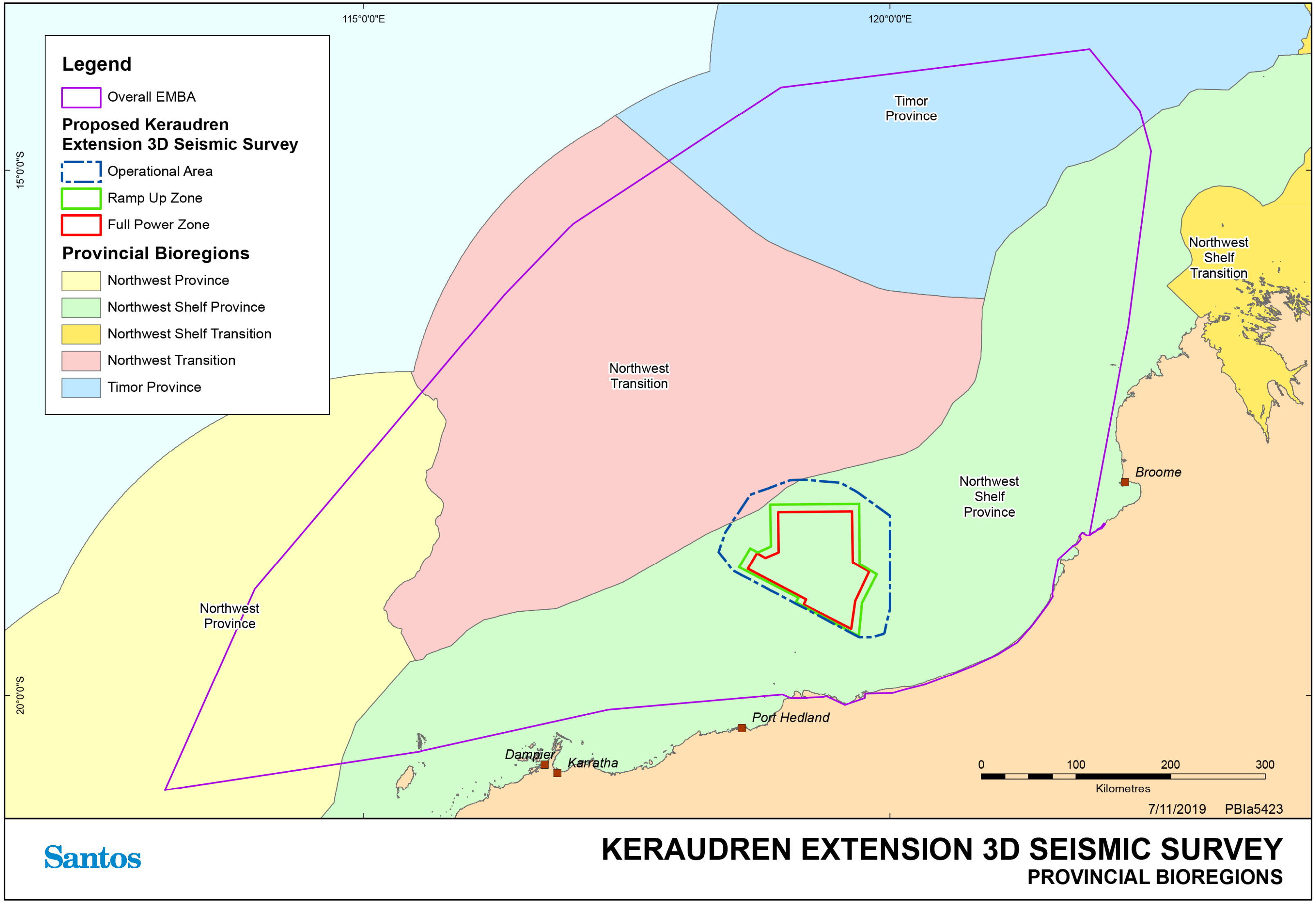

Figure 3-2: IMCRA 4.0 Provincial Bioregions within the EMBA

Table 3-2: Receptors listed according to presence within the operational area and EMBA

Category	Receptor	Operational Area Presence	EMBA Presence				Relevant events that may impact on the receptors
			Northwest Province	Northwest Transition	North West Shelf Province	Timor Province	
Water Column	Plankton Fish Turtles Cetaceans Seabirds	✓	✓	✓	✓	✓	Planned • Noise emissions • Light emissions • Planned operational discharges Unplanned • Hazardous and non-hazardous unplanned discharges - liquid • MDO/MGO release from vessel collision • Minor hydrocarbon release • Marine fauna collisions • Introduction of invasive marine species • Spill response operations
Benthic Habitats	Coral reefs (including emergent oceanic shoals)	x	x	✓	✓	✓	Planned • Noise emissions Unplanned • MDO/MGO release from vessel collision • Introduction of invasive marine species • Spill response operations
	Seagrass	x	x	✓	✓	✓	Unplanned • MDO/MGO release from vessel collision • Introduction of invasive marine species

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Category	Receptor	Operational Area Presence	EMBA Presence: Northwest Province	EMBA Presence: Northwest Transition	EMBA Presence: North West Shelf Province	EMBA Presence: Timor Province	Relevant events that may impact on the receptors
							• Spill response operations
	Macroalgae	x	x	✓	✓	✓	Unplanned • MDO/MGO release from vessel collision • Introduction of invasive marine species • Spill response operations
	Non-coral benthic invertebrates	✓	✓	✓	✓	✓	Planned • Noise emissions • Planned operational discharges Unplanned • Hazardous and non-hazardous unplanned discharges - solid • MDO/MGO release from vessel collision • Introduction of invasive marine species • Spill response operations
Shoreline habitats	Mangroves / shorebirds	x	x	x	✓	x	Unplanned • MDO/MGO release from vessel collision • Spill response operations
	Intertidal mud / sand flats/ shorebirds	x	x	x	✓	x	
	Sandy beaches / shorebirds / turtle nesting	x	x	✓	✓	✓	
	Intertidal rock platforms	x	x	x	✓	x	

Category	Receptor	Operational Area Presence	EMBA Presence				Relevant events that may impact on the receptors
			Northwest Province	Northwest Transition	North West Shelf Province	Timor Province	
	Rocky shorelines	x	x	x	✓	x	

3.2.2 Protected / Significant Areas

Protected areas and key ecological features (KEF) identified in the EMBA are detailed in **Table 3-3, Figure 3-3** (protected areas) and **Figure 3-4** (KEFs); with the exception of the various islands discussed in **Section 3.2.2.1**. These areas are further described in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

The conservation values and management zones associated with the Australian Marine Parks (AMPs) identified in the EMBA, and the relevant management objectives are detailed in **Section 3.2.2.2** in addition to information provided in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

The Eighty Mile Beach, Rowley Shoals and Montebello Islands State Marine Parks are also located in the EMBA. The conservation values and management objectives associated with these State Marine Parks are summarised in **Section 3.2.2.3** in addition to information provided in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

There are no World Heritage properties located in the EMBA. There are two Commonwealth Heritage places and one National Heritage place located in the EMBA, ‘Mermaid Reef - Rowley Shoals’ and ‘Scott Reef and Surrounds Commonwealth Area’, and the ‘West Kimberley’, respectively. These are described further in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

3.2.2.1 Islands

No islands or emergent reef systems are located within the operational area. Several islands and emergent reefs are located within the EMBA that provide intertidal and shoreline habitats for a variety of marine fauna and ecological communities. These islands and reefs are summarised below.

Bedout Island is located 45 km south of the operational area and is an A-class nature reserve. The island is a low and undulating, 0.3 km^2 sandy cay on limestone bedrock, heavily vegetated with *Spinifex longifolius*. Bedout Island supports breeding birds such as masked booby, white-bellied sea eagle, silver gull, crested tern and lesser crested tern (BirdLife International, 2018). Burbidge *et al.* (1986) report numbers of occupied nests of brown booby (~10,000), masked booby (~178) and lesser frigate bird (2,290) surveyed in 1984 on Bedout Island. Bedout Island is fringed by coral reef and provides seabird and turtle foraging habitat.

North Turtle Island is an A-class nature reserve located 87 km south of the operational area. The island is fringed by coral reef and provides turtle and seabird nesting and foraging habitat (BHP, 2011; Davidson and Thomas-Dans, Landscope article, undated).

The Lacepede Islands are located 290 km north-east of the operational area. They comprise four flat sand and coral rubble cay islands surrounded by platform coral reef and seagrass habitats. The islands support thousands of birds including brown boobies, roseate terns and lesser frigatebirds (BirdLife International, 2018). The islands and surrounding waters are also significant for turtle nesting, internesting and foraging, supporting regionally significant populations of nesting green turtles and flatback turtles (DoEE, 2017).

The Montebello Islands (Trimouille, North-west, Bluebell and Hermite Island). The Montebello Islands, located 350 km south-west of the operational area, consist of 315 low-lying islands and islets. The islands support mangrove communities and are fringed by extensive coral reefs, with macroalgae and sparse patches of seagrass (Parks and Wildlife Service, 2017). The islands also provide habitat for significant green, hawksbill, flatback turtle nesting populations.

Sandy Islet, Scott Reef is a sandy, low lying bank which provides nesting habitat for two species of marine turtle. The island is surrounded by an emergent shelf atoll, Scott Reef, and is located on the edge of the broad continental shelf, about 300 km from mainland north-western Australia. Scott Reef is regionally significant because of its high representation of species not found in coastal waters off Western Australia and for the unusual nature of its fauna which has affinities with the oceanic reef habitats of the Indo-West Pacific as well as the reefs of the Indonesian region (DoE 2014).

Rowley Shoals comprise three distinct reef systems, Imperieuse Reef, Clerke Reef and Mermaid Reef, each located approximately 30 to 40 km apart. The reefs rise vertically to the surface from depths of between 500 and 700 m. Mermaid Reef includes low lying sandy cays which are completely submerged at high tide and therefore fall under Australian Government jurisdiction (Commonwealth waters). The other two reefs, Clerke Reef and Imperieuse Reef are emergent reefs with sandy islets above the high-water mark and are managed as the WA Rowley Shoals Marine Park. The marine reef fauna of the Rowley Shoals are considered to be exceptionally rich and diverse, including species typical of the oceanic coral reef communities of the Indo-West Pacific. As many of these species are not found in the inshore tropical waters of northern Australia, such populations are of regional significance (DSEWPac 2012a).

Bedwell Island on Clerke Reef and **Cunningham Island** on Imperieuse Reef are unvegetated sand cays about 2 m and 3.7 m high respectively. Bedwell Island is home to one of only two colonies of red-tailed tropicbirds in WA (the other being located at Ashmore Reef and Cartier Island outside of the EMBA), along with several other bird species. Bedwell Island also provides occasional nesting habitat for a small number of hawksbill and green turtles. Both Bedwell Island and Cunningham Island are known resting sites for migratory birds (Department of Environment and Conservation 2007).

Table 3-3: Protected areas and features within the EMBA

Value/Sensitivity	Name	Approximate distance to operational area (km)
Australian Marine Parks	Eighty Mile Beach AMP: Multiple Use Zone – IUCN VI[1]	6
	Argo-Rowley Terrace AMP: Multiple Use Zone – IUCN VI	23
	Argo-Rowley Terrace AMP: Special Purpose Zone (Trawl) – IUCN VI	46
	Argo-Rowley Terrace AMP: National Park Zone – IUCN II	310
	Mermaid Reef AMP: National Park Zone – IUCN II	85
	Kimberley AMP: Multiple Use Zone – IUCN VI	185
	Montebello AMP: Multiple Use Zone – IUCN VI	301
	Gascoyne AMP: Multiple Use Zone – IUCN VI	540
State Marine Parks	Eighty Mile Beach	50
	Rowley Shoals	29
	Montebello Islands	350
Islands	Bedout Island	45
	North Turtle Island	87
	Lacepede Islands	290
	Trimouille Island (Montebello Group)	350
	North-west Island (Montebello Group)	355
	Bluebell Island (Montebello Group)	360

[1] International Union for Conservation of Nature (IUCN) categories are presented in Roman numerals.

Value/Sensitivity	Name	Approximate distance to operational area (km)
	Hermite Island (Montebello Group)	361
Wetlands of International Importance (Ramsar)	Eighty Mile Beach	55
Key Ecological Features	Ancient coastline at 125 m depth contour	Overlap
	Glomar Shoals	207
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	19
	Canyons linking the Argo Abyssal Plain with the Scott Plateau	390
	Continental slope demersal fish communities	225
	Seringapatam Reef and Commonwealth waters in the Scott Reef Complex	480
	Exmouth Plateau	425

3.2.2.2 Australian Marine Parks

The operational area does not overlap with any AMP or any other protected areas, however, the EMBA overlaps the following marine parks: Eighty Mile Beach AMP, Argo-Rowley Terrace AMP, Mermaid Reef AMP, Kimberley AMP, Gascoyne AMP and Montebello AMP. Values for these AMPs are summarised in **Table 3-4** below and are described further in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

Management plans for AMPs have been developed and came into force on 1 July 2018. Under these plans AMPs are allocated conservation objectives (IUCN Protected Area Category) based on the Australian IUCN reserve management principles in Schedule 8 of the EPBC Regulations 2000. These principles determine what activities are acceptable within the different zones of the AMP network. As the Keraudren Extension 3D MSS operational area does not overlap any AMPs, there are no AMPs that restrict the undertaking of the Keraudren Extension 3D MSS. Therefore, the Activity will be undertaken in compliance with the AMP network zone rules. In the event of spill response operations being required within an AMP, emergency spill response activities are allowed in accordance with the *Australian National Plan for Maritime Environmental Emergencies* (MEE) without the need for a permit, class approval or activity licence or lease issued by the Director.

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Table 3-4: Values of Australian Marine Parks overlapping the EMBA

Commonwealth Marine Park	Management Zone/s	Values
Eighty Mile Beach AMP	Multiple Use Zone (VI)	The Eight Mile Beach Marine Park protects the following conservation values: • Foraging areas for migratory seabirds; • Important foraging areas for marine turtles adjacent to significant nesting sites; • Part of the migratory pathway of the protected humpback whale; • Areas adjacent to important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish; • Protection for terrace, banks and shoal habitats; • Communities and seafloor habitats of the North West Shelf Province; • Sea country valued for indigenous cultural identify.
Argo-Rowley Terrace AMP	• Multiple Use Zone (VI) • Special Purpose Zone (Trawl) • National Park Zone (II)	The Agro-Rowley Marine Park is located approximately 270 km north-west of Broome, Western Australia. Important conservation values include: • Foraging areas that are important for migratory seabirds as well as the endangered loggerhead turtle; • Important habitat and foraging for sharks; • Migratory pathway for pygmy blue whales; • Protection for communities and habitats of the deeper offshore waters of the region; • Seafloor features including aprons and fans, canyons, continental rise, knolls/abyssal hills and the terrace and continental slope; • Communities and seafloor habitats of the North West Shelf Province and Timor Province bioregions; • Connectivity between the existing Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals Marine Park; and • Two key ecological features: Canyons linking the Argo Abyssal Plain with the Scott Plateau and Mermaid Reef and Commonwealth waters surrounding Rowley Shoals.
Mermaid Reef AMP	National Park Zone (II)	During periods of high tide, Mermaid Reef is completely submerged underwater and protects the following conservation values: • National and international significant habitats including coral formations, geomorphic features and diverse marine life; • Key area for over 200 species of hard corals and 12 classes of soft corals with coral formations in pristine condition;

Commonwealth Marine Park	Management Zone/s	Values
		• Important areas for sharks; • Important foraging for marine turtles; • Important area for toothed whales, dolphins, tuna and billfish; • Important resting and feeding sites for migratory seabirds; • A migratory pathway for the pygmy blue whale; • The reserve, along with nearby Rowley Shoals Marine Park, provides the best geological example of shelf atolls in Australia; and • Examples of the seafloor habitats and communities of the Northwest Transition.
Kimberley AMP	• Multiple Use Zone (VI) • National Park Zone (II)	The Kimberley Marine Park protects the following conservation values: • Important foraging areas for migratory seabirds, dugongs, dolphins and threatened and migratory marine turtles; • Important migratory pathway for nursery areas for the protected humpback whale; • Migratory pathway for pygmy blue whales; • Adjacent to important foraging and pupping areas for sawfish and important nesting sites for green turtles; • Protection for communities and habitats of waters offshore of the Kimberley coastline; • Representation of continental shelf, slope, plateau, pinnacle, terrace, banks and shoals and deep hole/valley seafloor features; • Communities and seafloor habitats; and • Two key ecological features: the ancient coastline at the 125 m depth contour and the continental slope demersal fish communities.
Gascoyne AMP	Multiple Use Zone VI	The Gascoyne Marine Park protects the following conservation values: • Important foraging areas for migratory seabirds threatened and migratory hawksbill and flatback turtles and vulnerable and migratory whale shark; • A continuous connectivity corridor from shallow depths around 15 m out to deep offshore waters on the abyssal plain at over 5,000 m; • Seafloor features including canyon, terrace, ridge, knolls, deep hole/valley and continental rise. It also provides protection for sponge gardens in the south of the reserve adjacent to WA coastal waters; • Ecosystem examples from the surrounding provinces;

Commonwealth Marine Park	Management Zone/s	Values
		• Four key ecological features: Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula, Commonwealth waters adjacent to Ningaloo Reef, Continental slope demersal fish communities and Exmouth Plateau; • The canyons in the reserve are believed to be associated with the movement of nutrients from deep water over the Cuvier Abyssal Plain onto the slope where mixing with overlying water layers occurs at canyon heads; and • The reserve therefore provides connectivity between the inshore waters of the existing Ningaloo Commonwealth Marine Park and the deeper waters of the area.
Montebello AMP	Multiple Use Zone (VI)	The Montebello Marine Park is located offshore of Barrow Island and 80 km west of Dampier extending from the Western Australian state water boundary and is adjacent to the Western Australian Burrow Island and Montebello Island Marine Parks. The park protects the following marine values: • Foraging areas for migratory seabirds; • Areas used by vulnerable and migratory whale sharks for foraging; • Foraging areas marine turtles which are adjacent to important nesting sites; • Section of the north and south bound migratory pathway of the humpback whale; • Shallow shelf environments with depths ranging from 15-150 m which provides protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features; • Seafloor habitats and communities of the North West Shelf Province provincial bioregions; and • One key ecological feature for the region: the ancient coastline at the 125 m depth contour.

3.2.2.3 State Marine Parks

There are three State Marine Parks located in the EMBA, however none overlapping the operational area. The three Marine Parks (MPs) include: the Rowley Shoals Marine Park, Montebello Islands Marine Park and Eighty Mile Beach Marine Park. Values for these MPs are outlined briefly in **Table 3-5** below and are described further in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

Table 3-5: State Marine Parks overlapping the EMBA

State Marine Park	Values
Rowley Shoals Marine Park	The Rowley Shoals are situated approximately 300 km north-west of Broome and comprise of three oceanic systems, approximately 30 to 40 km apart, namely Mermaid Reef, Clerke Reef and Imperieuse Reef. The Rowley Shoals Marine Park is characterised by intertidal and subtidal coral reefs, exceptionally rich and diverse marine fauna and high-water quality. These attributes and the low level of use of the area contribute to the Park's unique qualities. The Rowley Shoals are of national and international significance.
Montebello Islands Marine Park	The Montebello Islands Marine Park is located approximately 20 kilometres north of Barrow Island and 120 kilometres west of Dampier. The Park protects more than 58,000 hectares of ocean surrounding more than 250 low-lying islands. The complex system of reefs, lagoons and channels support a large range of habitats, and marine flora and fauna. The area supports a minimum of 150 species of hard coral, 450 species of fish, 630 species of molluscs and 170 species of sea stars, urchins and other echinoderms (Department of Environment and Conservation, 2009).
Eighty Mile Beach Marine Park	Eighty Mile Beach Marine Park covers almost 210 km^2 of the remote north-west coast of Western Australia. The area supports feeding grounds for migratory shorebirds and waders and is listed under the Ramsar Convention. It also supports a significant nesting population of flatback turtles which are endemic to northern Australia (Department of Fisheries, 2015).

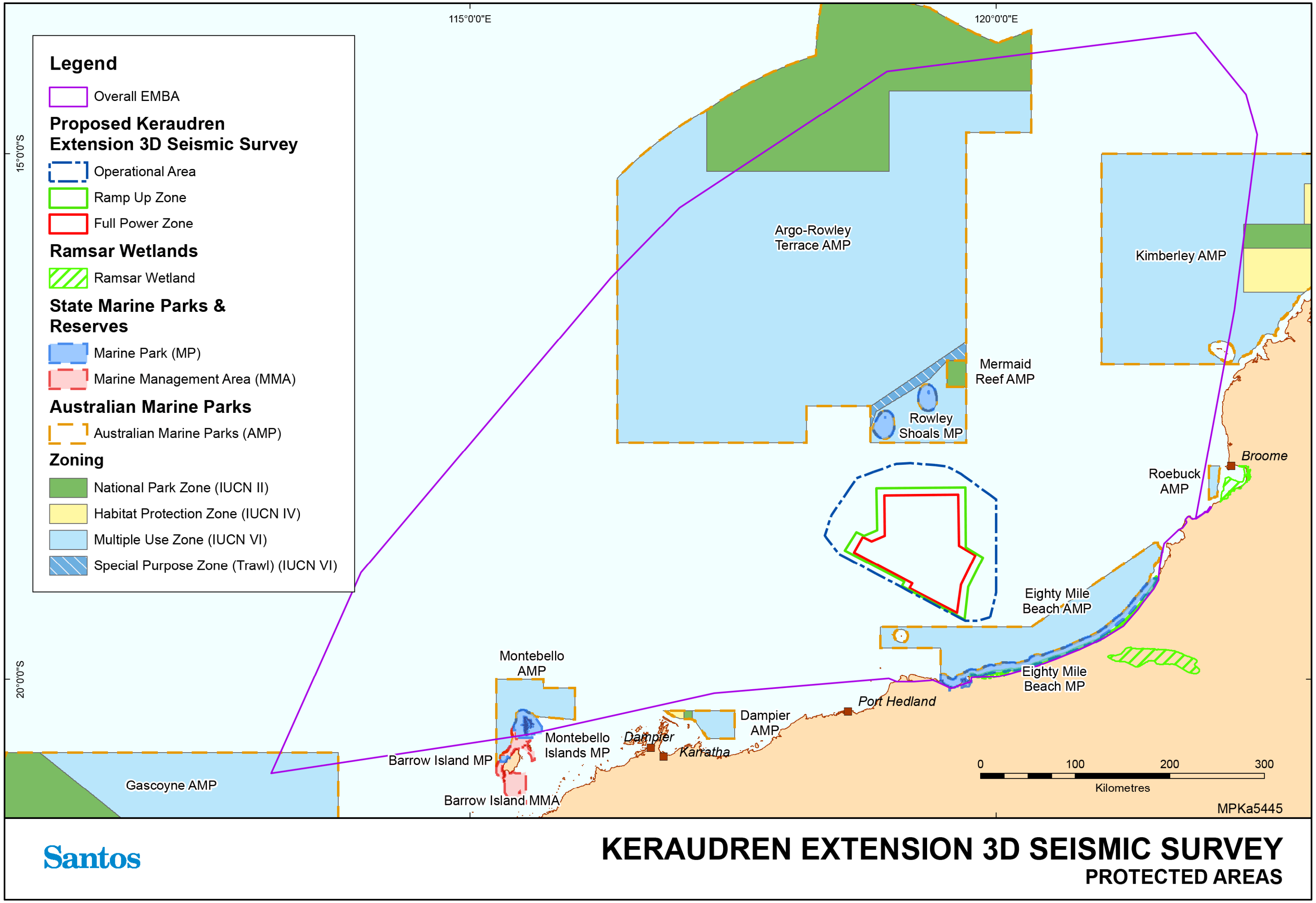


Figure 3-3: Protected areas within and adjacent to the EMBA

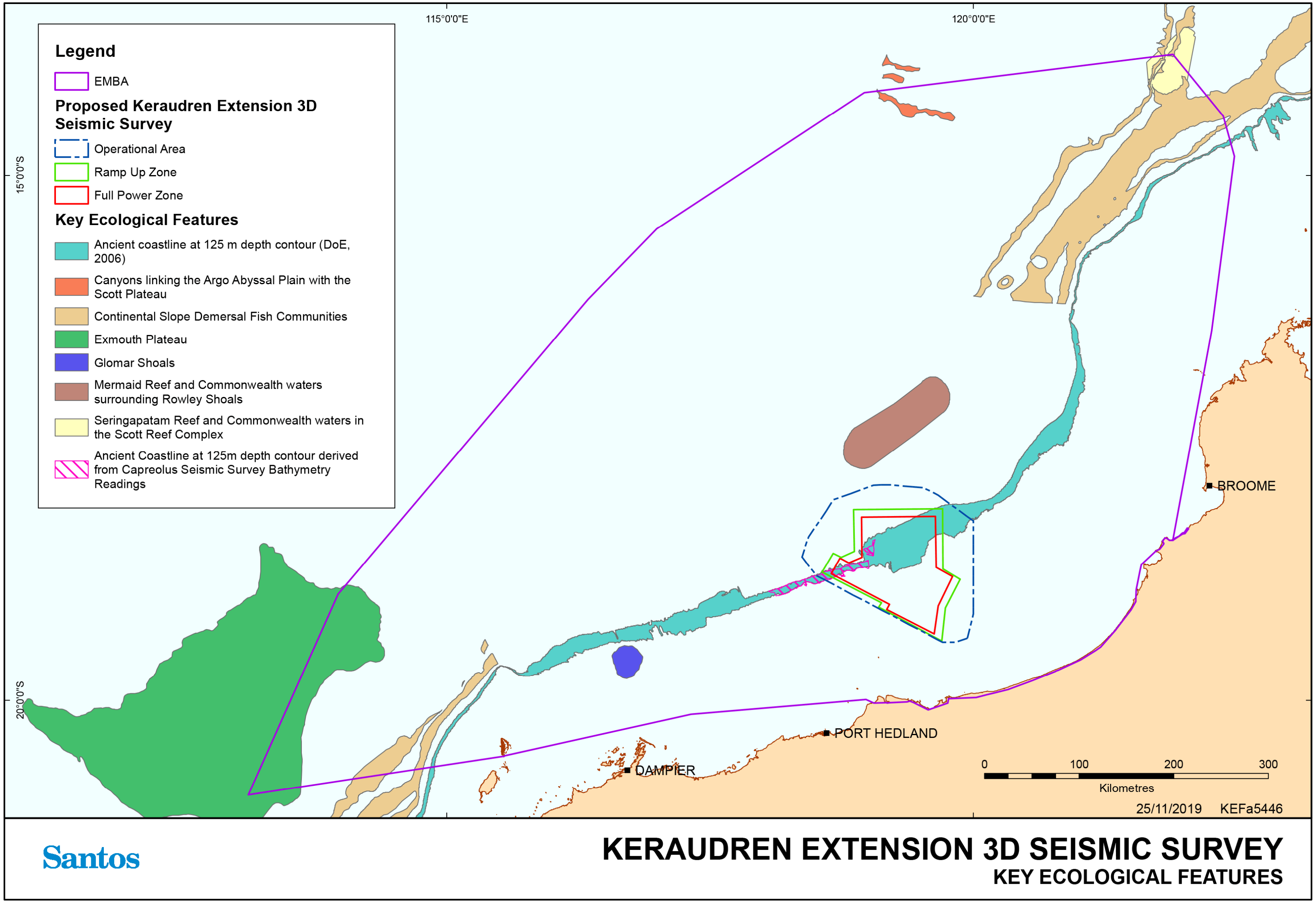


Figure 3-4: Key ecological features within and adjacent to the EMBA

3.2.3 Marine Fauna

The PMST was used to identify Listed Threatened Species (LTS) and Listed Migratory Species (LMS) relevant to the operational area and the EMBA (**Appendix C**). The PMST report for the operational area identified 19 LTS and 37 LMS, and for the EMBA identified 42 LTS and 82 LMS.

An examination of the Species Profile and Threats (SPRAT) database showed that some LTS are not expected to occur in the marine and coastal environments due to their terrestrial distributions. These species will not come into contact with any potential hydrocarbon spill, or be exposed to underwater noise emissions, and therefore will not be discussed further.

Species listed as threatened, migratory or conservation-dependent which occur or potentially occur within the EMBA are summarised in **Table 3-6**. The relevant planned and unplanned events that may impact them are also discussed in **Table 3-6**. Threatened and migratory species within these listed groups are described in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**). Conservation dependent species are not described in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062); they are summarised below.

Biologically Important Areas (BIAs), such as an aggregation, breeding, resting, nesting or feeding areas or known migratory routes, for marine mammals, marine turtles, fish and sharks, and seabirds are shown in **Figure 3-6** to **Figure 3-8.** The BIAs are described in the *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

Table 3-7 lists those species that may be affected by the identified threats described in Species Conservation and Recovery Management Plans due to planned or unplanned events associated with the Activity. Cross references to the relevant EP section for the assessment of impacts and risks are also provided in **Table 3-7.**

The following environmental values and sensitivities have been identified as being relevant to the Activity, with information provided in the following subsections to supplement the information available in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**):

- Epibenthos in 40 to 60 m water depth (**Section 3.2.2.3**);
- Fish associated with the ancient coastline at 125 m depth contour KEF (**Section 3.2.3.2**);
- EPBC Act-listed threatened and migratory fish species (**Section 3.2.3.3**);
- Conservation-dependent fish species (**Section 3.2.3.4**);
- Humpback whale migration (**Section 3.2.3.5**);
- Pygmy blue whale migration (**Section 3.2.3.6**); and
- Marine turtles (**Section 3.2.3.7**).

Table 3-6: Environmental values and sensitivities – EPBC Act-listed threatened, migratory and conservation-dependent marine fauna reported by the Protected Matters Search Tool

EPBC Act status: CE= Critically Endangered, E= Endangered V= Vulnerable, M= Migratory, CD = Conservation Dependent

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	**Scientific name**						
Fish, Sharks and Rays							
Dwarf sawfish	*Pristis clavata*	V, M	✓	Habitat preference for shallow estuarine waters and therefore presence is not expected	✓	Breeding known to occur BIAs for pupping, nursing and foraging	Unplanned MDO/MGO release from vessel collision Spill response operations
Freshwater sawfish	*Pristis pristis*	V, M	✓	Habitat preference for inshore coastal, estuarine and river environments and therefore presence is not expected	✓	Species or habitat known to occur BIAs for pupping and foraging	
Green sawfish	*Pristis zijsron*	V, M	✓	Habitat preferences a restricted to a few square kilometres within the coastal fringe	✓	Breeding known to occur BIAs for pupping, nursing and foraging	
Northern River Shark	*Glyphis garricki*	E	x	Species not expected to occur	✓	Species or species habitat known to occur	
Grey nurse shark (west coast population)	*Carcharias taurus*	V	x	Species not expected to occur	✓	Species or species habitat known to occur	Unplanned MDO/MGO release from vessel collision

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	**Scientific name**						
Giant manta ray	*Manta birostris*	M	✓	Species or habitat likely to occur	✓	Species or habitat likely to occur	Planned Noise emissions Light emissions Planned operational discharges Unplanned Marine fauna collision Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Great white shark	*Carcharodon carcharias*	V, M	✓	Species or habitat may occur but is not common in tropical waters	✓	Species or habitat may occur	
Longfin mako	*Isurus paucus*	M	✓	Species or habitat likely to occur	✓	Species or habitat likely to occur	
Narrow sawfish	*Anoxypristis cuspidata*	M	✓	Habitat preference for inshore coastal, estuarine and river environments but may occur in the operational area	✓	Species or habitat known to occur	
Reef manta ray	*Manta alfredi*	M	✓	Species or habitat known occur	✓	Species or habitat known to occur	
Shortfin mako shark	*Isurus oxyrinchus*	M	✓	Species or habitat likely to occur	✓	Species or habitat likely to occur	
Whale shark	*Rhincodon typus*	V, M	✓	Foraging, feeding or related behaviour known to occur BIA for foraging	✓	Foraging, feeding or related behaviour known to occur BIA for foraging	
Southern Bluefin tuna	*Thunnus maccoyii*	CD	✓	Species distribution overlaps operational area but more likely in deeper offshore waters between the Australian continental slope and Indonesia.	✓	Species or species habitat known to occur	
Scalloped hammerhead shark	*Sphyra lewini*	CD	✓	Species or species habitat known to occur	✓	Species or species habitat known to occur	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	**Scientific name**						
Marine Mammals							
Antarctic minke whale	*Balaenoptera bonaerensis*	M	x	Species not expected to occur	✓	Species or habitat may occur	<u>Unplanned</u> Marine fauna collision Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision
Dugong	*Dugong dugon*	M	x	Distribution strongly associated with seagrass habitat, which does not occur in the operational area	✓	Species or habitat known to occur but typically found in shallow coastal waters. Unlikely to occur in the operational area.	
Blue whale	*Balaenoptera musculus*	E, M	✓	Species or habitat likely to occur BIA for distribution	✓	Migration route and BIA located 30 km NW of the operational area.	<u>Planned</u> Noise emissions Planned operational discharges Spill response operations <u>Unplanned</u> Marine fauna collision Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release
Bryde's whale	*Balaenoptera edeni*	M	✓	Species or habitat may occur	✓	Species or habitat likely to occur	
Fin whale	*Balaenoptera physalus*	V, M	✓	Species or habitat likely to occur	✓	Foraging, feeding or related behaviour likely to occur	
Humpback whale	*Megaptera novaeangliae*	V, M	✓	Species or habitat known to occur BIA for migration	✓	Migration route and BIA passes through the southern part of the operation area s	
Indo-Pacific humpback dolphin	*Sousa chinensis*	M	✓	Species or habitat may occur	✓	Species or habitat known to occur	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	**Scientific name**						
Killer whale	*Orcinus orca*	M	✓	Species or habitat may occur	✓	Species or habitat may occur	MDO/MGO release from vessel collision
Sei whale	*Balaenoptera borealis*	V, M	✓	Species or habitat likely to occur	✓	Foraging, feeding or related behaviour likely to occur within area	
Sperm whale	*Physeter macrocephalus*	M	✓	Species or habitat may occur	✓	Species or habitat may occur	
Spotted bottlenose dolphin	*Tursiops aduncus*	M	✓	Species or habitat likely to occur	✓	Species or habitat likely to occur	
Australian Snubfin Dolphin	*Orcaella heinsohni*	M	x	Species not expected to occur	✓	Species or habitat likely to occur	<u>Unplanned</u> MDO/MGO release from vessel collision
Marine Reptiles							
Flatback turtle	*Natator depressus*	V, M	✓	Congregation or aggregation known to occur BIA for internesting around North Turtle Island and Eighty Mile Beach A minor portion of the operational area (most southern tip) overlaps a Habitat Critical to survival of the species[2].	✓	Breeding known to occur BIAs for nesting, interesting, mating, foraging and migration corridor Habitat Critical to survival of the species – 60 km radius around Eighty Mile Beach	<u>Planned</u> Noise emissions Light emissions Planned operational discharges <u>Unplanned</u> Marine fauna collision

[2] The EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance, define 'Habitat Critical to the survival of a species' as areas necessary: 1) for activities such as foraging, breeding or dispersal; 2) for the long-term maintenance of the species (including the maintenance of species essential to the survival of the species);

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	Scientific name						
Green turtle	*Chelonia mydas*	V, M	✓	Species or species habitat known to occur No overlap with Habitat Critical to survival of the species	✓	Breeding known to occur within area BIAs for foraging and internesting No overlap with Habitat Critical to survival of the species	Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Leatherback turtle	*Dermochelys coriacea*	E, M	✓	Species or species habitat likely to occur No overlap with Habitat Critical to survival of the species	✓	Breeding likely to occur within area No overlap with BIAs or Habitat Critical to survival of the species	
Hawksbill turtle	*Eretmochelys imbricata*	V, M	✓	Species or species habitat known to occur No overlap with Habitat Critical to survival of the species	✓	Breeding known to occur within area BIA for foraging, internesting, nesting, and mating No overlap with Habitat Critical to survival of the species	
Loggerhead turtle	*Caretta caretta*	E, M	✓	Species or habitat known to occur No overlap with Habitat Critical to survival of the species	✓	BIA for foraging and internesting Foraging, feeding or related behaviour known to occur within area	

Cont'd from previous page: 3) to maintain genetic diversity and long term evolutionary development; and 4) for the reintroduction of populations or recovery of the species. Nesting and internesting habitat critical to the survival of marine turtle species is outlined in the Recovery Plan for Marine Turtles in Australia 2017 - 2027.

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	**Scientific name**						
						No overlap with Habitat Critical to survival of the species	
Olive Ridley Turtle, Pacific Ridley Turtle	*Lepidochelys olivacea*	E, M	x	Species not expected to occur	✓	Foraging, feeding or related behaviour likely to occur	
Short-nosed seasnake	*Aipysurus apraefrontalis*	CE	x	Habitat preference for reef flats or shallow waters along the outer reef edge in water depths to 10 m	✓	Species or species habitat likely to occur	<u>Unplanned</u> Hazardous and non-hazardous unplanned discharges - solid MDO/MGO release from vessel collision
Salt-water crocodile	*Crocodylus porosus*	M	x	Species not expected to occur	✓	Species or habitat likely to occur	<u>Unplanned</u> MDO/MGO release from vessel collision Spill response operations
Seabirds							
Lesser frigatebird	*Fregata ariel*	M	✓	Species likely to occur BIA for breeding	✓	Breeding known to occur BIA for breeding	<u>Planned</u> Noise emissions Light emissions Planned operational discharges Atmospheric emissions <u>Unplanned</u> Hazardous and non-hazardous unplanned discharges - solid
Greater frigatebird	*Fregata minor*	M	✓	Species may occur	✓	Species or habitat known to occur	
Common noddy	*Anous stolidus*	M	✓	Species may occur	✓	Species or habitat likely to occur	
White-tailed tropicbird	*Phaethon lepturus*	M	✓	Foraging, feeding or related behaviour likely to occur within area BIA for breeding (provisioning of chicks)	✓	Breeding likely to occur BIA for breeding	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	Scientific name						
Streaked shearwater	*Calonectris leucomelas*	M	✓	Species likely to occur	✓	Species or habitat known to occur	Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO oil release from vessel collision Spill response operations
Abbott's booby	*Papasula abbotti*	E	✓	Species may occur	✓	Species or habitat may occur	
Brown booby	*Sula leucogaster*	M	✓	Breeding known to occur BIA for breeding	✓	Breeding known to occur BIA for breeding	
Australian fairy tern	*Sternula nereis nereis*	V	✓	Species or species habitat may occur	✓	Breeding known to occur BIA for breeding	
Crested tern	*Thalasseus bergii*	M	x	Species not expected to occur	✓	Breeding known to occur	<u>Unplanned</u> Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Roseate tern	*Sterna dougallii*	M	x	Species not expected to occur	✓	Breeding known to occur BIA for breeding and resting	
Caspian tern	*Hydroprogne caspia*	M	x	Species not expected to occur	✓	Breeding known to occur	
Little tern	*Sternula albifrons*	M	x	Species not expected to occur	✓	Breeding known to occur BIA for breeding and resting	
Wedge-tailed shearwater	*Ardenna pacifica*	M	x	Species not expected to occur	✓	Breeding known to occur BIA for breeding	
Southern giant-petrel	*Macronectes giganteus*	E, M	x	Species not expected to occur	✓	Species or habitat may occur	
Fork-tailed swift	*Apus pacificus*	M	x	Species not expected to occur	✓	Species or habitat likely to occur	
Masked booby	*Sula dactylatra*	M	x	Species not expected to occur	✓	Breeding known to occur	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	Scientific name						
Australian Lesser Noddy	*Anous tenuirostris melanops*	V	x	Species not expected to occur	✓	Species or species habitat may occur within area	
Bridled Tern	*Onychoprion anaethetus*	M	x	Species not expected to occur	✓	Breeding known to occur	
Red-tailed Tropicbird	*Phaethon rubricauda*	M	x	Species not expected to occur	✓	Breeding known to occur	
Red-footed Booby	*Sula sula*	M	x	Species not expected to occur	✓	Breeding known to occur	
Shorebirds							
Eastern curlew	*Numenius madaga-scariensis*	CE, M	✓	Species reportedly may occur but unlikely given coastal and shoreline habitat preference	✓	Species or habitat known to occur	<u>Planned</u> Noise emissions Light emissions Planned operational discharges Atmospheric emissions <u>Unplanned</u> Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Osprey	*Pandion haliaetus*	M	✓	Species reportedly may occur but unlikely given coastal and shoreline habitat preference	✓	Breeding known to occur BIA for breeding	
Pectoral sandpiper	*Calidris melanotos*	M	✓	Species reportedly may occur but unlikely given coastal and shoreline habitat preference	✓	Species or habitat likely to occur	
Red knot	*Calidris canutus*	E, M	✓	Species reportedly may occur but unlikely given coastal and shoreline habitat preference	✓	Species or habitat known to occur	
Common sandpiper	*Actitis hypoleucos*	M	✓	Species reportedly may occur but unlikely given	✓	Species or habitat known to occur	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	Scientific name						
				coastal and shoreline habitat preference			
Curlew sandpiper	*Calidris ferruginea*	CE, M	✓	Species reportedly may occur but unlikely given coastal and shoreline habitat preference	✓	Species or habitat known to occur	
Sharp-tailed sandpiper	*Calidris acuminata*	M	✓	Species reportedly may occur but unlikely given coastal and shoreline habitat preference	✓	Roosting known to occur	
Great Knot	*Calidris tenuirostris*	CE, M	x	Species not expected to occur	✓	Roosting known to occur	Unplanned MDO/MGO release from vessel collision Spill response operations
Common greenshank	*Tringa nebularia*	M	x	Species not expected to occur	✓	Species or habitat known to occur	
Greater Sand Plover, Large Sand Plover	*Charadrius leschenaultii*	V,	x	Species not expected to occur	✓	Roosting known to occur	
Oriental plover	*Charadrius veredus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Oriental pratincole	*Glareola maldivarum*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Bar-tailed godwit	*Limosa lapponica baueri*	V, M	x	Species not expected to occur	✓	Species or habitat known to occur	
Northern Siberian bar-tailed godwit	*Limosa lapponica menzbieri*	CE	x	Species not expected to occur	✓	Species or habitat known to occur	
Australian painted-snipe	*Rostratula australis*	E	x	Species not expected to occur	✓	Species or habitat likely to occur	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	**Scientific name**						
Swinhoe's Snipe	*Gallinago megala*	M	x	Species not expected to occur	✓	Roosting likely to occur	
Pin-tailed Snipe	*Gallinago stenura*	M	x	Species not expected to occur	✓	Roosting likely to occur	
Broad-billed Sandpiper	*Limicola falcinellus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Asian Dowitcher	*Limnodromus semipalmatus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Black-tailed Godwit	*Limosa limosa*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Little Curlew	*Numenius minutus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Whimbrel	*Numenius phaeopus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Ruff	*Philomachus pugnax*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
PPacific Golden Plover	*Pluvialis fulva*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Grey Plover	*Pluvialis squatarola*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Grey-tailed Tattler	*Tringa brevipes*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Marsh Sandpiper	*Tringa stagnatilis*	M	x	Species not expected to occur	✓	Roosting known to occur within area	
Common Redshank	*Tringa totanus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	

Value/Sensitivity		EPBC Act status	Operational area presence	Assessment of values or sensitivities within the operational area	EMBA presence	Assessment of values or sensitivities within EMBA	Relevant events
Common name	Scientific name						
Terek Sandpiper	*Xenus cinereus*	M	x	Species not expected to occur	✓	Roosting known to occur within area	

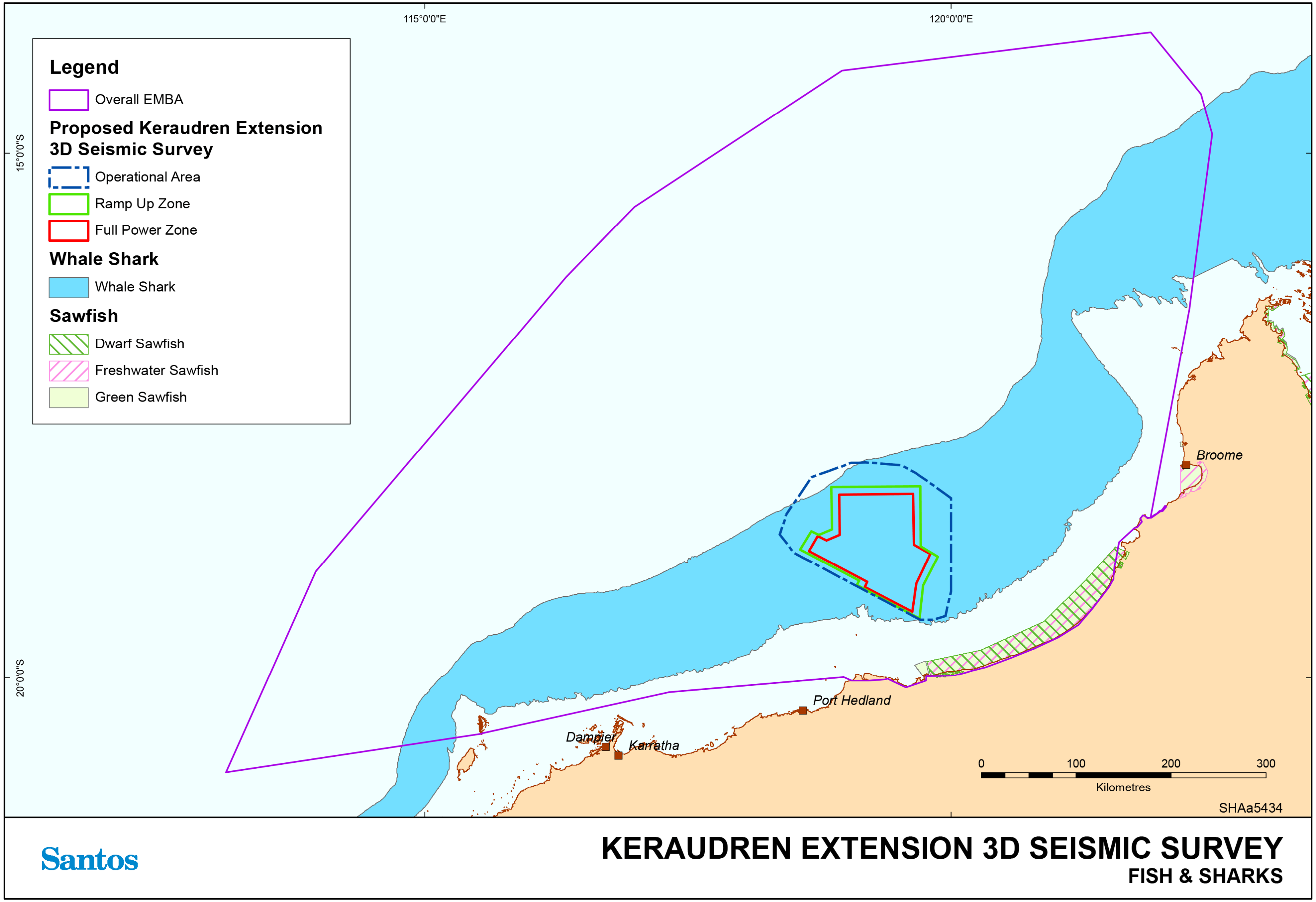


Figure 3-5: BIAs for EPBC Act-protected fish and sharks within the EMBA

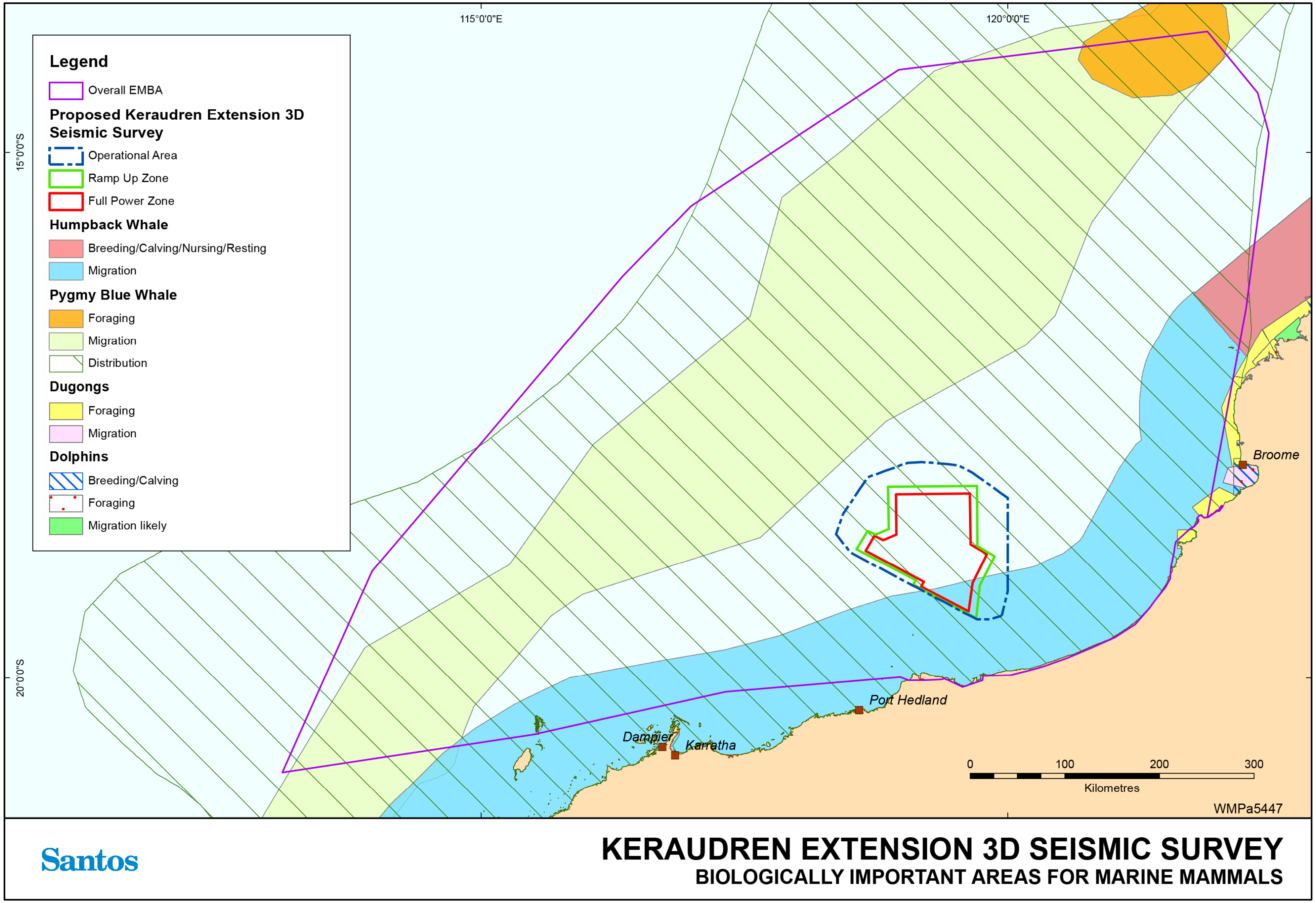


Figure 3-6: BIAs for EPBC Act-protected marine mammal species within the EMBA

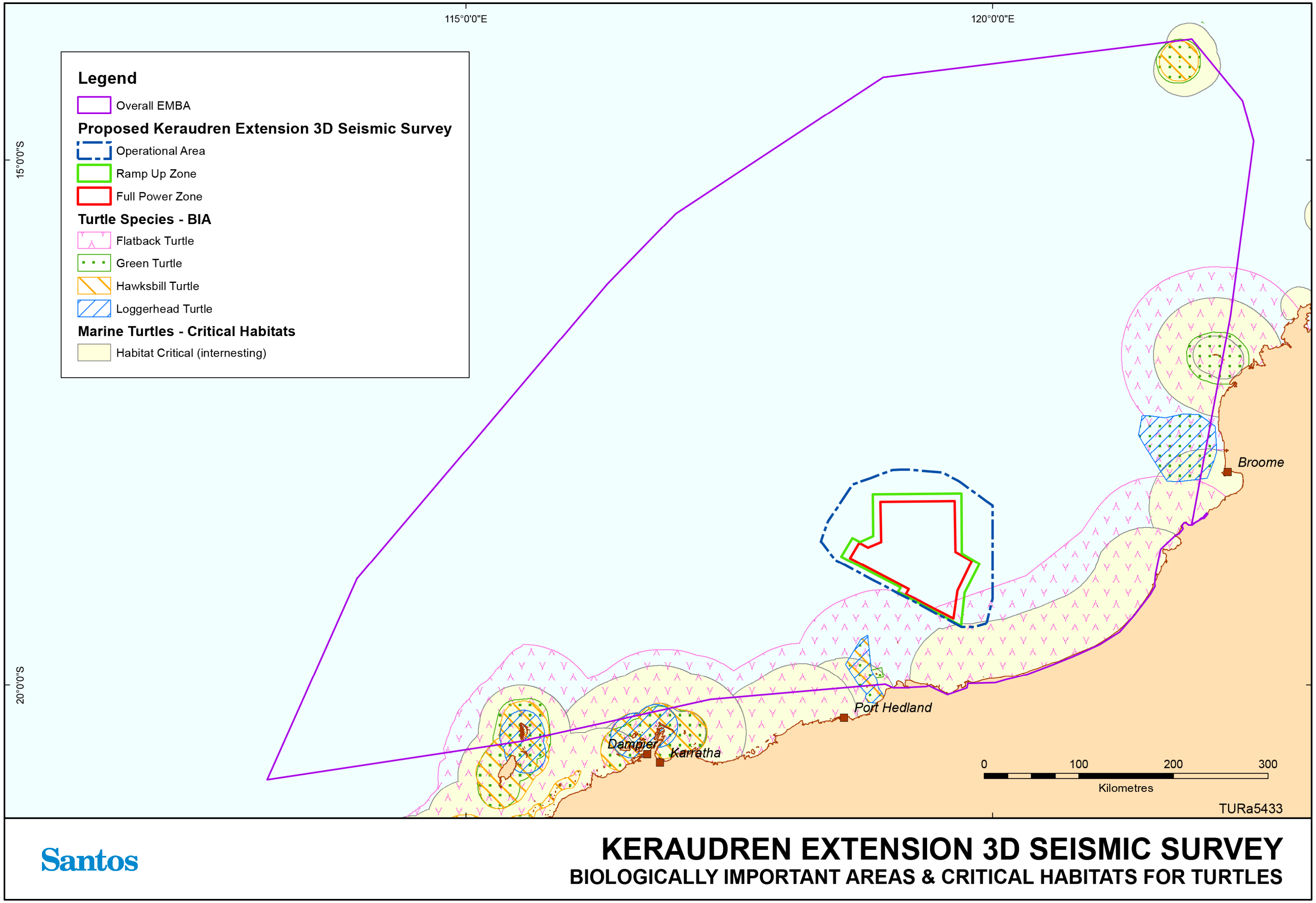


Figure 3-7: BIAs and Habitat Critical for EPBC Act-protected turtles within the EMBA

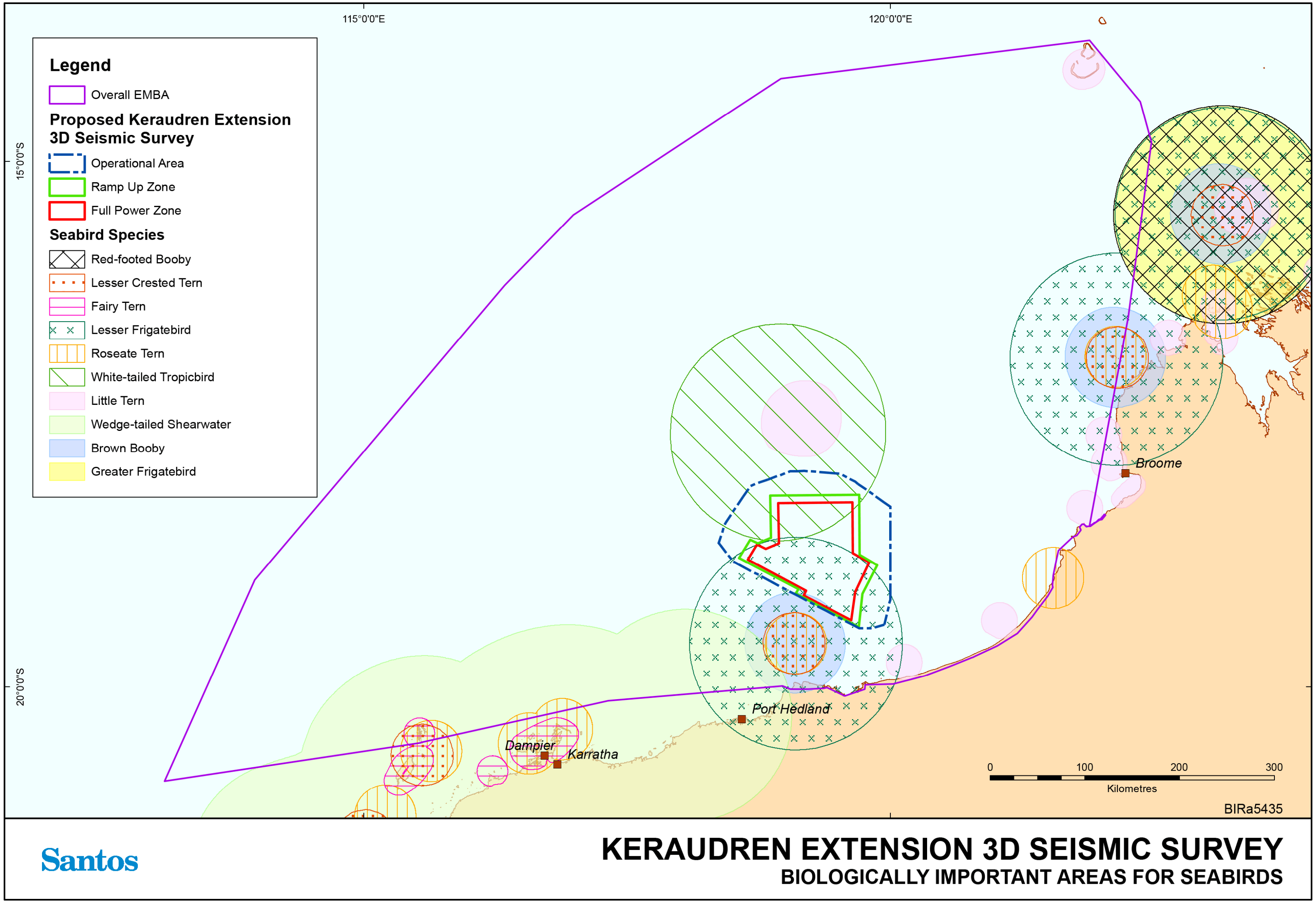


Figure 3-8: BIAs for EPBC Act-protected seabird species within the EMBA

Table 3-7: Relevant threats identified in Recovery Plans and Conservation Advice for species that occur or may occur within the EMBA and which may be affected by the Activity

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
Fish and Sharks	Dwarf sawfish	Sawfish and River Sharks Multispecies Recovery Plan (2015)	Habitat degradation and modification	• Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life. • Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	**7.5**
	Green sawfish	Commonwealth Conservation Advice on *Pristis zijsron* (green sawfish) Sawfish and River Sharks Multispecies Recovery Plan (2015)	Habitat degradation and modification	• Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life. • Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	**7.5**
	Freshwater sawfish	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (2014).	Habitat degradation/ modification	• Implement measures to reduce adverse impacts of habitat degradation and/or modification. • Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	**7.5**
	Great white shark	Recovery plan for the White Shark (*Carcharodon carcharias*) (2013)	Ecosystem effects as a result of habitat modification and climate change	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**6.6**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
	Whale shark	Approved Conservation Advice for *Rhincodon typus* (whale shark) (2015)	Boat strike from large vessels	• Minimise transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef, Christmas Island and the Coral Sea) and along the northward migration route.	**7.6**
			Habitat disruption from mineral exploration, production and transportation	• Implement measures to reduce adverse impacts of habitat disruption.	**6.2, 6.3, 6.5**
			Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on whale sharks. • Take into account and protect BIAs for whale sharks when assessing the impact of proposed activities in the marine environment.	**7.5**
	Northern river shark	Approved Conservation Advice for *Glyphis garricki* (Northern River Shark) (2014)	Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life. • Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	**7.5**
Mammals	Blue whale	Blue Whale Conservation Management Plan 2015 - 2025 (2015)	Noise interference	• Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury and is not displaced from a foraging area. • EPBC Act Policy Statement 2.1—Interaction between offshore seismic exploration and whales is applied to all seismic surveys.	**6.2**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
			Habitat modification	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.5**
			Vessel disturbance	• Ensure all vessel strike incidents are reported in the National Ship Strike Database. • Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, implement appropriate mitigation measures.	**7.6**
	Fin whale	Approved Conservation Advice for *Balaenoptera physalus* (fin whale) (2015)	Pollution (persistent toxic pollutants)	• Implement measures to manage and reduce, where possible waste generation. • Reduce and, where possible, eliminate any adverse impacts of marine debris.	**7.4, 7.5**
			Vessel strike	• Ensure all vessel strike incidents are reported in the National Vessel Strike Database.	**7.6**
			Anthropogenic noise and acoustic disturbance	• All seismic surveys must be undertaken consistent with Part A of the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales.	**6.2**
			Habitat degradation	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Humpback whale	Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (2015)	Noise Interference	• For actions involving acoustic impacts on humpback whale calving, resting, feeding areas, or confined migratory pathways site specific acoustic modelling should be undertaken (including cumulative noise impacts). • All seismic surveys must be undertaken consistent with Part A of the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales.	**6.2**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
				• Should a survey be undertaken in or near a calving, resting, foraging area, or a confined migratory pathway then Part B (Additional Management Procedures) must also be applied.	
			Habitat degradation	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
			Entanglement (marine debris)	• Reduce and, where possible, eliminate any adverse impacts of marine debris.	**7.5**
			Vessel Strike	• Ensure the risk of vessel strike on humpback whales is considered and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike. • All collisions with whales in Commonwealth waters are reported via the National Ship Strike Database.	**7.6**
	Sei whale	Approved Conservation Advice for *Balaenoptera borealis* (sei whale) (2015)	Pollution (persistent toxic pollutants)	• Implement measures to manage and reduce, where possible, waste generation.	**7.4, 7.5**
			Vessel strike	• Ensure all vessel strike incidents are reported in the National Vessel Strike Database.	**7.6**
			Anthropogenic noise and acoustic disturbance	• All seismic surveys must be undertaken consistent with Part A of the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales.	**6.2**
			Habitat degradation including pollution (increasing port expansion and coastal development)	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
Rept iles	Green turtle	Recovery plan for marine turtles in	Deteriorating water quality	• Implement measures to manage and reduce, where possible waste generation.	**7.1, 7.2, 7.5**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
		Australia 2017 – 2027 (2017)	Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on marine turtles.	**7.5**
			Light pollution	• Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.	**6.4**
			Vessel disturbance	• Manage activities to ensure marine turtles are not displaced from identified Habitat Critical to the survival and biological important areas.	**7.6**
			Noise interference	• A precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. • Seismic surveys must undertake soft starts during surveys irrespective of location and time of year to protect marine turtles.	**6.2**
	Hawksbill turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Deteriorating water quality	• Implement measures to manage and reduce, where possible, waste generation.	**7.1, 7.2**
			Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on marine turtles.	**7.5**
			Light pollution	• Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.	**6.4**
			Vessel disturbance	• Manage activities to ensure marine turtles are not displaced from identified Habitat Critical to the survival and biological important areas.	**7.6**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
			Noise interference	• A precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. • Seismic surveys must undertake soft starts during surveys irrespective of location and time of year to protect marine turtles.	**6.2**
	Flatback turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Deteriorating water quality	• Implement measures to manage and reduce, where possible, waste generation.	**7.1, 7.2**
			Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on marine turtles.	**7.5**
			Light pollution	• Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.	**6.4**
			Vessel disturbance	• Manage activities to ensure marine turtles are not displaced from identified habitat critical to the survival and biological important areas.	**7.6**
			Noise interference	• A precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. • Seismic surveys must undertake soft starts during surveys irrespective of location and time of year to protect marine turtles.	**6.2**
	Leatherback turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Deteriorating water quality	• Implement measures to manage and reduce, where possible, waste generation.	**7.1, 7.2**
			Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on marine turtles.	**7.5**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
			Light pollution	• Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.	**6.4**
			Vessel disturbance	• Manage activities to ensure marine turtles are not displaced from identified habitat critical to the survival and biological important areas.	**7.6**
			Noise interference	• A precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. • Seismic surveys must undertake soft starts during surveys irrespective of location and time of year to protect marine turtles.	**6.2**
	Loggerhead turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Deteriorating water quality	• Implement measures to manage and reduce, where possible, waste generation.	**7.1, 7.2**
			Marine debris	• Reduce and, where possible, eliminate any adverse impacts of marine debris on marine turtles.	**7.5**
			Light pollution	• Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.	**6.4**
			Vessel disturbance	• Manage activities to ensure marine turtles are not displaced from identified habitat critical to the survival and biological important areas.	**7.6**
			Noise interference	• A precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season.	**6.2**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
				• Seismic surveys must undertake soft starts during surveys irrespective of location and time of year to protect marine turtles.	
	Short-nosed seasnake	Commonwealth Conservation Advice on *Aipysurus apraefrontalis* (short-nosed seasnake) (2011)	Degradation of reef habitat	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1**
Birds	Australian lesser noddy	Approved Conservation Advice for *Anous tenuirostris melanops* (Australian lesser noddy) (2015)	Habitat loss, disturbance and modification	• Manage disturbance at important sites when Australian lesser noddy are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Bar-tailed godwit	Approved Conservation Advice for *Limosa lapponica baueri* (bar-tailed godwit western Alaskan) (2016)	Habitat loss and degradation from pollution	• Manage disturbance at important sites when bar-tailed godwits are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Curlew sandpiper	Approved Conservation Advice for *Calidris ferruginea* (Curlew Sandpiper) (2015)	Habitat loss and degradation from pollution	• Manage disturbance at important sites when curlew sandpipers are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Eastern curlew	Approved Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (2015)	Habitat loss and degradation from pollution	• Manage disturbance at important sites when eastern curlews are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
	Northern Siberian bar-tailed godwit	Approved Conservation Advice for *Limosa lapponica menzbieri* (bar-tailed godwit northern Siberian)(2016)	Habitat loss and degradation from pollution	• Manage disturbance at important sites when northern Siberian bar-tailed godwits are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Red knot	Approved Conservation Advice for *Calidris canutus* (Red knot) (2016)	Pollution/contamination impacts	• Implement measures to manage and reduce, where possible, waste generation.	**7.1, 7.2**
			Disturbance	• Manage disturbance at important sites when red knots are present.	**7.1, 7.2**
			Habitat loss and degradation	• Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Abbott's booby	Conservation advice *Papasula abbotti* Abbott's booby (northern Siberian) (2015)	Modification and destruction of breeding habitat	• Manage disturbance at important sites when Abbott's booby are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Australian painted snipe	Approved Conservation Advice for *Rostratula australis* (Australian painted snipe) (2013)	Habitat loss, disturbance and modification	• Manage disturbance at important sites when Australian painted snipes are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Common sandpiper, red knot, oriental plover, oriental pratincole, bar tailed godwit, common greenshank	Wildlife conservation plan for migratory shorebirds (2015)	Habitat degradation/ modification (oil pollution)	• Manage disturbance at important sites migratory shorebirds are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Keraudren Extension 3D MSS	Addressed in EP Section
	Great knot	Approved Conservation Advice for *Calidris tenuirostris* (great knot) (2016)	Habitat loss and degradation	• Manage disturbance at important sites when great knots are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Greater sand plover	Approved Conservation Advice for *Charadrius leschenaultii* (greater sand plover) (2016)	Habitat loss and degradation from pollution	• Manage disturbance at important sites when greater sand plovers are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Lesser sand plover	Approved Conservation Advice for *Charadrius mongolus* (lesser sand plover) (2016)	Habitat loss and degradation from pollution	• Manage disturbance at important sites when lesser sand plovers are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**
	Australian fairy tern	Approved Conservation Advice for *Sternula nereis nereis* (Australian fairy tern) (2011)	Habitat loss, disturbance and modification from pollution	• Manage disturbance at important sites when Australian fairy terns are present. • Implement measures to reduce adverse impacts of habitat degradation and/or modification.	**7.1, 7.2**

3.2.3.1 Epibenthos in 40 to 60 m water depth

In 2019, Santos commissioned a study to investigate the potential presence of silver-lipped pearl oysters, *Pinctada maxima*, and pearl oyster habitat targeted at 40 to 60 m water depths (measured from lowest astronomical tide [LAT]) within the Keraudren 3D MSS operational area using towed video imagery (RPS 2019; **Appendix D**). The 40 to 60 m water depths corresponded with the shallowest water depths within the Keraudren 3D MSS operational area, with towed video transects targeting morphological features that were considered most likely to support pearl oysters. The Keraudren Extension 3D MSS operational area overlaps with the towed video target area, and the depth range and seabed morphology are similar (**Figure 3-9**).

Therefore, the findings of the RPS (2019) study results are considered to be representative of the potential presence of pearl oysters and pearl oyster habitat in the Keraudren Extension 3D MSS operational area. Consequently, the epibenthic communities at these water depths have now been described for the former configuration area. As this information is recent and specific to the Keraudren seismic survey, it is not yet included in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

The following dot points provide a summary of the epibenthos recorded in this depth range:

- Common epibiota included sponges, hydroids, whip corals, soft corals, crinoids, echinoderms (starfish, basket stars and sea cucumbers), gorgonians and ascidians;
- Densities and growth forms of epibiota (e.g. hydroids and sponges) were often a characteristic of specific habitat types. For example, habitats characterised by low abundance, short, turf-like forms were often characterised by mobile sand habitats with patches/troughs of more consolidated gravel/rock prone indicating periodic inundation by sand waves;
- Most transects comprised several different habitat types with high abundance, diverse assemblages in patches interspersed by lower abundance/diversity sand or sandy gravel habitats;
- Most common substrate type was consolidated sandy gravel with shell fragments, which was stabilised by patchy, very low-lying hydroid/bryozoan turf (40-75% cover). Large epibiota was generally evenly distributed as shorter forms at relatively low abundance (<5% cover) or occurred as denser patches of larger growth forms on consolidated gravel in depressions or troughs (up to 24% cover);
- Another common habitat observed was large sand waves (with gently sloping relief) and very low abundance of epibiota (<1%) or no conspicuous epibiota;
- Of note was a mesophotic gorgonian forest with high densities of large epibiota on relatively flat emergent bedrock with sand/gravel veneer. Gorgonians were estimated at between 1 to 1.8m high, with shorter colonies also present;
- Only two pearl oysters were identified from a total of 21.9 km of seabed surveyed. Both individuals were observed growing in water depths of 50-54 m (LAT). This indicated that although potential pearl habitat was likely to occur in the depth range surveyed, the habitat did not support a high density of pearl oysters (only a few individuals); and
- The majority of potential pearl oyster habitat was found on the western side of the Keraudren 3D MSS operational area, with habitats in the central and eastern sections of the study area (overlapped by the current Keraudren Extension 3D MSS operational area) considered to be sub-optimal for pearl oysters.

Based on the findings of this study, the shallowest areas of the Keraudren Extension 3D MSS operational area are likely to support only sub-optimal pearl oyster habitat and low densities of pearl oysters (a few individuals). These findings are consistent with preliminary survey results from the Santos funded and Australian Institute of Marine Science (AIMS) led North West Shoals to Shore research program (NWSSRP), which has surveyed for pearl oysters and pearl oyster habitat in waters off Eighty Mile Beach to the west of the operational area. Preliminary data from this study indicates that pearl oysters are more common in water depths less than 40 m. Only a few individual pearl oysters have been found in water depths between 40 and 70 m (Miller 2019).

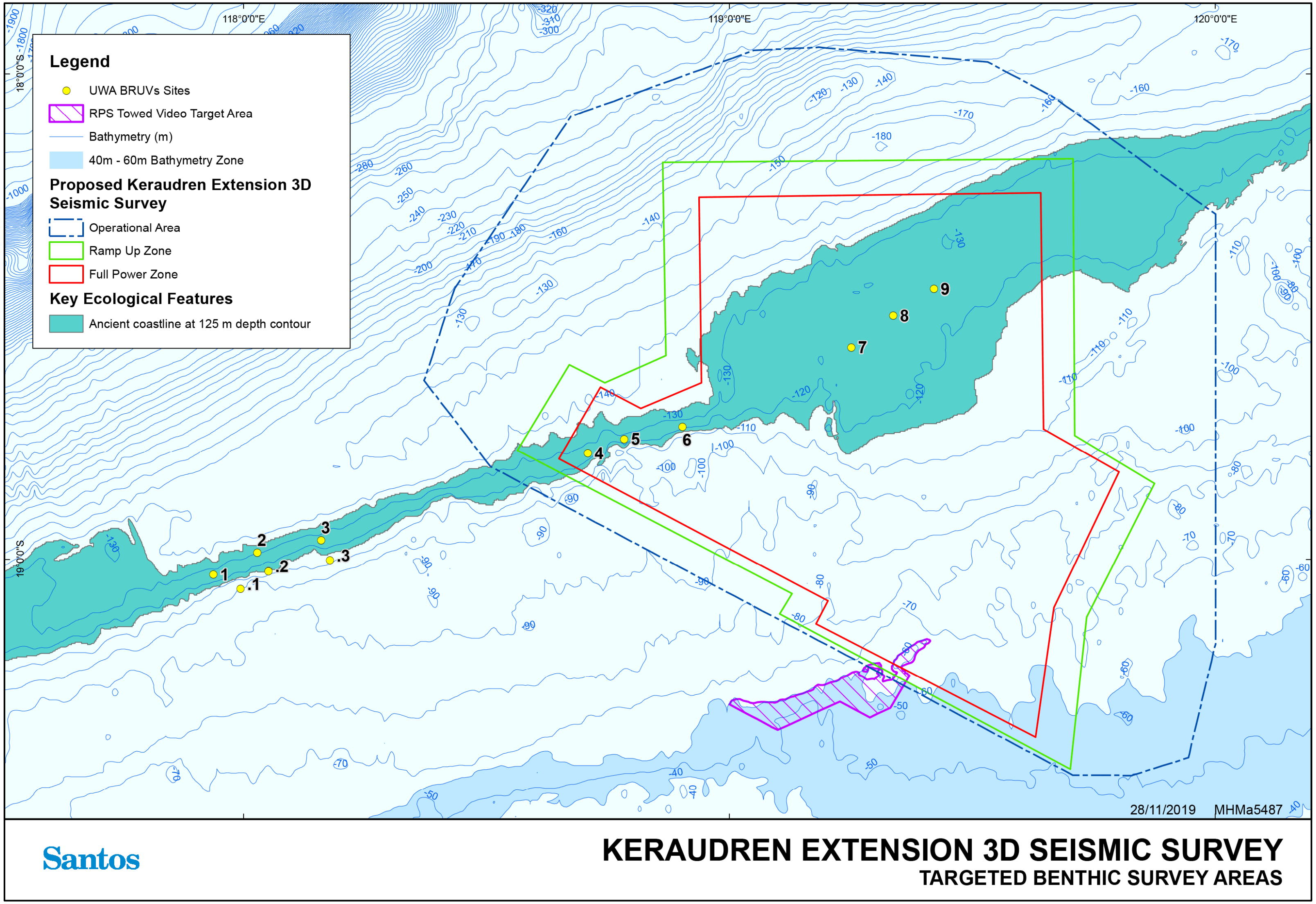


Figure 3-9: Targeted RPS (2019) survey areas within and near the Keraudren Extension 3D MSS operational area

3.2.3.2 Fish associated with the ancient coastline KEF

As described in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**), the ancient coastline at the 125 m depth contour KEF is thought to provide areas of hard substrate that may contribute to higher biological diversity. There is currently limited published information available, but the hard substrate and raised epibiota predicted to occur in this area may provide suitable habitat for demersal fish species. Preliminary data from the AIMS North West Shoals to Shore research program, which includes multibeam and towed video surveys of some areas of the ancient coastline at the 125 m depth contour KEF, has found that these depth contours are dominated by sandy habitats with only some areas of hard substrate filter feeder communities. However, diverse fish populations are still associated with the sandy substrates (Miller 2019).

Santos commissioned a study to describe the fishes associated with the ancient coastline at the 125 m depth contour KEF (RPS 2019; **Appendix D**). Nine sites at three separate geographic locations were surveyed in the KEF, as presented in **Figure 3-9**. The study sites in Location 1 (sites 1, 2 and 3) are over 40 km west from the Keraudren Extension 3D MSS operational area while the study sites at Location 2 (sites 4, 5 and 6) and Location 3 (sites 7, 8 and 9) are located within the Keraudren Extension 3D MSS full power zone. Field work was completed in late October 2018 using a stereo baited remote underwater video system (SBRUVS) technique with 5 units deployed on the 125 m depth contour at each of the 9 sites within a depth range of 120 m to 130 m (RPS 2019; **Appendix D**).

Key findings from the survey in relation to the ancient coastline at the 125 m depth contour KEF were:

- A total of 643 fish from 39 species and 17 families were recorded across the 3 KEF study locations, with goldband snapper (*Pristipomoides multidens*) and yellow spotted rock cod (*Epinephelus areolatus*) being the only commercially important species observed at these locations on the KEF;
- No escarpment, complex relief, emergent bedrock or complex epibiota assemblages were recorded on video or observed on the vessel sounder at the KEF survey sites;
- Limited variation in fish assemblages of the KEF were observed between the three KEF study locations;
- Although within-site variability was high, abundances of fish species were low in the area, comprising relatively mobile demersal fish species; and
- The four most ubiquitous species were lunartail pufferfish (72% deployments), threadfin bream (67% deployments), longnose trevally (59% deployments) and giant trevally (47% deployments).

As part of the above study, an area of high relief seabed that was evident on the vessel depth sounder between 97 to 114 m water depths outside of the KEF, to the south of Location 1 (over 40 km to the west of the Keraudren Extension operational area) was also explored opportunistically. At this location, 5 SBRUVS units were deployed at 3 sites (**Figure 3-9**). A total of 388 fish from 38 species and 20 families were recorded. Two of these sites exhibited higher relief emergent habitat, a significant increase in cover of octocoral and greater occurrence and abundance of commercially important species such as red emperor (*Lutjanus sebae*), the yellow spotted rock cod (*Epinephelus areolatus*) and goldband snapper (*Pristipomoides multidens*). Seven commercially fished species were found at these sites compared to the two species on the ancient coastline at the 125 m depth contour KEF. The third 'exploratory' site was more like the planned locations surveyed than the two sites with higher relief habitat and greater number of fish species and abundance (RPS 2019; **Appendix D**).

3.2.3.3 EPBC Act-listed Threatened and Migratory Fish Species

The BIAs for EPBC Act-protected fish and sharks are shown in **Figure 3-5**. The whale shark foraging BIA overlaps with the operational area. Whale sharks are known to forage northward from Ningaloo along the

200 m isobath. Aggregation timing of whale sharks at Ningaloo Reef is from March to June (Wilson *et al*. 2006). The small size and general absence of female whale sharks from Ningaloo Reef suggests that the region may be important for feeding rather than breeding (Norman and Stevens 2007).

Individuals tagged at Ningaloo Reef have been shown to migrate north, north-east or north-west into Indonesian waters, using both inshore and offshore habitats (Reynolds *et al*. 2017; Sleeman *et al*. 2010; Wilson *et al*. 2006). This migration route has been identified as a BIA which follows the 200 m isobath and extends from Ningaloo to waters in the north Kimberley region.

The BIA that overlaps the Keraudren Extension 3D MSS operational area represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in Spring (September to November).

The EMBA also overlaps the foraging, pupping and nursing BIAs for dwarf sawfish, green sawfish and freshwater sawfish (**Figure 3-5**).

3.2.3.4 Conservation-dependent Fish Species

Two fish species listed as Conservation Dependent (CD) under the EPBC Act, the southern bluefin tuna (*Thannus maccoyli*) and the scalloped hammerhead shark (*Sphyra lewini*), have been identified in the EMBA but are not described in the *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B***)* document.

Southern Bluefin Tuna

The southern bluefin tuna occurs throughout waters 30-50 °S but mainly in the eastern Indian Ocean and south-western Pacific Ocean. In Australian waters, the species ranges from northern Western Australia, around the southern coast to northern New South Wales. Spawning occurs in warm waters south of Java, to the north-west of the operational area (**Figure 3-10**), from August to April, with a peak during October-February (Honda *et al*. 2010). Following spawning, juveniles migrate south following the Western Australian coast, with juveniles commonly found in coastal waters off southern Australia during summer, and in deeper, temperate oceanic waters during winter (Phillips *et al*., 2009). Juveniles inhabit inshore waters (Honda *et al.* 2010) where they are thought to congregate at reefs, lumps and seamounts (Fujioka *et al*. 2010). Southern bluefin tuna may occur within the operational area and EMBA, particularly during summer/autumn when juveniles migrate southwards.

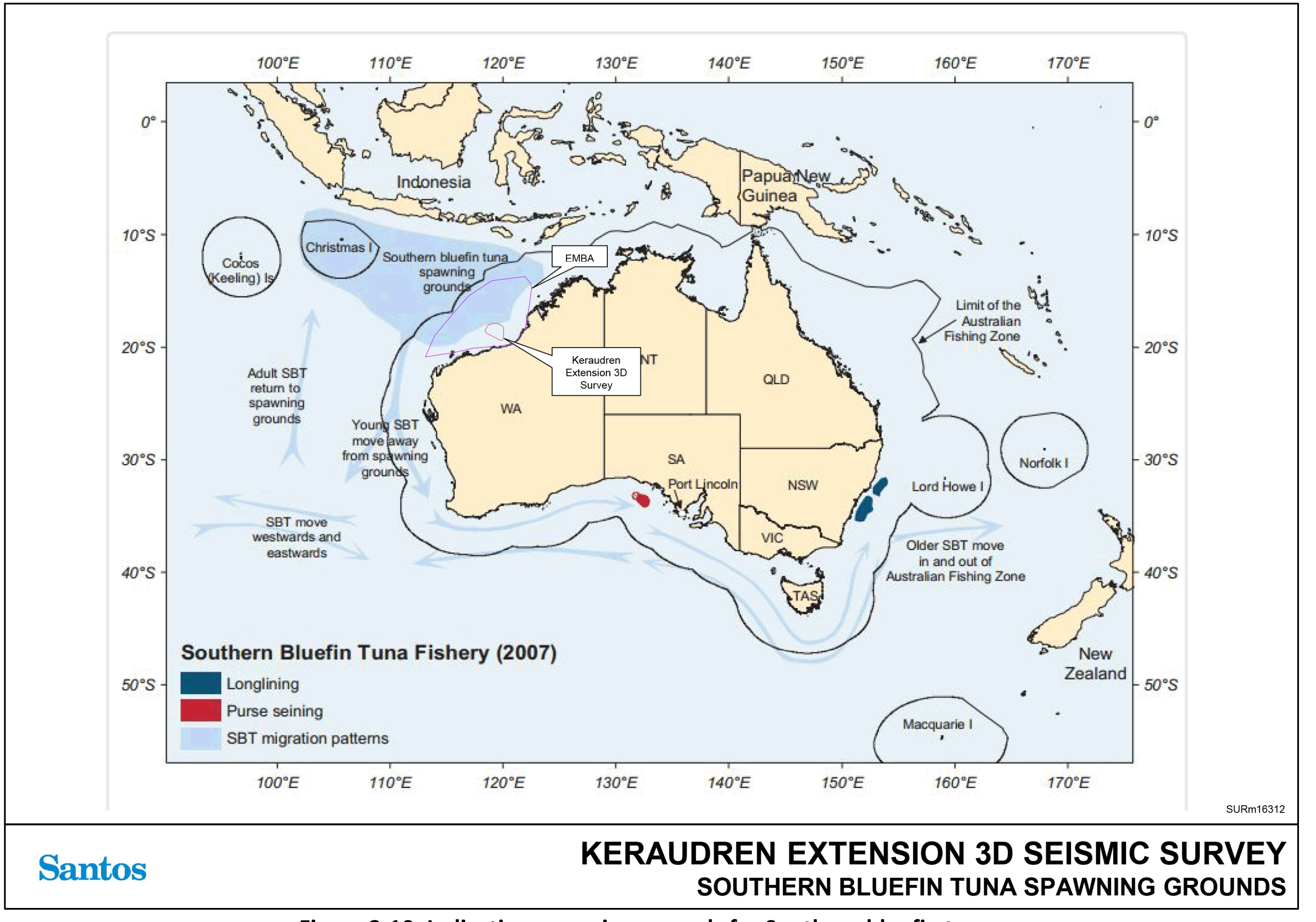


Figure 3-10: Indicative spawning grounds for Southern bluefin tuna

Scalloped Hammerhead Shark

The scalloped hammerhead shark is widely distributed in tropical and sub-tropical waters, primarily inhabiting shallow coastal shelfs. In Australia, the species ranges from Geographe Bay in Western Australia, around the northern coast to Wollongong in New South Wales (Harry *et al*. 2011). Pupping has been reported year-round on the east coast of Australia, peaking during November and December, with juveniles remaining in shallow inshore habitats (Harry *et al*. 2011). The species is highly mobile but rarely ventures into deep offshore waters. Hammerhead sharks have been observed close inshore, even entering estuarine habitats, as well as offshore to depths up to 275 metres. Accordingly, the hammerhead shark may occur in the operational area and shallower depths of the EMBA. A recent study recorded five individuals on the ancient coastline at the 125 m depth contour KEF using SBRUVS (See **Section 3.2.3.2** and Supplementary Table 1 in RPS 2019; **Appendix D**).

3.2.3.5 Humpback Whale Migration

Humpback whales traverse waters off the west coast of Australia as they migrate annually from summer feeding grounds in Antarctica to the nearshore waters of the Kimberley region where they breed and calve during winter. The waters up to 50 km from the coast of north-west WA are designated as a migration BIA (**Figure 3-6**). The humpback whale migration BIA overlaps with the southern portion of the operational area. Characteristics of the northern and southern migrations are summarised in **Table 3-8**.

During the northbound migration, the data presented in Jenner *et al.* (2001) indicates the whales appear to remain within the 200 m isobath near the Montebello Island before moving closer to shore as they head further north to the calving grounds in the Kimberley. The humpback whale migration corridor is not an identified aggregation area or critical habitat, whales are in transit, and are migrating from their southern polar 'summer' feeding grounds to their northern tropical 'winter' calving / breeding grounds.

The northern migration across the North West Shelf towards resting and calving grounds in the Kimberley region may occur from as early as June through to August and the southward migration from September to October, though actual timing of annual migration may vary by as much as 3 weeks from year to year due to food availability in the Antarctic (Jenner *et al.* 2001; Thums *et al*. 2018). Peak northward migration across the North West Shelf is identified from late July to early August, and peak southward migration from late August to early September. Data collected between 1995 and 1997 by the Centre for Whale Research indicates that the period for peak northern migration into the calving grounds in the Kimberley is mid to late July and the peak for southern migration from the Kimberley is in the first half of September.

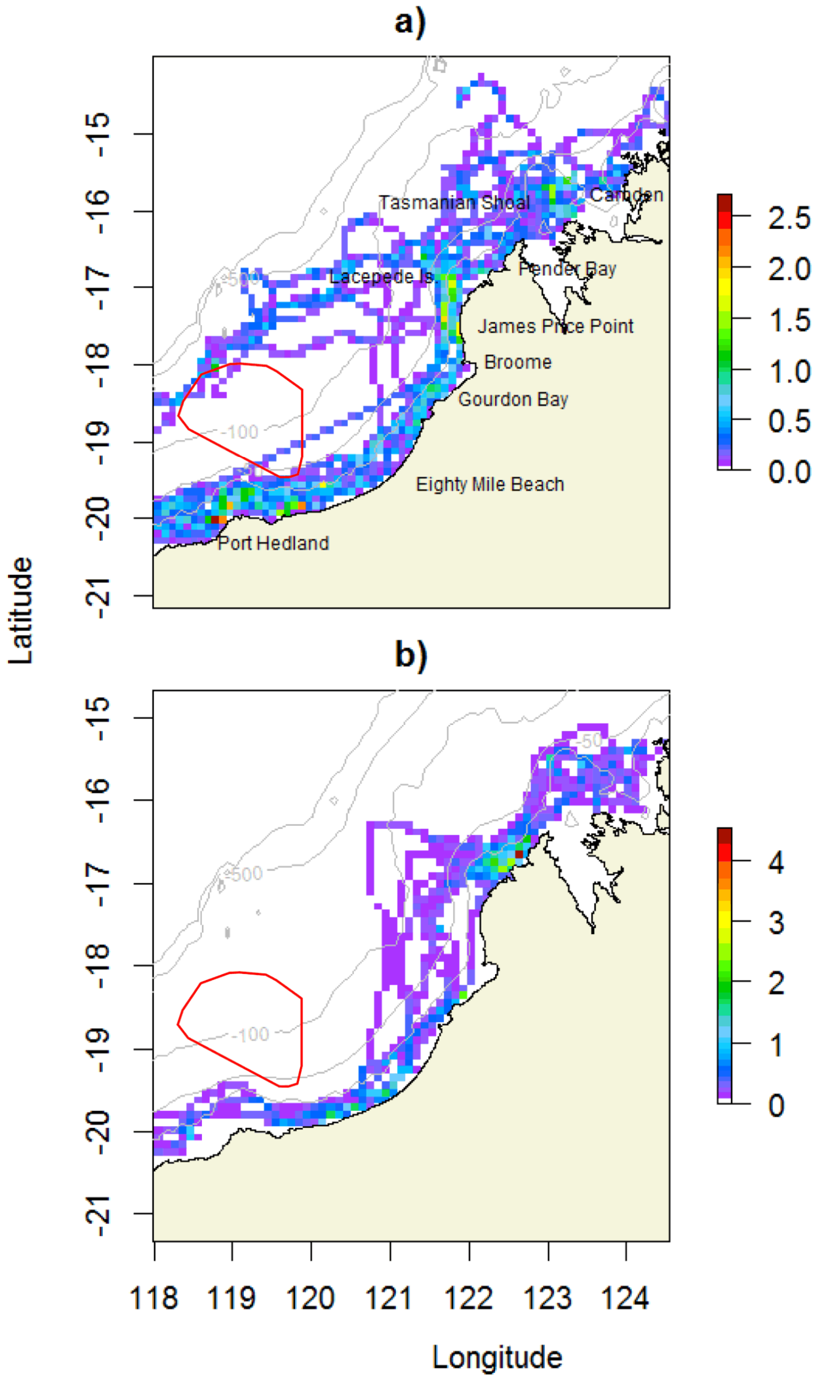
Based on migration data presented in Thums *et al.* (2018), it is possible that a small number of migrating individuals will traverse the operational area prior to seismic survey termination (**Figure 3-11**). This migration data collected over 2008, 2009 and 2011 for tagged humpback whales shows there are few migration paths that overlap with the proposed Keraudren Extension 3D MSS operational area, and where there is overlap the number of days that the humpback whales may spend within the operational area during their northern migration would be hours rather than days (i.e., <0.5 days; **Figure 3-11**).

Marine fauna sightings data collected during the previous Santos Keraudren 3D MSS between May and July 2019 included 42 confirmed sightings of humpback whales. The first sighting occurred on 8^{th} of June 2019. Occasional sightings of humpback whales were subsequently made every few days throughout June, becoming more frequent in late June and through to mid-July when multiple sightings were made most days. The final recorded humpback whale sighting was on 15^{th} of July 2019, following which the survey was terminated. Of all 42 humpback whale sightings, 38 were made at longitudes greater than 19˚S, which correspond with the southern part of the operational area and water depths less than 90 m. The other four sightings were made near the north-west boundary of the survey in water depths of approximately 150 m or greater. These sightings are broadly consistent with the data presented in Jenner *et al.* (2001), Thums *et al.*

(2018) and the basis for the migration BIA, where the majority of the migrating humpback population pass through these waters within approximately 100 km of the coast, with a relatively small number of animals passing further offshore.

Table 3-8: Key periods for migrating humpback whales in the vicinity of the operational area

Migrations	Description	Timing
Northbound migration: Port Hedland to Broome	Peaks July and tapers off by August (may vary by 3 weeks from year to year). Extends further from the coast compared to the southern migration, in water depths up to 200 m with the greatest number of animals in water depths of approximately 50 m (**Figure 3-11**).	Commences in June. Peaks in late July - Early August
Southbound migration: Broome to Port Hedland	Southerly migration in this area is contracted in a narrower band than the northerly migration route generally occurring closer to the coast within the 50 m isobath, and generally in waters less than 35 m deep (**Figure 3-11**).	Commences in August. Peaks late September - Early October
Note: This information has been sourced from Jenner *et al.* (2001); DoEE (2015); DMP (2003); and Thums *et al.* (2018).		



Number of days spent by northbound (a) and southbound (b) humpback whales per 10 km × 10 km grid cell for the Kimberley Region, within proximity of the Keraudren Extension survey area, from tagged humpback whales from 2008, 2009 and 2011. (source Thums et al, 2018).

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NORTHBOUND AND SOUTHBOUND HUMPBACK WHALES MIGRATION DURATIONS (2008-2011)

Figure 3-11: Northbound (a) and southbound (b) humpback whales migration durations (2008-2011) (Thums et al. 2018)

3.2.3.6 Pygmy Blue Whale Migration

The pygmy blue whale (*Balaenoptera musculus brevicauda*) is a subspecies of the blue whale, of which there are four species. Pygmy blue whales migrate as solitary animals or in small groups along the continental slope, typically at depths between 500 m and 1,000 m on the way to grounds in the Banda and Molucca Seas near Indonesia, where calving is understood to occur (Double *et al.* 2014).

The northern migration passes the Perth Canyon from January to May and north bound animals have been detected off Exmouth and the Montebello Islands between April and August (Double *et al*. 2012, McCauley and Jenner 2010). During the southern migration, pygmy blue whales pass south of the Montebello Islands and Exmouth from October to the end of January, peaking in late November to early December (Double *et al*. 2012).

Tagging surveys have shown pygmy blue whales migrating northward past the North West Cape after which they travelled approximately 240 km offshore (Woodside 2012). During the southern migration, Gavrilov *et al*. (2018) found that pygmy blue whales tended to travel southward much further away from the coast, at distances of up to 400 km from shore.

The BIA for migrating pygmy blue whales is located approximately 30km north-west of the operational area over 100 km from the survey area. A broader distribution BIA indicates where pygmy blue whales may also occur outside of the key migration route, which overlaps the operational area. Further, at the most northerly limit of the EMBA there is a foraging BIA in waters surrounding Scott reef (**Figure 3-6**).

Marine fauna sightings data collected during the previous Santos Keraudren 3D MSS between May and July 2019 did not include any confirmed pygmy blue whale sightings, likely due to the distance of the survey from the key migration route. Similarly, very few or no pygmy blue whales are expected to occur within the Keraudren Extension 3D MSS operational area.

3.2.3.7 Marine Turtles

The BIAs and Habitat Critical to the survival of turtles are shown in **Figure 3-7**. The EMBA overlaps with BIAs for flatback, green, hawksbill and loggerhead turtles. These turtle species and BIAs are described in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

The operational area intersects a BIA (internesting) and Habitat Critical (internesting) for flatback turtles. The Habitat Critical for internesting is defined as a 60-km buffer zone seaward of designated nesting habitat, while the BIA for internesting is 90 km from the nesting habitat.

In the Kimberley and Pilbara regions of Western Australia, from approximately the Lacepede Islands to Exmouth, there is a mid-summer peak nesting season for flatback turtles. More specifically, nesting and internesting in the Pilbara and south-west Kimberley stocks occurs between October and March with a peak period of December to January (DoEE, 2017). Flatback turtle hatchlings do not have an offshore pelagic phase. Instead, hatchlings grow to maturity in shallow coastal waters thought to be close to their natal beaches (DoEE, 2017).

Although turtles remain close to nesting beaches during the internesting period, there is evidence that some flatback turtles undertake long-distance migrations between breeding and feeding grounds. A survey carried out in the region between 2005 and 2012 identified the distances 73 female flatback turtles travelled to their foraging grounds; 11 remained within 100 km of their rookeries, four migrated an average of 400 km and 58 migrated between 1,000 and 1,500 km (Pendoley *et al*. 2014).

3.2.4 Socio-economic

The section describes the socio-economic values within the EMBA being commercial fisheries, shipping, recreational fishing, oil and gas industry, tourism, cultural heritage, submarine cables and defence activities. As active and socio-economically important co-users of the marine environment within the operational area and surrounds, the focus of this section is on commercial fishers.

3.2.4.1 Commercial Fisheries

Commonwealth and Western Australian State-managed fisheries overlapping the EMBA are illustrated in **Figure 3-12** and **Figure 3-13** respectively.

Identification of relevant fisheries within the Bedout Sub-basin has been ongoing since 2008 through consultation with the WA Department of Primary Industries and Regional Development (DPIRD) and West Australian Fishing Industry Council (WAFIC). Further, Santos continually updates its understanding of the fisheries through reviews of annual status of the fishery reports published by DPIRD and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), other relevant fisheries management publications, and fishery catch and effort data (**Section 3.2.4.2**).

A review of available fishery management information for pelagic and demersal finfish fisheries indicated that whilst fisheries management measures includes annual quotas, and closure of specific areas all the time, none of the fisheries have specific time periods of closure for spawning/ aggregation.

The commercial fisheries that overlap the EMBA are summarised in **Table 3-9** below.

3.2.4.2 FishCube Data

Santos requested annual catch and effort data (FishCube data) from DPIRD for fisheries understood to operate within or near to the operational area. Data was assessed for 60 nm x 60 nm and for 10 nm x 10 nm Catch and Effort System (CAES) blocks for the following:

- Catch and effort data for the most recent 10 years (2009-2018, aggregated); and
- Annual catch and effort data for each of the most recent 5 years (2014, 2015, 2016, 2017, 2018).

Data was assessed to identify where the greatest fishing effort in each fishery occurred and the relative importance of waters within the operational area.

Data provided by DPIRD included:

- Weight (kg) – a measure of fish catches per CAES block during the period of interest;
- Vessel Count – a measure of the number of vessels that fished in a CAES block during the period of interest; and
- Fishing Day Count – a measure of fishing effort, represented by the number of days when one or more vessels fished in a CAES block during the period of interest.

Due to confidentiality reasons, DPIRD do not release catch and effort data for CAES blocks where less than three vessels fished during the period of interest (i.e. less than three vessels per year or less than three vessels over the complete 10-year period). Where this applies, the Vessel Count is marked ‘Less than 3’, while Weight and Fishing Day Count are marked as ‘N/A’. CAES blocks where the results are provided in this way confirm that fishing effort did occur within the block during that period, but the associated catch and effort values are not available. CAES blocks where no fishing is recorded do not return any data.

Appendix E presents the FishCube data that has been mapped for the following fisheries, which have a spatial overlap and/or recorded fishing effort within the operational area:

- Mackerel Managed Fishery (Area 2 - Pilbara);
- Pilbara Fish Trawl (Interim) Managed Fishery;
- Pilbara Line Fishery;
- Pilbara Trap Managed Fishery;
- Specimen Shell Managed Fishery; and
- Pearl Oyster Managed Fishery.

Additional catch data by fish species was also provided by commercial fishers, MG Kailis and Westmore Seafoods, which shows the total volume of catch per 10x10 nm block for bluespotted emperor, brownstripe snapper, crimson snapper, frypan bream, goldband snapper, rankin cod, red emperor, saddletail snapper, spangled emperor, threadfin breams – noting that these data are the total volume of fish caught per year in kg for each block and not catch-per-unit-effort (CPUE). For permissioning reasons, this data cannot be presented in this EP but it has previously been submitted to NOPSEMA with the previous Keraudren Extension 3D MSS EP.

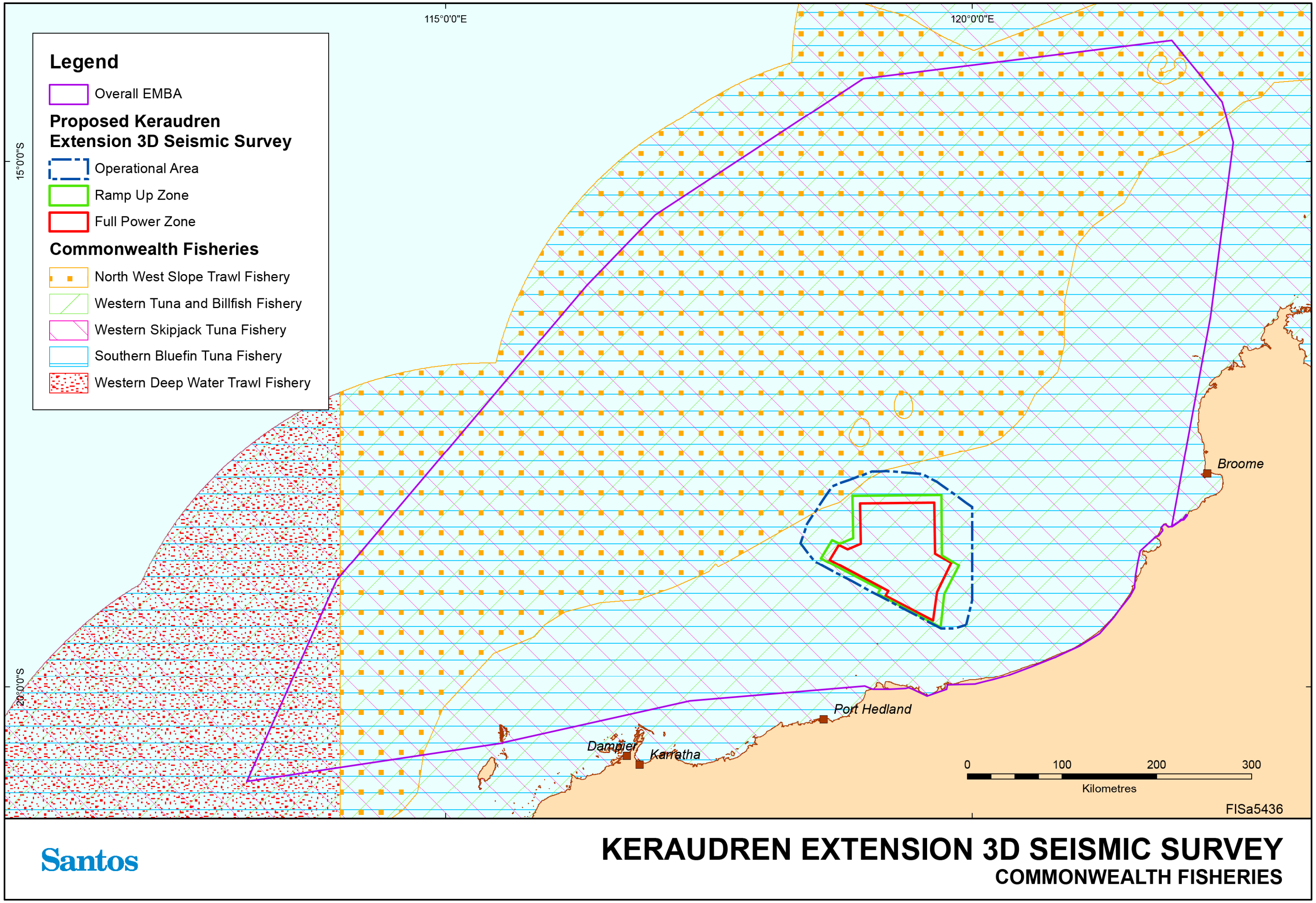


Figure 3-12: Commonwealth-managed fisheries within the EMBA

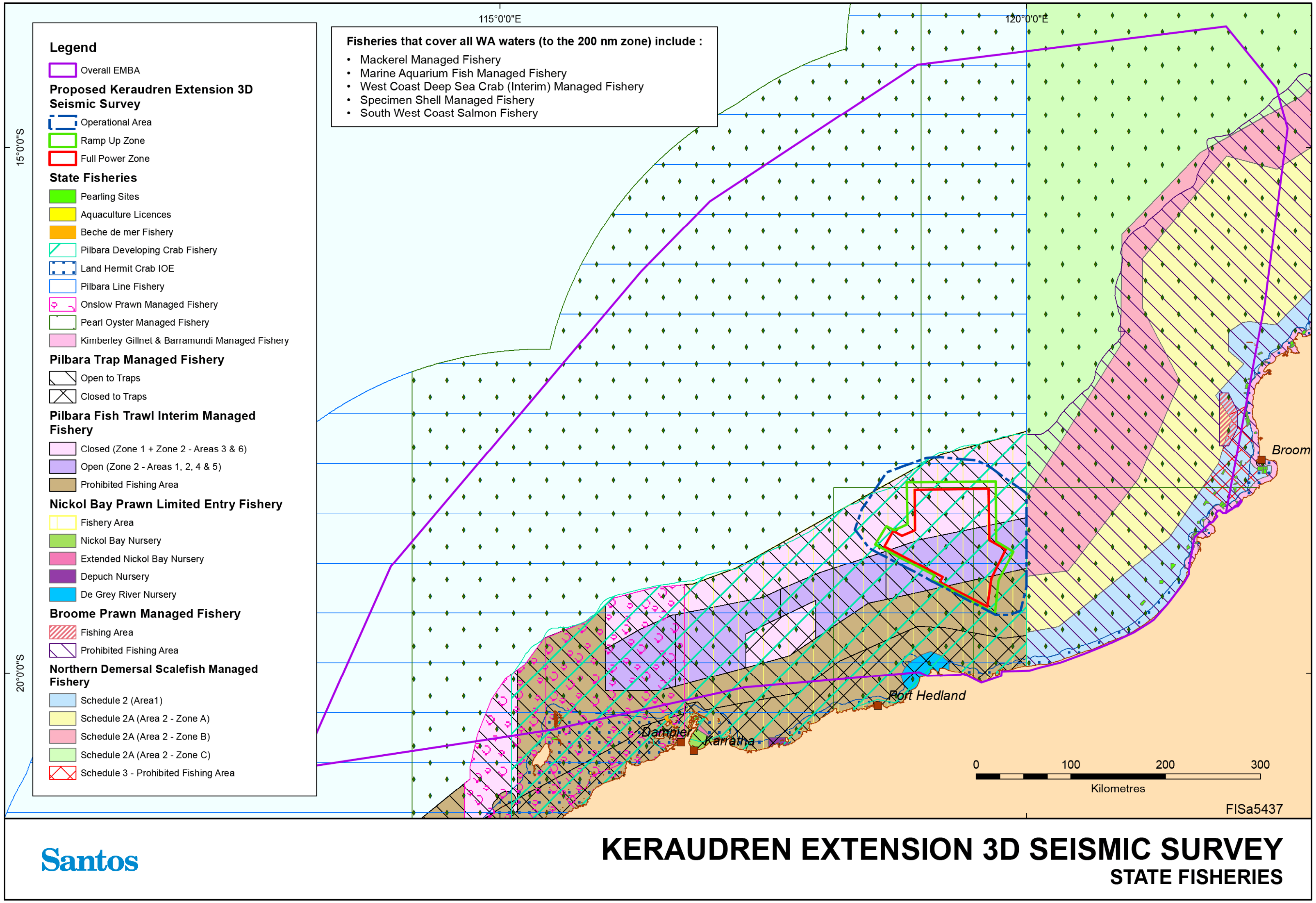


Figure 3-13: State-managed fisheries within the EMBA

Table 3-9: State-managed and Commonwealth-managed fisheries overlapping the operational area and EMBA

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
State-Managed Fisheries						
Pilbara Fish Trawl Interim Managed Fishery (PFTIMF) Newman *et al*. (2019a)	The Pilbara Fish Trawl Interim Managed Fishery (PFTIMF) is situated in the Pilbara region in the north-west of Australia. It occupies the waters north of latitude 21°35’S and between longitudes 114°9’36”E and 120°E. The Fishery is seaward of the 50 m isobath and landward of the 200 m isobath. The Fishery consists of two zones; Zone 1 in the south west of the Fishery (which is closed to trawling) and Zone 2 in the north, which consists of six management areas, Areas 1 to 6. Areas 1, 2, 4 and 5 are open to trawl fishing all year round. The total area of these areas is 6,900 nm^2 (23,666 km^2).	Demersal trawl	Bluespotted emperor (*Lethrinus punctulatus*) Red emperor (*Lutjanus sebae*) Rankin cod (*Epinephelus multinotatus*) Goldband snapper (*Pristipomoides multidens*) Other demersal snapper, emperor, cod and grouper species are also caught.	In 2018, the total catch for the PTIMF was 1,975 tonnes, making up 75% of the total catch by the Pilbara Demersal Scalefish Fisheries (PDSF), comprising the trawl, trap and line fisheries. In the 2018 season, there were 11 licences in this fishery held by four licence holders. According to FishCube data up to four vessels were active during the 2018 season. Fishing occurs year-round.	Fishing activity and target species occur in the operational area. FishCube data (**Appendix E**) shows fishing effort in the last ten years occurs over an area of 23,058 km^2. The operational area overlaps with 6,310 km^2 (27%) of the area of fishing effort. Fishing effort has occurred consistently within the operational area each year for the last 5 years.	<u>Planned:</u> Interaction with other marine users Noise emissions <u>Unplanned:</u> Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Pilbara Trap Managed Fishery (PTMF) Newman *et al*. (2019a)	The Pilbara Trap Managed Fishery lies north of latitude 21°44’S and between longitudes 114°9.6’E and 120°00’E on the landward side of a boundary approximating the 200 m isobath and seaward of a line generally following the 30 m isobath.	Demersal fish traps	Bluespotted emperor (*Lethrinus punctulatus*) Red emperor (*Lutjanus sebae*) Rankin cod (*Epinephelus multinotatus*) Goldband snapper (*Pristipomoides multidens*) Other demersal snapper, emperor, cod and grouper species are also caught.	In the 2018 season, there were six licenses in the Pilbara Trap Fishery, held between two operators. According to FishCube data less than three vessels were active for majority of the season, with a third vessel active only in July. In 2018, the total catch for the PTMF was 562 tonnes, making up 21% of the total catch by the PDSF. Fishing occurs year-round.	Fishing activity and target species occur in the operational area. FishCube data (**Appendix E**) for the last ten years reports that a maximum of 3 vessels have operated in the operational area. Fishing effort occurs over an area of 86,006 km^2. The operational area overlaps with 19,691 km^2 (23%) of the area of fishing effort. Less than three vessels have operated in the operational area each year for the last 5 years.	<u>Planned:</u> Interaction with other marine users Noise emissions <u>Unplanned:</u> Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Pilbara Line Fishery (PLF) Newman *et al*. (2019a)	The PLMF fishing boat licensees are permitted to operate anywhere within "Pilbara waters", bounded by a line commencing at the intersection of 21°56’S latitude and the high water mark on the western side of the North West Cape on the mainland of Western Australia; west along the parallel to the intersection of 21°56’S latitude and the boundary of the Australian Fishing Zone and north to longitude 120°E.	Demersal long line	Goldband snapper (*Pristipomoides multidens*) Ruby snapper (*Etelis carbunculus*) Other demersal snapper, emperor, cod and grouper species are also caught.	In the 2018 season there are nine individual licences in the Pilbara Line Fishery, held by seven operators. According to FishCube data less than three vessels were active during the season. The total catch in 2018 for the PLF was 95 tonnes, making up 4% of the total catch by the PDSF. Fishing occurs year-round.	Fishing activity and target species occur in the operational area. FishCube data (**Appendix E**) shows fishing effort in the last ten years has occurred over an area of 146,414 km^2. The operational area overlaps with 8,802 km^2 of the area of effort (6%). FishCube data reports that less than three vessels have operated in the operational area each year for the last 5 years, compared with greater fishing effort located to the west of the Operational Area between Exmouth and Dampier.	<u>Planned:</u> Interaction with other marine users Noise emissions <u>Unplanned:</u> Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
Northern Demersal Scalefish Managed Fishery (NDSMF) Newman *et al*. (2008) Newman *et al*. (2019a)	The Northern Demersal Scalefish Managed Fishery licence area includes waters off the north-west coast of Western Australia (WA) in the waters east of 120° E longitude, extending from Eighty Mile Beach to the WA-Northern Territory (NT) border and out to the edge of the Australian Fishing Zone (200 nautical miles). The fishery is divided into two fishing areas; an inshore sector (Area 1) and an offshore sector (Area 2). Area 2 extends offshore from the 30 metres depth contour and is further subdivided into Zones A, B and C.	Fish traps. Handlines and droplines also permitted in the fishery.	Red emperor (*Lutjanus sebae*) Goldband snapper (*Pristipomoides multidens*) Other demersal snapper, emperor, cod and grouper species are also caught, including but not limited to bluespotted emperor, spangled emperor, saddletail snapper, crimson snapper and rankin cod.	The fishery principally operates in depths of 60–150 metres water. Most catch occurs in Zone B of Area 2. Fishing occurs year-round. Vessels in the fishery operate out of Broome and Darwin. Fishers travel long distances to fishing grounds and typically fish at multiple sites over a period of 4-10 days. Including steaming time, vessels are typically away from port for 1-2 weeks at a time. Traps are typically set for 4-5 hours or left overnight before being pulled. Eight vessels operated in the fishery between 2013 and 2015, reducing to seven vessels 2015 and 2017.	The NDSMF is located adjacent to the operational area. Therefore, no fishing activity will occur in the operational area, but may occur in waters adjacent to the operational area from time to time. Target species occur in the operational area.	Planned: Noise emissions Unplanned: Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Mackerel Managed Fishery (MMF) **(Area 2 – Pilbara)** Lewis and Brand-Gardner (2019) Mackie *et al*. (2010)	The Mackerel Managed Fishery licence area extends from Cape Leeuwin in the south west of WA to the WA/NT border. Management Area 1 of the fishery (Kimberley sector) extends from 121º E to the WA/NT border. Management Area 2 of the fishery (Pilbara sector) extends from 114° E near the North West Cape to 121° E. Management Area 3 of the fishery (Gascoyne/West Coast sector) extends south from 114° E to Cape Leeuwin. The operational area overlaps Area 2 – Pilbara sector.	Primarily surface or mid-water trolling by line. Jigging methods are also used.	Spanish mackerel (*Scomberomorus commerson*) Grey mackerel (also called broad-barred Spanish mackerel), school mackerel, spotted mackerel, shark mackerel and other pelagic species are also caught as bycatch species.	Mackerel fishers troll for mackerel in nearshore waters. FishCube data (**Appendix E**) shows that fishing effort in the vicinity of the operational area occurs in <60 m water depth, which is corroborated by consultation with stakeholders for the previous Keraudren 3D MSS in this area. The fishery operates year-round, however, most fishing effort occurs from April/May to October/November. In the Pilbara sector, ~65% of effort has historically occurred from July to August. The commercial catch of Spanish mackerel from all sectors of the fishery has been 270-330 tonnes per year since 2006.	Fishing activity and target species occur in the operational area. FishCube data for the last ten years (**Appendix E**) shows the Mackerel Managed Fishing effort within Area 2 is 51,848 km^2. The operational area overlaps with 2,439 km^2 of the area of effort (5%). Effort is restricted to the southern portion of the operational area. The FishCube data shows that a greater than average number of fishing days have occurred in one block in the southern part of the operational area. In the last 5 years, this area has been fished by a maximum of 3 vessels in any year. In 2018 less than three vessels were active. Santos was advised during consultation for the previous Keraudren 3D MSS that the southern portion of the operational area comprises important fishing grounds which are fished each year.	Planned: Interaction with other marine users Noise emissions Unplanned: Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
Pearl Oyster Fishery Hart *et al*. (2016) Hart *et al*. (2019a)	The Pearl Oyster Fishery licence area extends from 114° 10' E near Exmouth to the WA/NT border, and out to the edge of the Australian Fishing Zone (200 nautical miles). The licence area is subdivided into four zones. Zone 1 extends from 114° 10' E to 119° 30' E. Zone 2 extends from 118° 10' E and includes the Eighty Mile Beach region out to 18° 14' S. Zone 3 include waters offshore from Broome and the North Kimberley coast, north of 18° 14' S and between 119° 00' E and 125° 20' E. Zone 4 extends from 125° 20' E to the WA/NT border.	Drift diving in waters up to 35 m depth	Indo-Pacific, silver-lipped pearl oysters (*Pinctada maxima*).	Drift diving, with divers towed behind vessels, allows collection of legal-sized pearl oysters from the seabed by hand. Following collection, pearl oysters are kept in wire mesh panels on the seabed at holding sites near fishing grounds. After 2-3 months, oysters are transferred from holding sites to pearl farm leases for cultivating pearls. Fishing usually commences in March/April and ceases in June/July. Seeding of the pearl oysters is undertaken during winter months (June – August). This may occur at holding sites or at pearl farms. The principal fishing grounds, holding sites and pearl farms are in waters off Eighty Mile Beach and Broome. A single approved pearl farm lease is located near North Turtle Island and pearl diving activities have previously occurred in coastal waters near Port Hedland and the De Grey river mouth.	Operational area occurs within the boundaries of Zone 2 of the fishery. Pearl diving activities do not intersect the operational area. FishCube data (**Appendix E**) shows no effort within the operational area, due to the restriction of pearl diving operational activities to shallow diving depths below 35 m. The nearest pearl diving activities in the last ten years have occurred over 30 km south of the operational area. Target species may occur in the shallow southern part of the operational area.	Planned: Noise emissions Unplanned: MDO/MGO release from vessel collision Spill response operations
Nickol Bay Prawn Managed Fishery (NBPMF) Kangas *et al*. (2019)	The boundaries of the NBPMF are all the waters of the Indian Ocean and Nickol Bay between 116°45' east longitude and 120°east longitude on the landward side of the 200 m isobath. The NBPMF incorporates the Nickol Bay, Extended Nickol Bay, Depuch and De Grey size-managed fish grounds.	Trawl	Banana prawns Brown tiger prawns	The total landings of major penaeids for the 2017 season were 227.1 tonnes. Fishing effort in 2017 increased to 281 boat days, well up on the low effort of 43 boat days in 2016 (Kangas *et al*., 2017).	Prawn trawling activities do not occur in the operational area. Target species may occur in operational area, but are found predominantly in shallow, turbid nearshore waters. FishCube data shows effort in the NBPMF does not intersect the operational area. The nearest fishing activities occur near the coast approximately 50 km south of the operational area.	Unplanned: MDO/MGO release from vessel collision Spill response operations
Broome Prawn Kangas *et al*. (2019)	The boundaries of the Broome Prawn Managed Fishery licence area are 'all Western Australian waters of the Indian Ocean lying east of 120° east longitude and west of 123°45' east longitude on the landward side of the 200 m isobath'.	Trawl	Banana prawns Western king prawns Brown tiger prawns Endeavour prawns	The majority of the Broome Prawn Managed Fishery is permanently closed to trawling and is not fished. The Broome Prawn Managed Fishery operates in a small designated trawl zone off Broome. Only trial fishing was undertaken by one boat during 2016 to investigate whether commercial fishing was warranted. This resulted in negligible landings.	No overlap between the fishery and the operational area. The fishery occurs in the EMBA.	Unplanned: MDO/MGO release from vessel collision Spill response operations

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
Onslow Prawn Kangas *et al*. (2019)	The boundaries of the OPMF are 'all the Western Australian waters between the Exmouth Prawn Fishery and the Nickol Bay prawn fishery east of 114º39.9' on the landward side of the 200 m depth isobath'.	Trawl	Brown tiger prawns Banana prawns	The total landings in 2017 were negligible. Only 5 days of fishing effort was undertaken (one boat) in 2017.	No overlap between the fishery and the operational area. The fishery occurs in the EMBA.	Unplanned: MDO/MGO release from vessel collision Spill response operations
WA North Coast Shark Fishery (WANCSF) Department of Fisheries (2005)	The WANCSF include Australian waters north of Broome, from longitude 120° E to 123°45' E (Koolan Island).	Long line	Dusky whaler shark Sandbar shark Gummy shark Whiskery shark	This fishery is currently closed to protect the breeding grounds of the resource which support the two southern shark fisheries. No fishing effort since 2008/09.	The fishery is currently closed. Target species may occur in operational area.	None
Pilbara Crab Managed Fishery (PDCMF) Johnston *et al*. (2019)	The boundaries of the PDCMF are consistent with the boundaries of the NBPMF and Onslow Prawn Fishery, which includes waters between 114°39.9' E and 120° E, and on the landward side of the 200 m depth isobath.	Traps	Blue swimmer crab	Crabbing activity along the Pilbara coast is centred largely on the inshore waters from Onslow through to Port Hedland, with most commercial and recreational activity occurring in and around Nickol Bay. Blue swimmer crabs are targeted by the PDCMF within inshore waters around Nickol Bay using hourglass trap (Gaughan and Santoro, 2018).	PDCMF operational activities are not expected to intersect the operational area. FishCube data shows no fishing effort within the operational area. Consultation with WAFIC has indicated that while they do mostly fish nearshore (less than 50 metres of water) they may venture into deeper waters. Target species may occur in the southern portion of operational area (<50 m depth).	Unplanned: MDO/MGO release from vessel collision Spill response operations
Marine Aquarium Fish Managed Fishery (MAFMF) Newman *et al*. (2019b)	The MAFMF can operate in all State waters (between the Northern Territory border and South Australian border).	Hand collection, diving	Various species of fish, coral, algae, seagrass and invertebrates	The fishery is typically more active in waters south of Broome with higher levels of effort around the Capes region, Perth, Geraldton, Exmouth and Dampier.	Activities in the operational area are unlikely due to the depth and the dive-based method of collection. FishCube data shows no fishing effort within the operational area. Consultation with WAFIC has confirmed the Activity will not impact fishing activities in this fishery.	Unplanned: MDO/MGO release from vessel collision Spill response operations

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
Specimen Shell Managed Fishery Hart *et al*. (2019b)	The fishing area includes all Western Australian waters between the high-water mark and the 200 m isobath.	Hand collection, wading, diving in shallow coastal waters. One licence exemption permits the use of ROV.	Various shells	The main method of specimen shell collection is by hand, by a small group of divers operating from small boats in shallow coastal waters or by wading along coastal beaches below the high-water mark. A current Exemption permits the use of a remote-controlled underwater vehicle at depths of up to 300 m. This is a limited entry fishery with 23 active licences in 2016. A maximum of 2 divers are allowed in the water per licence at any one time and specimens may only be collected by hand. Remotely operated vehicles were limited to one per license in 2016.	Specimen shell collection activities with ROV may potentially occur in the operational area but are expected to be rare. FishCube data indicates some activity in the vicinity of the operational area. In consultation with WAFIC and the Specimen Shell Industry Association for the Keraudren 3D MSS, it was confirmed this would have occurred from a boat with an ROV. Further consultation with WAFIC and directly with the Specimen Shell Industry Association for the previous Keraudren 3D MSS confirmed that seismic surveys in these waters should not impact specimen shell collecting activities.	<u>Planned:</u> Interaction with other marine users Noise emissions <u>Unplanned:</u> Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations
Beche-de-mer Fishery Gaughan *et al*. (2019)	The beche-de-mer fishery is permitted to operate throughout Western Australian waters except for a number of specific closures around the Dampier Archipelago, Cape Keraudren, Cape Preston and Cape Lambert, the Rowley Shoals and the Abrolhos Islands.	Hand collection, diving	Sandfish (*H. scabra*) Redfish (*A. echinites*)	Sea cucumbers (also known as bêche-de-mer or trepang) are collected by hand by divers and waders in shallow waters throughout the Kimberley region as part of the Bêche-de-Mer Fishery (State of the Fisheries 2016-17). The Western Australian beche-de-mer fishery is primarily based in the northern half of the State, from Exmouth Gulf to the Northern Territory border, however fishers do have access to all Western Australian waters not specifically closed to fishing (Gaughan & Santoro, 2018).	No activity within the operational area. Target species are unlikely to occur in the operational area due to the water depths.	<u>Unplanned:</u> MDO/MGO release from vessel collision Spill response operations
Hermit Crab Fishery Newman *et al*. (2019b)	The HCF is permitted to fish WA waters north of Exmouth Gulf (22° 30'S).	Land-based hand collection	Australian land hermit crab (*Coenobita variabilis*)	Activity is land based and occurs on beaches along large areas along the Western Australian coastline.	No fishing activity or target species in the operational area.	<u>Unplanned:</u> MDO/MGO release from vessel collision Spill response operations
Kimberley Gillnet and Barramundi Managed Fishery Newman *et al*. (2019c)	The KGBF includes all WA waters north of 19° south latitude and west of 129° east longitude and within three nautical miles of the high-water mark of the mainland of WA and the waters of King Sound south of 16°21.47´ S.	Gillnet and other	Barramundi (*Lates calcarifer*)	The fishery operates in the nearshore and estuarine waters of the Kimberley. It encompasses the taking of any fish by means of gillnet in inshore waters and the taking of barramundi by any means.	No fishing activity or target species in the operational area.	<u>Unplanned:</u> MDO/MGO release from vessel collision Spill response operations

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
Abalone Managed Fishery Strain *et al*. (2019)	The fishery covers all Western Australian coastal waters, which are divided into 8 management areas.	Hand collection, diving	Roe's abalone Brownlip abalone Greenlip abalone	Abalone are collected by hand in shallow coastal waters in the south-west of WA. The target species do not occur in tropical waters. The management area covering waters north of Moore River (near Perth) is closed.	No fishing activity or target species in the operational area or EMBA.	None
South West Coast Salmon Fishery Smith and Grounds (2019)	The fishery includes all WA waters north of Cape Beaufort (south coast) except Geographe Bay.	Seine net	Australian salmon	The South West Coast Salmon Managed Fishery operates on various beaches south of the metropolitan area.	No fishing activity or target species in the operational area or EMBA.	None
West Coast Deep Sea Crustacean Managed Fishery How *et al*. (2015)	The boundaries of this fishery include all the waters lying north of latitude 34° 24' S (Cape Leeuwin) and west of the Northern Territory border on the seaward side of the 150m isobath out to the extent of the Australian Fishing Zone.	Fish traps	Crystal crab (*Chaceon albus*)	Fishing effort and the target species occurs on the west and south coasts of WA, primarily in water depths of 400 – 900 m.	No fishing activity or target species in the operational area or EMBA.	None
Commonwealth-Managed Fisheries						
North West Slope Trawl Fishery Harte & Curtotti (2018) Patterson *et al*. (2018) Patterson *et al*. (2019)	Extends from 114° E to approximately 125° E off the WA coast between the 200 m isobath and the outer limit of the Australian Fishing Zone (AFZ).	Deep water demersal trawling	• Australian scampi (*Metanephrops australiensis*) • Smaller quantities of velvet scampi (*M. velutinus*) and Boschma's scampi (*M. boschmai*) are also harvested. • Mixed deep-water snappers are also a component of the catch.	Fishing occurs on the continental slope in water depths greater than 200 metres. Fishing effort has typically occurred along the slope offshore from the Pilbara region, in the Rowley Shoals area and north-east towards and around Scott Reef. Fishing occurs year-round. The number of vessels involved in the fishery has been one or two vessels each year since 2008/2009. The primary landing ports are Point Samson in WA and Darwin in the NT. Four fishing permits and two vessels were active in the fishery during the 2016-17 fishing season. Total catch in the 2016-17 fishing season was 57.8 tonnes over 114 days of fishing effort. Fishing effort increased in the 2017-2018 season. Total catch was 79.7 tonnes over 219 days.	Fishing effort occurs along the northern edge of the operational area in water depths greater than 200 m. Target species may occur in the northern portion of the operational area, although they are most common on Globigerina ooze (deep sea muds rich in the shells of planktonic organisms) at depths of 420-500 metres.	Planned: Interaction with other marine users Noise emissions Unplanned: Hazardous and non-hazardous unplanned discharges - solid Hazardous and non-hazardous unplanned discharges - liquid Minor hydrocarbon release MDO/MGO release from vessel collision Spill response operations

Fishery	Licence Area Description	Gear Types	Key Target / Indicator Species	Summary of Fishing Activities	Operational Area Presence	Relevant Events
Western Tuna and Billfish Fishery Williams *et al*. (2018)	The Western Tuna and Billfish Fishery covers the sea area west from the tip of Cape York in Queensland, around Western Australia, to the border between Victoria and South Australia.	Primarily pelagic longline. Minor line (including handline, troll, rod and reel) and purse seine are also used.	Key target species: • Bigeye tuna • Yellowfin tuna • Broadbill swordfish • Striped marlin • Some albacore tuna are also taken.	Fishing occurs in both the Australian Fishing Zone and adjacent high seas of the Indian Ocean. Fishing occurs year-round. In recent years, fishing effort has concentrated off south-west Western Australia and South Australia. Between 2014 and 2018, fishing effort has consistently focussed on waters west of Carnarvon and to the south off south-west WA. The main landing ports are Geraldton and Fremantle. Since 2005, fewer than five vessels have been active in the fishery each year (3 vessels in 2016, 4 vessels in 2017).	No overlap of fishing activities with the operational area or EMBA. There is no recent fishing effort on the North West Shelf. This correlates with consultation feedback from AFMA and WAFIC. Tuna and billfish may occur in the operational area.	None
Southern Bluefin Tuna Fishery Patterson and Nicol (2018)	Fishery includes all waters of Australia, out to 200 nm from the coast. Young fish move from spawning grounds in the north-east Indian Ocean into the Australian EEZ and southward along the Western Australian coast (Patterson *et al*., 2019).	Purse seine Pelagic longline	Southern Bluefin tuna	Most of the Australian catch has been taken by purse seine, targeting juvenile tuna in the Great Australian Bight. Australian domestic longliners operating along the east coast catch some tuna and recreational fishing has increased (Patterson *et al*. 2019). No current effort on NWS, fishing activity is concentrated in the Great Australian Bight and off South-east Australia (Patterson *et al*. 2019). Consultation with the Australian Southern Bluefin Tuna Industry Association (ASBTIA) regarding a previous version of the Keraudren EP confirmed that the seismic survey will not impact on southern Bluefin tuna fishing activities.	No overlap of fishing activities with the operational area or EMBA. Target species may occur in operational area from time to time.	None
Western Skipjack Fishery Australian Fisheries Management Authority (2019)	The Western Skipjack Tuna Fishery is located in all Australia waters west of 142° 30' 00°E, out to 200 nm from the coast (Patterson *et al*., 2019).	Purse seine Some pole and line	Skipjack tuna (*Katsuwonus pelamis*)	There has been no fishing effort in the Skipjack Tuna Fishery since the 2009 season, and in that season, activity concentrated off South Australia (Patterson *et al*. 2019). Fishing in the Skipjack Tuna Fishery is opportunistic, and highly dependent on availability and the domestic cannery market. Currently, no domestic cannery has active contracts for skipjack tuna.	No overlap of fishing activities with the operational area or EMBA. Target species may occur in operational area from time to time.	None

3.2.4.1 Pilbara Demersal Scalefish Fisheries

The Pilbara Demersal Scalefish Fisheries (PDSF) comprise the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF), The Pilbara Trap Managed Fishery (PTMF) and the Pilbara Line Fishery (PLF). **Figure 3-15** shows the boundaries of these fisheries. The operational area overlaps with all these fisheries. As summarised in **Table 3-9**, the PFTIMF is the most active of these three fisheries and is expected to be the most active fishery in the vicinity of the operational area during the survey.

The western areas of the Pilbara Trap, Line and Trawl fisheries are closest to the home port of the fishers and have higher historical and current levels of effort compared to the eastern areas of the fisheries; these are more distant from port (i.e. increased fuel costs to operate further east) (Gaughan *et al*. 2018). During consultation with the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF) for the previous Keraudren 3D MSS, the home port for MG Kailis was identified as Exmouth and the home port for Westmore Seafoods was identified as Point Samson.

The total number of days of fishing and total tonnes of fish caught per fishery[3] (in the Pilbara Demersal Scalefish Fisheries) over the last 10 years based on FishCube data is presented in **Figure 3-14**. Effort values (i.e. total number of days of fishing) were not available from 2015 to 2018 for these fisheries. This data was extracted from various DPIRD Status reports of the fisheries and aquatic resources of Western Australia (State of the fisheries) (Gaughan, Molony and Santoro 2019).

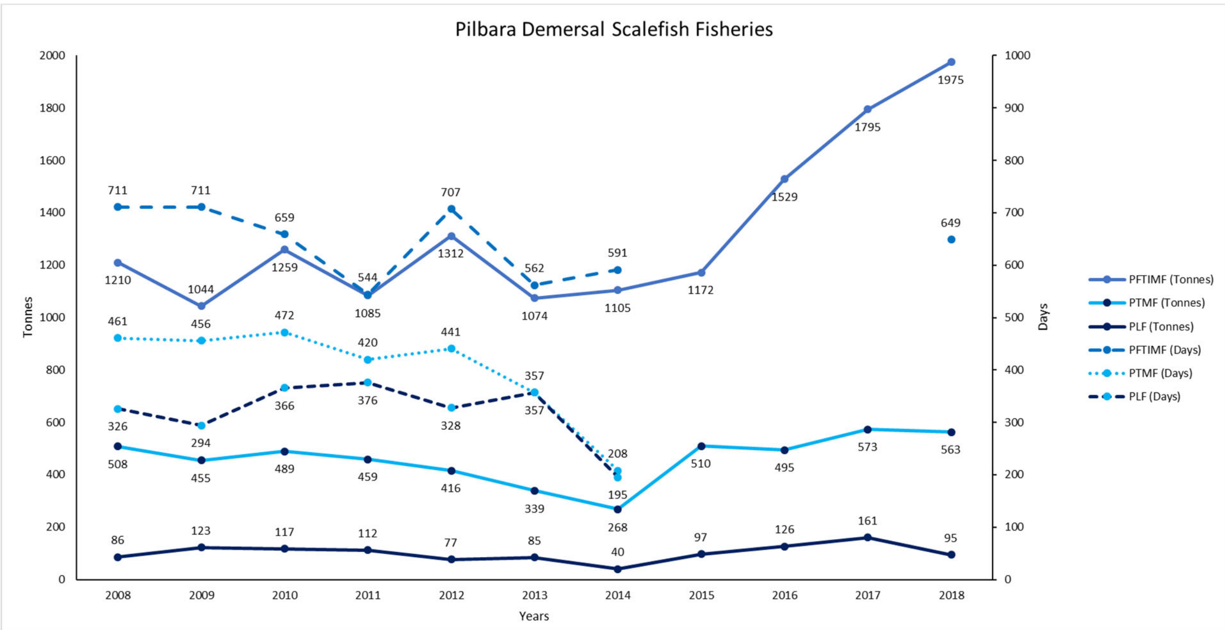


Figure 3-14: Total days fishing and tonnes caught per year from the Pilbara Demersal Scalefish Fisheries over the last 10 years

Figure 3-14 indicates total catch levels in the PFTIMF have increased steadily from 2015, whilst catch levels in the PTMF and PLF have remained relatively consistent over the last 5 to 10 years. According to Newman *et al*. (2019a), landings in the PFTIMF have increased despite no material increases in the level of effort. Given that fishing effort is measured in number of vessels or number of days, it is not clear whether the increases in catch relate instead to improvements in vessels or gear capacity or are driven by an increase in the numbers of fish available. Gaughan, Molony and Santoro (2019) suggest that these increasing catch rates

[3] Note due to discrepancies in the DPIRD source data the numbers represented in the figure are based on the State of the fisheries report for the stated year (i.e. data for 2008 was extracted from the the 2008-2009 report and not the latest 2017-2018 report).

(combined with fishing mortality spawning biomass estimates) are a result of increased fish abundance and stock rebuilding in the PFTIMF since effort reductions were introduced in 2008. If correct, this suggest that the fishery is resilient and through active management is capable of recovery.

The key exploited species of the tropical fishery resources that were examined in Newman *et al*. (2004) occupy a range of marine environments from the pelagic to inshore demersal reef areas; the key species are, goldband snapper, *Pristipomoides multidens* (deep-water demersal), red emperor, *Lutjanus sebae* (offshore demersal), Rankin cod, *Epinephelus multinotatu*s (offshore demersal), bluespotted emperor, *Lethrinus hutchinsi*[4] (inshore–offshore demersal) and spangled emperor, *L. nebulosus* (inshore–offshore demersal). This review is relevant to the fisheries that overlap the operational area as these species are key commercial species that these fisheries target. Red emperor and Rankin cod represent large, long-lived species with low natural mortality. Bluespotted emperor (common name for both *Lethrinus hutchinsi* and *Lethrinus punctulatus* fish species*)* and rosy threadfin bream represent the smaller, short-lived species with high natural mortality (DoF, 2004).

As part of the Santos commissioned study undertaken by RPS in October 2018 significant numbers of commercially targeted species were not observed at ancient coastline KEF at 125 m water depth sampling sites, however, areas in shallower water that may support these species were in steeper gradient areas within the 95 to 115 m water depth range and in some areas in less than 60 m water depth (**Appendix D**).

3.2.4.1 Mackerel Managed Fishery

The Pilbara region (Area 2) of the Mackerel Managed Fishery (MMF) extends from Exmouth, through to Eighty Mile beach. The fishery is known to operate in the southern part of the operational area and fishing vessels may be encountered in these waters during the survey. The commercial catch by the MMF occurs in water depths less than approximately 60 m in the Pilbara region, with the fishery targeting Spanish mackerel which congregate in nearshore and coastal waters around reefs, islands and headlands prior to and during annual spawning activities. Other mackerel species, including grey mackerel are secondary target species.

Given the water depths, MMF fishing effort is limited to the southern portion of the operational area. FishCube data (**Appendix E**) shows that up to maximum of 3 vessels have fished in these waters each year during the last ten years. Potentially the greatest fishing effort in the operational area during the last five years (based on more than 3 vessels fishing compared with less than 3 vessels in other years) occurred during 2015 and was limited to 13 days during the entire year.

3.2.4.2 Pearl Oyster Managed Fishery

Figure 3-16 shows the locations of pearl farms leases and holding sites used by the Pearl Oyster Managed Fishery. The collection of pearl oysters is undertaken by divers and is typically restricted to diving depths of below 35 m. FishCube data (**Appendix E**) shows no fishing effort within the operational area. Most fishing effort occurs in waters near central and eastern Eighty Mile Beach and near Broome where the main pearl farm leases and holding sites are located. A low level of historic fishing effort has occurred in waters over 30 km south of the operational area in waters near Port Hedland, North Turtle Island, Little Turtle Islet and the DeGrey river mouth. A single holding site is located in waters to the west of North Turtle Island (**Figure 3-16**).

[4] Dr Glenn Moore – Curator of Fishes, Western Australian Museum confirmed that in the process of giving bluespotted emperor a name through taxonomic literature, it was determined that it already had a name *L. punctulatus*, however in the meantime Department of Fisheries had given it a new name of *L. hutchinsi*, and it appears there are a number of names applied to this fish. From a taxonomic perspective, it is not clear exactly what fish the name *L. punctulatus* actually belongs to (i.e. the bluespotted or something else in the NT) and several names are considered synonyms of it. The name *L. hutchinsi* does not exist and should not have been used. More recent publications refer to *L. punctulatus*.

Condie *et al*. (2006) surveyed spat from Eighty Mile Beach in conjunction with particle dispersion modelling to identify likely spawning grounds for the silver-lip pearl oyster (*Pinctada maxima*). The model results suggest that:

- The "inshore" stocks of the silver-lip pearl oyster appear to be self-sustaining, and may even provide larvae to deeper stocks in irregular recruitment events;
- Spawning in the Eighty Mile Beach region is concentrated between 8 and 15m water depth. These spawning events are likely to lead to the successful recruitment locally and alongshore to the southwest;
- Spat abundances in these areas are low suggesting that recruitment is strongly limited by habitat availability and possibly high mortality rates in the shallow water;
- Occasionally high local abundances of broodstock and spat observed in deeper water of approximately 30 m which seem to be supported by intermittent larval transport from inshore populations. Spawning in this area seems to contribute little to recruitment in the inshore populations.

The extent to which pearl oysters are distributed in waters greater than 35 m and their relevance to the pearl oyster fishery has been debated in recent years. Preliminary survey results from the recent North West Shoals to Shore research program confirms that pearl oysters are more common in water depths less than 40 m. Only a few individual pearl oysters have been found in water depths greater than 40 m (Miller 2019).

As summarised in **Section 3.2.2.3**, Santos commissioned a study to document the presence of pearl oysters and describe the habitats present at 40 to 60 m water depth in the vicinity of the operational area. Key findings of the study, which collected 17 transects of towed video footage covering a total length of 21.9 km of seabed over a 3-day period, are (RPS, 2019):

- Only two pearl oysters were identified from a total of 21.9 km of seabed surveyed. Both individuals were observed growing in water depths of 50-54 m (LAT).
- The depth ranges surveyed do not support a high density of pearl oysters (only a few individuals).

The video footage, analyses and report has been provided to the Australian Institute of Marine Science for incorporation into their study on pearl oyster distribution and genetic connectivity as part of the North West Shoals to Shore Research Programme.

For the purpose of this EP, pearl oysters are conservatively estimated to occur out to 70 m water depth (which aligns with consultation with the Pearl Producers Association during the previous Keraudren 3D MSS).

3.2.4.3 Key Commercial Fish Species

Demersal and pelagic fish known to occur in the vicinity of the operational area include free-roaming species that have naturally large ranges (several kilometres or even hundreds to thousands of kilometres).

The biology of key commercially targeted species in this region, including the indicator species is summarised in **Table 3-10**. This includes the distribution, stock structures and spawning characteristics of the various species. As outlined in Gaughan *et al*. (2018), stock structures may be considered in terms of the genetic stock, whereby there is genetic connectivity between regions from the dispersal and settlement of eggs and larvae, or they may also be described in terms of fisheries management units. Generally, the genetic stocks of the key indicator species in the Pilbara region occur over long distances and across northern Australia. However, movement and mixing of juvenile and adult fishes is usually more limited. Given the large distances involved and uncertainty over the mixing rates of juveniles and adults, stock assessments conducted by DPIRD according to regional management units (also termed "stocks") provide a more conservative approach to managing the resource. Therefore, fish may be considered in terms of separate management units but are not genetically discrete populations.

Commensurate with having extended pelagic dispersal of their eggs and larvae, spawning at any one location within the Pilbara region by each of the key indicator species is likely to contribute to recruitment at the regional scale, not just the local scale (Gaughan *et al*., 2018). The continuous habitat and distribution of these species across the North West Shelf suggests that they do not constitute true metapopulations, which by definition requires that a population inhabit discrete patches. Although continuously distributed, there is a lack of widespread mixing of adults of these species indicating that the populations are not fully panmictic, i.e. every adult does not have the opportunity to mate with every other adult (of the opposite sex) because they are isolated by distance (Gaughan *et al*., 2018). Nonetheless, the extended bidirectional flow of eggs and larvae means there is no simple source-sink relationship; rather, there is most likely to be connectivity via a continuum of "overlapping" sources and sinks and there is likely to be high levels of mixing among generations.

Key Demersal Fish Species

The major demersal species in the North Coast Bioregion in order of gross tonnage caught by the Pilbara Demersal Scalefish Fisheries are bluespotted emperor, goldband snapper, rosy threadfin bream, red emperor, crimson snapper, and Rankin cod (Gaughan *et al*. 2019). The indicator species monitored for the sustainability of the fishery are red emperor, Rankin cod and bluespotted emperor. The status of ruby snapper is also used as an indicator species for the offshore demersal scalefish resources targeted by the Pilbara Line Fishery.

The Pilbara demersal biological stocks are ranked by DPIRD as Sustainable-Adequate (Gaughan *et al*. 2019). The stock status is assessed periodically (approximately every 5 years), and in 2017 the spawning biomass stock for the three demersal indicator species for the Pilbara region, Red Emperor, Rankin cod and bluespotted emperor was assessed as above the threshold target spawning biomass levels, classifying the biological stocks for the Pilbara region of the north coast demersal resource as adequate. The status of the ruby snapper was considered in the above stock status assessment.

Goldband snapper is assessed as an indicator species of the adjacent Northern Demersal Scalefish resource in the Kimberley region and this species also makes up a significant proportion of the demersal catch in the Pilbara region. The Kimberley demersal biological stocks are also ranked by DPIRD as Sustainable-Adequate (Gaughan *et al*. 2019).

The demersal indicator species are considered to have similar stock structures and spatial dynamic patterns across the North West Shelf of Western Australia. They each:

- are widely distributed both alongshore and across the continental shelf within the entire NWS region;
- have a high likelihood for bidirectional dispersal of their pelagic stages over the course of their extended spawning seasons;
- have no barriers to movement at any life history stage; and
- have a more or less continuous distribution of suitable habitat (Gaughan et al., 2018).

Figure 3-17 provides the spatial distribution of catch per unit effort (CPUE) for indicator species of the north western (Australia) scalefish resources for 2004 - 2008, sourced from Gaughan *et al*. (2018). The data shows that there is variability in the CPUE for the fishery indicator species including the specific areas the fish are caught, i.e., west areas (Area 1 and 2), versus east areas (Area 4 and 5), as well as variability in the water depths that have the greatest CPUE for each of the species. In summary:

- Red emperor are caught across all four of the PFTIMF areas, with the greatest effort being in Area 2, followed by Area 5, and Area 4. The CPUE was greatest at 50 to 55 m water depth, at 10 $kg.hr^{-1}$, and averaged 5 $kg.hr^{-1}$ for depths 55 to 110 m.

- Rankin cod was fished in all areas, with the greatest CPUE from the western part of Area 5, with a CPUE of up to 9 $kg.hr^{-1}$. The correlating water depth with the highest CPUE throughout the fishery was 45 to 50m (5 $kg.hr^{-1}$) and averaged 2-4.5 $kg.hr^{-1}$ from 50 to 100 m water depth.
- Bluespotted emperor had the highest CPUE of approximately 35 $kg.hr^{-1}$ within Area 1, and approximately 25 $kg.hr^{-1}$ within Area 2. The highest CPUE was within water depths 45 to 70 m (5$kg.hr^{-1}$).
- Goldband snapper had the highest CPUE with Area 5, peaking at 45-60 $kg.hr^{-1}$. There was little catch effort within the shallow waters (i.e., 45 to 90 m water depth), with a peak at 100 to 105 m water depth of 75 $kg.hr^{-1}$.

The distribution of CPUE sourced from Gaughan *et al*. (2018) is broadly comparable to the regional distribution of catch shown in the data provided by commercial fishers, MG Kailis and Westmore Seafoods.

Newman *et al*. (2014) presents spatial distribution catch data for key commercial demersal fish species including bluespotted emperor, spangled emperor, Rankin cod, red emperor and goldband snapper for 2001 across a much larger spatial scale than the Gaughan *et al*. (2018) study. These are shown in **Figure 3-17** with the operational area overlain (indicatively).

Key Pelagic Fish Species

A large commercial pelagic fish resource is distributed throughout Western Australia (Gaughan *et al*. 2019). The indicator species of the pelagic fish resource in the North Coast Bioregion are Spanish mackerel (*Scomberomorus commerson*) and grey mackerel (*Scomberomorus semifasciatus*). The catch rates in the Pilbara management zone (and the Kimberley management zone) are stable and increasing, suggesting that the spawning stock for indicator species is stable or increasing and considered to be Sustainable-Adequate (Gaughan *et al*. 2019).

Commensurate with having extended pelagic dispersal of their eggs and larvae, spawning at any one location within the Pilbara region by each of these species is likely to contribute to recruitment at the regional scale, not just the local scale (Gaughan *et al*. 2018). The continuous habitat and distribution of these species across the North West Shelf of Western Australia suggests that they do not constitute true metapopulations, which by definition requires that a population inhabit discrete patches. Although continuously distributed, there is a lack of widespread mixing of adults of these species indicating that the populations are not fully panmictic, i.e. every adult does not have the opportunity to mate with every other adult (of the opposite sex) because they are isolated by distance (Gaughan *et al*. 2018). Nonetheless, the extended bidirectional flow of eggs and larvae means there is no simple source-sink relationship; rather, there is most likely to be connectivity via a continuum of "overlapping" sources and sinks and there is likely to be high levels of mixing among generations.

Spatial distribution catch data for Spanish mackerel are shown in **Figure 3-18** with the operational area overlain (indicatively).

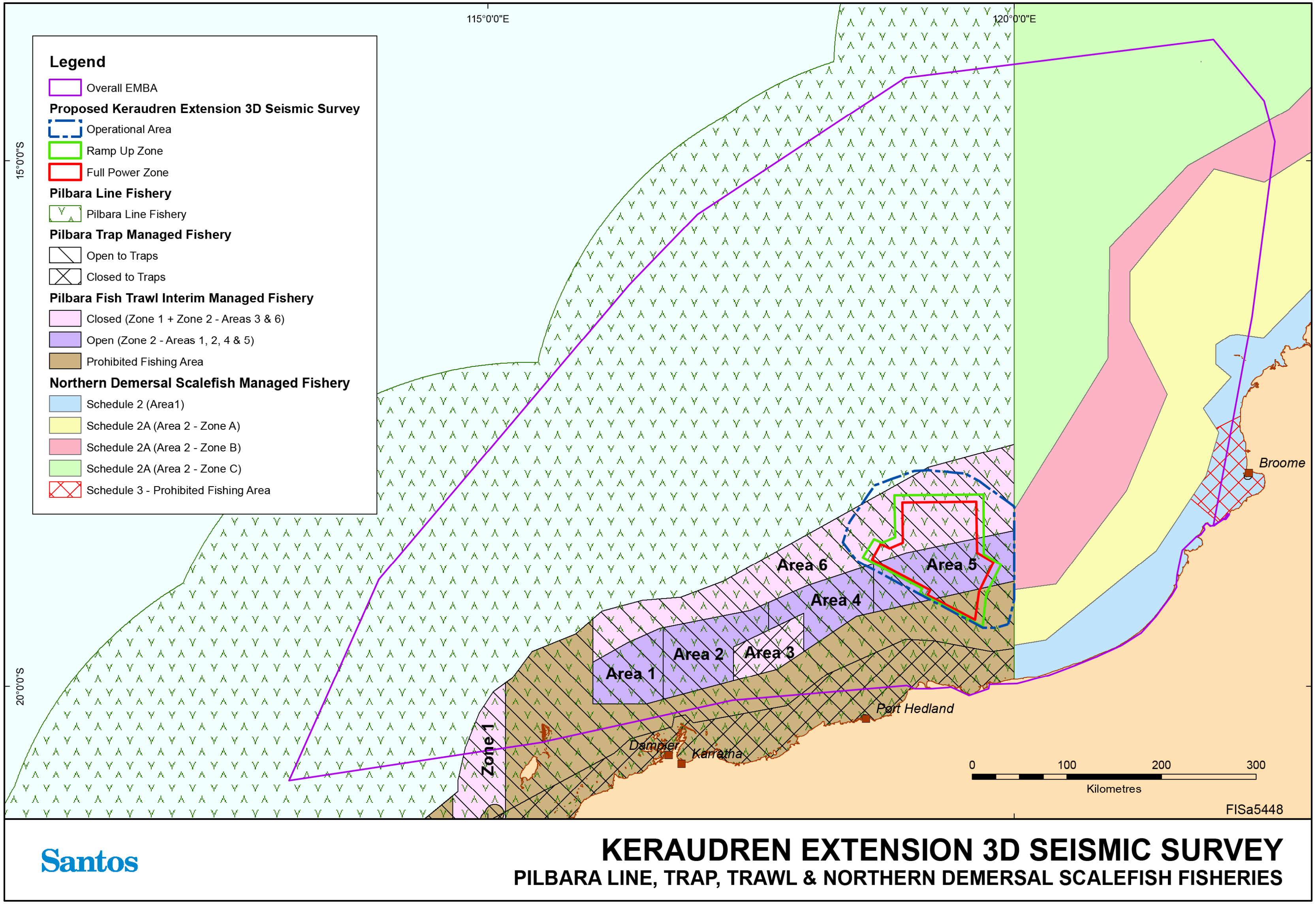


Figure 3-15: Pilbara Demersal Trawl, Trap and Line, and Northern Demersal Scalefish fisheries

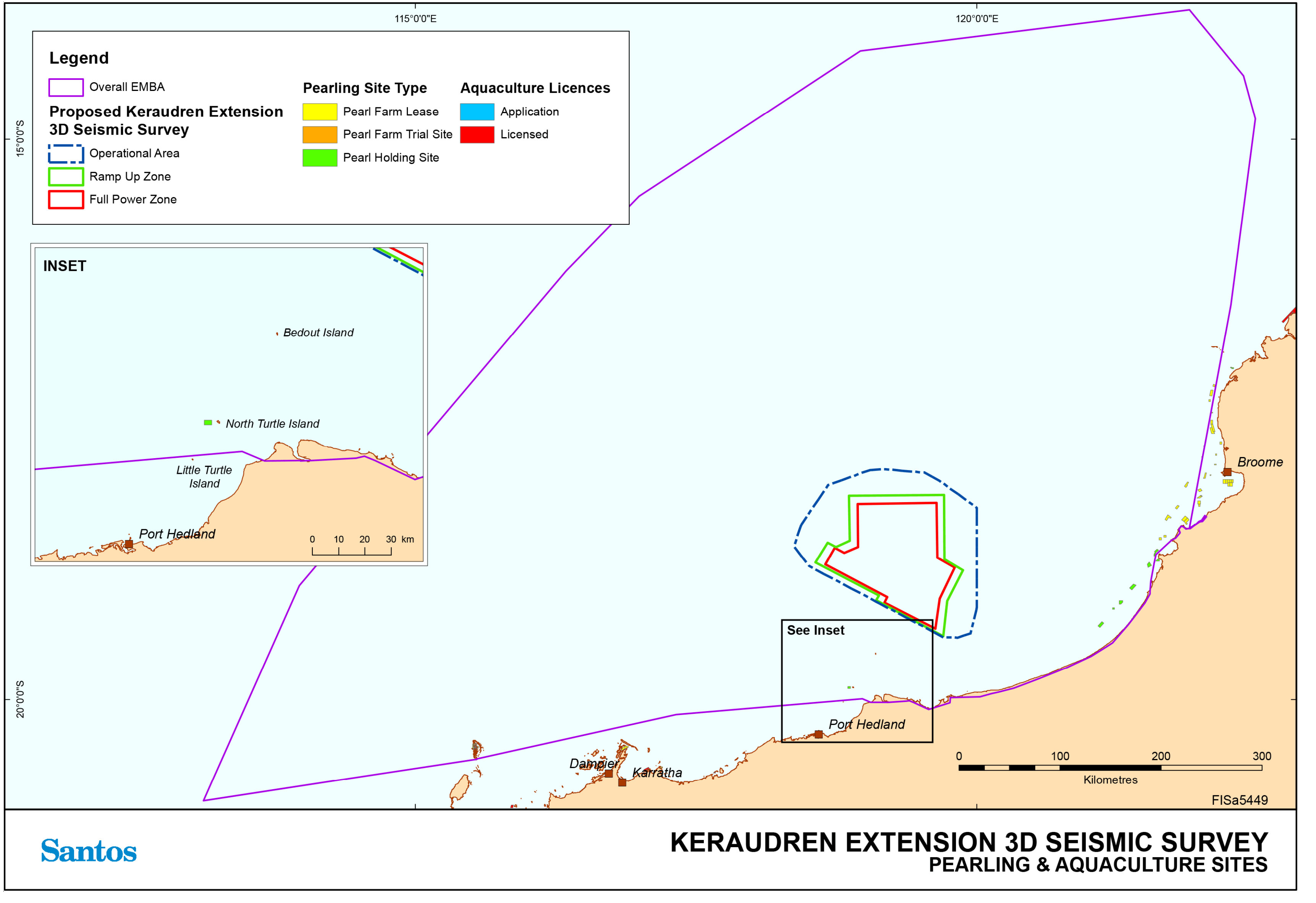


Figure 3-16: Pearling and aquaculture sites

Table 3-10: Key commercial fish and invertebrate species

Species	**Distribution and habitat**	**Stock structure, reproduction and recruitment**	**Food / Prey**	**Stock Status**	**References**
Demersal species					
Goldband snapper *Pristipomoides multidens*	• Goldband snapper typically occur in 50 – 200 m water depths, and often concentrated in depths from 80 – 140 m. • Catch Per Unit Effort (CPUE) data presented in Gaughan *et al* (2018) indicates that the depth range with the highest CPUE for goldband snapper is 90 - 100m (refer **Figure 3-17**). • Adults occur around offshore reefs, shoals, and areas of hard flat bottom with occasional benthos or vertical relief. Note that this habitat is widely distributed throughout the fishery and it is not fixed in space and time as seabed sediments move (e.g. strong currents, cyclones etc.). • The species is not considered site attached due to good swimming ability and minimal reliance on reef structures for shelter. • Juvenile fish may remain in deep offshore waters but occur in association with different habitats, over uniform sandy and gravelly substrate. • Goldband snapper occur in waters throughout the tropical Indo-Pacific region. • Goldband snapper are widely distributed throughout northern Australia, from the Gascoyne region of WA to SE Queensland.	• The stock structure for goldband snapper in the National Status report (available at http://fish.gov.au/report/221-Goldband-Snapper-2018) describes separate fishery management units for goldband snapper for the Kimberley, Pilbara and Gascoyne due to limited mixing of adults and juveniles, and the extent of the fisheries that target the species. • The National Status report also indicates that Australian populations of Goldband Snapper are likely to form a single biological stock and that there is gene flow among goldband snapper from the Northern Territory and between the Western Australian management units (Kimberley, Pilbara and Gascoyne). However, there is evidence that the northern Kimberley population (extending from approximately 122ºE [Lynher Bank]) may exhibit restricted gene flow and be distinct from other regions, including the Pilbara region. Therefore, a stock subdivision may exist between the northern Kimberley stock and stocks to the west. • Goldband snapper are broadcast, serial/multiple spawners, producing millions of eggs per season. • Based on discussions between Santos and Dr Stephen Newman for the previous Keraudren 3D MSS, goldband snapper can spawn every three days, or every week during the spawning period. • Goldband snapper spawn throughout their range (rather than aggregating at specific locations). • Spawning in the Pilbara region occurs consistently during October – May (extended peak spawning period). • Larval settlement and juvenile development is likely to occur in similar water depths to adults, although juveniles are often separate and associated with different habitat. • Fish are estimated to reach maturity after approximately 4.6 years.	Goldband snapper feed on the bottom and in the water column, consuming fish, crustaceans, gastropods, squid and scallops.	Sustainable	Personal communication with Dr Stephen Newman (DPIRD) DPIRD finfish advice received on 02 December 2019 Lloyd *et al*. (2000) Lloyd (2006) Ovenden *et al*. (2002) Newman (2003) Newman *et al*. (2000) Newman *et al*. (2008) Newman *et al*. (2018a) Saunders *et al*. (2018)

Species	Distribution and habitat	Stock structure, reproduction and recruitment	Food / Prey	Stock Status	References
Red emperor *Lutjanus sebae*	• Red emperor typically occur in 10 – 180 m water depths, and are often concentrated in depths from 60 – 120 m. • CPUE data presented in Gaughan *et al*. (2018) indicates that the depth range with the highest CPUE for red emperor is 50m – 60m, however is broadly the same across all depths (refer **Figure 3-17**). • The WA stock occurs from Cape Naturaliste to the NT border. • Adult fish occur in a range of habitats including coral reef lagoons, reefs, banks, limestone sand flats and gravel patches. • Juveniles are common in nearshore turbid waters, such as mangroves, and also occur on coastal or offshore reefs.	• There is limited movement and mixing of adult red emperor between the Gascoyne, Pilbara and Kimberley regions. Red emperor in these regions are, therefore, treated as separate fishery management units. • However, there is extensive connectivity and gene flow among populations across northern Australia (Queensland to Shark Bay in WA), indicating a single genetic stock. • Lethrinids are broadcast, serial/multiple spawners, producing millions of eggs per season. • Red emperor spawn throughout their range (rather than aggregating at specific locations). • Red emperor spawn multiple times between September – June (with bimodal peaks from September – November and January – March) • Juvenile fish are more common in nearshore waters and move offshore as they mature. • Fish are estimated to reach maturity after approximately 4 – 6 years.	Lethrinids are carnivorous bottom feeders. Red emperor feed mainly on fish, benthic crustaceans and cephalopods.	Sustainable	DPIRD finfish advice received on 02 December 2019 Gaughan *et al*. (2018) Herwerden *et al*. (2009) Kailola *et al*. 1993 Newman *et al*. (2008) Newman *et al*. (2018b) Van Herwerden *et al*. (2009)
Bluespotted emperor *Lethrinus punctulatus*	• Bluespotted emperor typically occur in water depths of 5 – 110 m. • CPUE data presented in Gaughan *et al* (2018) indicates that the depth range with the highest CPUE for bluespotted emperor is 50m – 75m, and declining in deeper waters to 110m (refer **Figure 3-17**). • The distribution of bluespotted emperor is restricted primarily to Western Australian waters and extends from around Geraldton in the south to Darwin in the Northern Territory with its greatest relative abundances in the western Pilbara region. • Adults occur over substrates of hard coral, gravel, sand or rubble. They can also be associated with sponge and gorgonian dominated habitats and can occur in clear or turbid waters. • Juveniles are found in seagrass beds and mangrove swamps.	• There is extensive connectivity among populations of bluespotted emperor over large distances, and there is considered to be a single biological stock from the Lacepede Islands to Abrolhos Islands. The biological stock may also extend as far as the Northern Territory. • Particle dispersal modelling indicates there would be considerable alongshore movement of the pelagic egg and larval stages. • Lethrinids are broadcast, serial/multiple spawners, producing millions of eggs per season. • Spawn throughout their range (rather than aggregating at specific locations). • Blue spotted emperor spawn from July to March. • Fish are estimated to reach maturity after approximately 1.6 years.	Lethrinids are carnivorous bottom feeders	Sustainable	DPIRD finfish advice received on 02 December 2019 Gaughan *et al*. (2018) Newman *et al*. (2008) Newman *et al*. (2018c) Pattiaratchi *et al*. (2014)
Spangled emperor *Lethrinus nebulosus*	• Spangled emperor typically occur in water depths of 1 – 80 m+. • Widespread throughout the Indo-West Pacific. • Spangled Emperor inhabit inshore and offshore coral and rocky reefs, coralline lagoons, seagrass beds, mangrove swamps, and nearshore sandy and rocky areas. • Adults are usually solitary or form small groups, while juveniles form large schools.	• Low genetic subdivision between northwest Western Australia and the Great Barrier Reef suggests gene flow is likely to be high between these regions and there is possibly one genetic stock in Australia. Larvae are likely carried hundreds of kilometres. • Lethrinids are broadcast, serial/multiple spawners, producing millions of eggs per season. • Most likely to exhibit a peak spawning period from October – May. • Fish are estimated to reach maturity after approximately 3.6 years.	Lethrinids are carnivorous bottom feeders	Sustainable	DPIRD finfish advice received on 02 December Berry *et al*. (2012) Newman *et al*. (2008) Newman *et al*. (2018d)

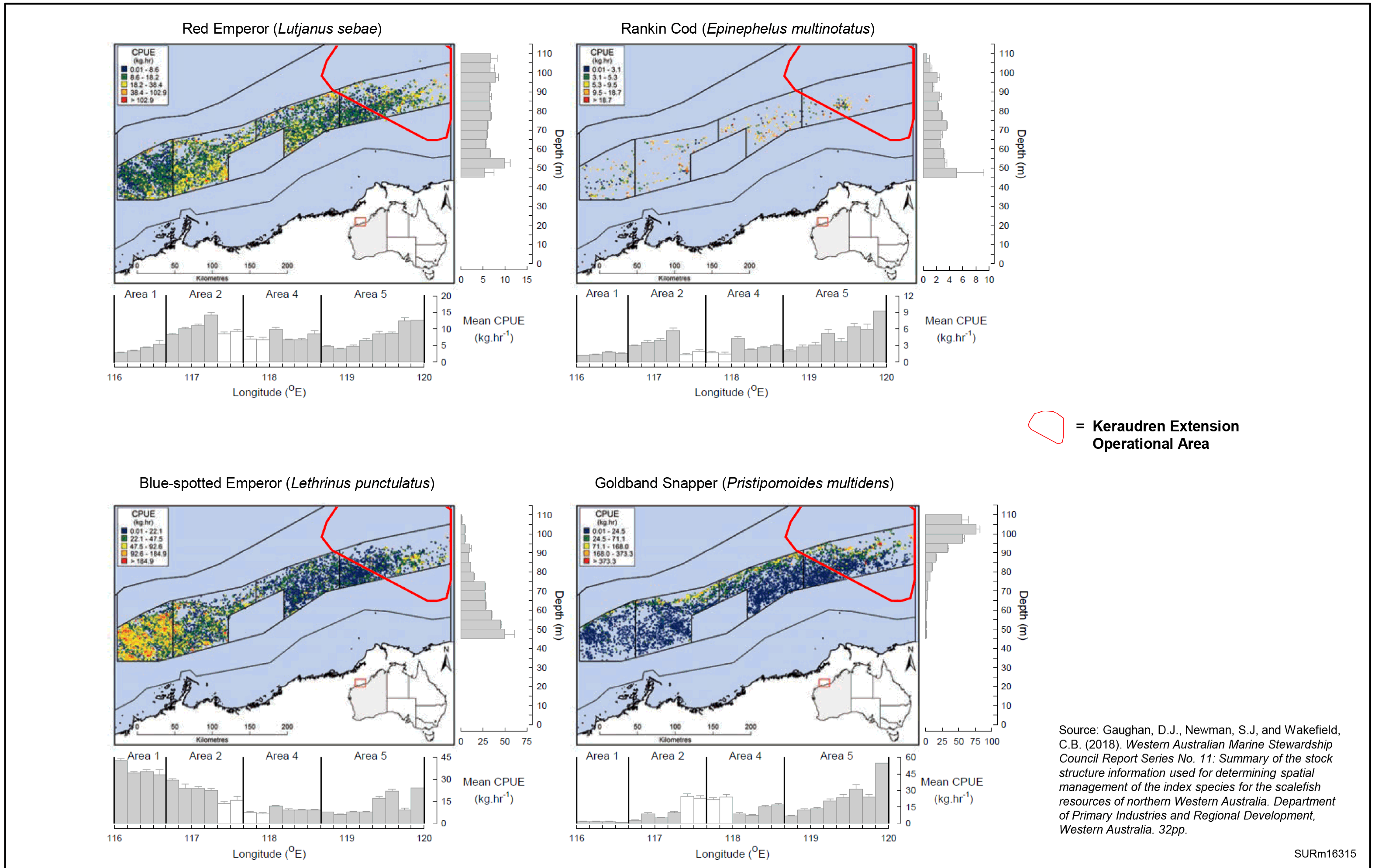
Species	Distribution and habitat	Stock structure, reproduction and recruitment	Food / Prey	Stock Status	References
Rankin cod *Epinephelus multinotatus*	• Rankin cod typically occur in water depths of 10 – 150 m. • CPUE data presented in Gaughan *et al* (2018) indicates that the depth range with the highest CPUE for Rankin Cod is 60m to 90m (refer **Figure 3-17**). • This species is found in continental shelf waters throughout the Indian Ocean, including tropical and sub-tropical northern Australia.	• Although adults do not mix extensively between regions, they all contribute to the total adult spawning biomass and larval dispersal of a single biological stock between the Lacepede Islands and Shark Bay. • However, the limited mixing of adults among locations supports the use of separate regional fishery management units in WA (e.g. Pilbara and Kimberley). • Broadcast, serial/multiple batch spawners, producing millions of eggs per season. • Spawn throughout their range (rather than aggregating at specific locations). • Rankin cod spawn from June to December and in March (peak spawning occurs from August to October). • Fish are estimated to reach maturity after approximately 2 years.	Small fishes, crabs and other benthic invertebrates.	Sustainable	DPIRD finfish advice received on 02 December 2019 Gaughan *et al*. (2018) Newman *et al*. (2008) Newman *et al*. (2018e)
Giant ruby snapper *Etelis carbunculus*	• Occurs in water depths of 150 – 480 m across the Indo-West pacific region. • In Australia it is recorded from north-western Western Australia and off north-eastern Queensland.	• The biological stock of ruby snapper is uncertain. • Spawn throughout their range (rather than aggregating at specific locations). • Spawn December to April (peak spawning period January – March).	Various fishes, squid and crustaceans.	Sustainable	Australian Museum (2019) DPIRD finfish advice received on 02 December 2019
Other demersal fish species	Variable	• Most likely to exhibit a peak spawning period from October – May.	Various	Sustainable	DPIRD finfish advice received during consultation on the previous Keraudren 3D MSS
Pelagic species					
Spanish mackerel *Scomberomorus commerson*	• Occur throughout the Indo-West Pacific. • Spanish mackerel occur in continental shelf waters and congregate in coastal waters around reefs, shoals and headlands to feed and spawn in winter and spring. • They occur in water depths from 1 m to at least 50 m. • Adult movements occur over ranges of 100 – 300 km.	• Spanish mackerel in northern Australia form just three distinct genetic stocks: an east coast stock, a Torres Strait stock, and a single stock across the north and west coasts of Australia (Northern Territory and WA). Consequently, the whole of the WA Mackerel Managed Fishery is defined as a single management unit. • Form spawning schools around inshore reefs in north coast bioregion • Congregate in coastal waters from approximately June onwards, but the peak spawning period is September to December in the Pilbara region. • Females are capable of producing a batch of hundreds of thousands of eggs every 1-3 days during the spawning season, though a spawning frequency of 1.9 to 5.9 days has also been reported. • Larvae are commonly associated with reef lagoonal areas, before juveniles move to estuary and foreshore nursery and feeding grounds where they tend to remain for the first year of life. • Fish are estimated to reach maturity after approximately 2 years.	Pelagic baitfish such as sardines, anchovies and pilchards, as well as squids and prawns.	Sustainable	Begg *et al*. (2006) Buckworth *et al*. (2007) DPIRD finfish advice received during consultation on the previous Keraudren 3D MSS Langstreth *et al*. (2018) Lewis and Jones (2017) Lewis and Jones (2018) Mackie *et al*. (2010) McPherson (1993)

Species	Distribution and habitat	Stock structure, reproduction and recruitment	Food / Prey	Stock Status	References
Grey mackerel *Scomberomorus semifasciatus*	• Grey mackerel area a highly mobile schooling fish species, which can be found on the continental shelf, although its preferred habitat in shallow inshore waters around rocky reefs and headlands. • Grey mackerel are dependent on near-shore waters for breeding and feeding.	• A single biological stock exists for the whole of WA. • Spawning may extend from approximately August to February, with a peak between August and December. • Fish are estimated to reach maturity after approximately 1-2 years. • Females produce approximately 250,000 eggs per spawning event and will spawn multiple times over the spawning season. • Larval and juvenile life history stages of grey mackerel are found inshore, often in estuarine environments.	Pelagic baitfishes such as anchovies and sardines.	Sustainable	Bray and Schultz (2018) Cameron and Begg (2002) Helmke *et al*. (2018) Mackie *et al*. (2010) Roelofs *et al*. (2014) Welch *et al*. (2014)
Southern bluefin tuna *Thunnus maccoyii*	• Southern bluefin tuna are circumglobal in temperate and cold temperate waters of the southern hemisphere, ranging across the Pacific, Indian, Southern and south-eastern Atlantic oceans, mostly between 30°S and 50°S.	• A single, highly migratory biological stock extends from the north-east Indian Ocean to the temperate Southern Ocean. • A single spawning ground is known for this species, located in waters south of Java. • Spawning mainly occurs from September to April, with females spawning daily and producing 14–15 million eggs per spawning season. • Juveniles migrate south over the continental shelf of WA during their first year. Some then head westwards into the Indian Ocean, while others head eastwards into the Great Australian Bight.	Pelagic fishes, crustaceans and squid.	Recovering	Australian Fisheries Management Authority (2018) Bray and Gomon (2019) Patterson and Nicol (2018)
Bigeye tuna *Thunnus obesus*	• Bigeye tuna occur in the tropical waters of the Pacific, Atlantic and Indian Oceans. • The Indian Ocean stock is considered to be a single biological stock. • Bigeye tuna are highly migratory and travel over thousands of kilometres. • They are typically found to depths of 500 m throughout the oceans.	• Bigeye tuna in WA waters belong to the Indian Ocean stock. • Spawning occurs throughout the year, with peak spawning in summer and autumn. • Females spawn every 2‑3 days producing 2.9–6.3 million eggs per spawning event.	Pelagic fishes, crustaceans and squid.	Sustainable	Australian Fisheries Management Authority (2018) Kailola *et al*. (1993) Schaefer *et al*. (2014) Williams *et al*. (2018)
Yellowfin tuna *Thunnus albacares*	• Yellowfin tuna occur throughout the Pacific, Atlantic and Indian Oceans. • The Indian Ocean stock is considered to be a single biological stock. • Yellowfin tuna are highly migratory and travel long distances. They are typically found to depths of 250 m.	• Yellowfin tuna in WA waters belong to the Indian Ocean stock. • Spawning occurs throughout the year in tropical waters, with peak spawning in summer. • Females spawn almost daily producing 0.2–8 million eggs per spawning event.	Pelagic fishes, crustaceans and squid.	Depleting Sustainable biomass, subject to overfishing	Australian Fisheries Management Authority (2018) Kailola *et al*. (1993) Williams *et al*. (2018)
Skipjack tuna *Katsuwonus pelamis*	• Skipjack tuna are circumglobal in tropical seas. • Found in all Australian states and territories.	• Skipjack tuna in WA waters belong to the Indian Ocean stock. • Spawning occurs throughout the year in tropical waters, with females spawning almost daily to produce 0.8–2 million eggs per spawning season.	Pelagic fishes, crustaceans and squid.	Sustainable	Schultz (2019)
Albacore tuna *Thunnus alalunga*	• Albacore tuna occur throughout the Pacific and Indian Oceans. • The Indian Ocean stock is assumed to be a single biological stock. • Albacore tuna are highly migratory and travel long distances. • They are typically found to depths of 200 m.	• Albacore tuna in WA waters belong to the Indian Ocean stock. • Peak spawning occurs in summer with females producing 2–3 million eggs per season.	Pelagic fishes, crustaceans and squid.	Sustainable	Australian Fisheries Management Authority (2018) Kailola *et al*. (1993) Williams *et al*. (2018)

Species	Distribution and habitat	Stock structure, reproduction and recruitment	Food / Prey	Stock Status	References
Broadbill swordfish *Xiphias gladius*	• Broadbill swordfish occur throughout the Pacific, Atlantic and Indian Oceans. • The Indian Ocean stock is considered to be a single biological stock. • Broadbill swordfish are highly migratory and are typically found to depths of 550 m.	• Broadbill swordfish in WA waters belong to the Indian Ocean stock. • Spawning occurs throughout the year in tropical waters. • Females spawn every 2–3 days producing 1.2–2.5 million eggs per spawning event.	Pelagic fishes such as tuna, flying fish and barracudas. Demersal prey includes hakes, gempylids and myctophids.	Sustainable – Not overfished	Australian Fisheries Management Authority (2018) Kailola *et al*. (1993) Williams *et al*. (2018)
Striped marlin *Kajikia audax*	• Striped marlin occur in tropical to temperate waters of the Pacific and Indian Oceans. • The Indian Ocean stock is considered to be a single biological stock. • They are highly migratory and are typically found to depths of 290 m.	• Striped marlin in WA waters belong to the Indian Ocean stock. • Spawning occurs in summer. • Females release eggs every few days, producing up to 120 million eggs per spawning season	Pelagic fishes, crustaceans and squid.	Uncertain biomass, subject to overfishing (Western stock)	Australian Fisheries Management Authority (2018) Kailola *et al*. (1993) Williams *et al*. (2018)
Black marlin *Istiompax indica*	• Black marlin occur circum-Australia and throughout tropical and subtropical Indo-Pacific waters, occasionally entering temperate waters. • An epipelagic, oceanic species often found near shore in coastal waters, around islands and coral reefs. • Highly migratory. • Common in nearshore waters off Eighty Mile Beach, Roebuck Bay, Broome and the Dampier Peninsula from June to September when productivity and baitfish activity in the region are highest.	• Black marlin in WA waters belong to the Indian Ocean stock. • Spawns from August to November, with females capable of producing 40 million eggs.	Pelagic fishes (e.g. small tunas), crustaceans and squid.	N/A – Stock not assessed	Pepperell *et al*. (2011) Wright and Pyke (2010)
Indo-Pacific sailfish *Istiophorus platypterus*	• Indo-Pacific sailfish are common and widespread in the tropical and sub-tropical Atlantic and Indo-Pacific oceans, ranging into temperate waters. • Epipelagic usually in oceanic waters and also found near continental coasts, islands and reefs. • Common in nearshore waters off Eighty Mile Beach, Roebuck Bay, Broome and the Dampier Peninsula from June to September when productivity and baitfish activity in the region are highest.	• Spawning occurs throughout the year, peaking in summer	Pelagic fishes, crustaceans and squid.	N/A – Stock not assessed	Pepperell *et al*. (2011) Wright and Pyke (2010)
Shark species					
Sandbar shark *Carcharhinus plumbeus*	• The sandbar shark inhabits tropical and temperate coastal waters, including shallow estuaries with sandy or muddy bottoms, bays, estuaries and around offshore islands, banks and reef flats across the continental shelf out to 280 m depth, but typically in waters less than 100 m • In WA, the species is primarily found between the west Kimberley (Cape Leveque) and Albany. • Adults are most commonly found in depths greater than 40 m between the Eighty Mile Beach and the Houtman Abrolhos Islands.	• Pupping occurs between North West Cape and Albany. • Adults reproduce every two years. Mating may begin as early as October, with peaks between January and April. This is followed by an 11-12-month gestation period, with pupping between February and April. Litter sizes range from 4 to 10 pups. • Unlike most other carcharhinid shark species in WA, juveniles move from shallow waters out to deeper, temperate continental shelf waters (80-130 m) south of Shark Bay and move into shallower waters (50–100 m) between summer and early winter. These movements separate them from adult sharks and the potential for predation and competition for food. • Juvenile sharks are largely absent from waters further north in WA but move northward to these waters as they mature.	Small bottom dwelling fishes, crustaceans and molluscs	Transitional, recovering	Braccini *et al*. (2018) Bray (2019c) Compagno (1984) Compagno (2001) Department of Fisheries (2005) McAuley and Gaughan (2005) McAuley *et al*. (2005) McAuley *et al*. (2007) Newman *et al*. (2003)

Species	Distribution and habitat	Stock structure, reproduction and recruitment	Food / Prey	Stock Status	References
Australian blacktip shark *Carcharhinus tilstoni*	• The Australian blacktip shark is endemic to the tropical continental shelf waters of northern Australia. • Adults occur across the continental shelf up to 150 m water depth, while newborn and juvenile sharks are found in shallow nearshore habitats. • Blacktip sharks are highly mobile animals, enabling them to readily move between preferred habitats.	• Adult females move inshore during the summer months when ready to give birth, and the young are also usually found in warm, shallow nearshore nursery areas. • Individuals breed each year. Mating occurs in February – March, giving birth to 1-6 pups in December – January after a ten-month gestation period.	Pelagic and benthic fishes, cephalopods and crustaceans	Sustainable	Compagno and Niem (1998) Harry *et al*. (2011) Harry *et al*. (2012) Harry *et al*. (2013) Johnson *et al*. (2018) Knip *et al*. (2010) Last and Stevens (2009) Stevens and Wiley (1986) Welch *et al*. (2014)
Common blacktip shark *Carcharhinus limbatus*	• Common blacktip sharks are found in tropical and sub-tropical continental shelf waters up to 150 m water depth, in bays, estuaries, over coral reefs and off river mouths. • Adults prefer deeper shelf waters while newborn and juvenile sharks are found in shallow, nearshore habitats. • Blacktip sharks are highly mobile animals, enabling them to readily move between preferred habitats.	• Adult females move inshore during the summer months when ready to give birth, and the young are also usually found in warm, shallow nearshore nursery areas. • Adults breed every two years with a ten to 12-month gestation period. • Females move into coastal waters to give birth to 4-10 pups between October and March, peaking in November.	Pelagic and benthic fishes, cephalopods and crustaceans	Sustainable	Burgess and Branstetter (2009) Davenport and Stevens (1988) Harry *et al*. (2011) Harry *et al*. (2012) Harry *et al*. (2013) Johnson *et al*. (2018) Knip *et al*. (2010) Last and Stevens (2009) Macbeth *et al*. (2009) Ovenden *et al*. (2010) Welch *et al*. (2014)
Invertebrate species					
Silver-lipped pearl oyster *Pinctada maxima*	• Pearl oysters are typically associated with stone and coral rubble or hard flat rocky bottom covered by a fine layer of sediment with occasional sponges, soft corals, sea fans, hydroids, ascidians and other fauna. • Habitat range off the WA coast is known to extend from the shallow waters of the sub-tidal zone, to water depths of up to 70 metres or more. Most common in water depths less than 40 m.	• The breeding season starts in September/October extending to April/May. • Although there is variability from month to month, the primary spawning occurs from the middle of October to December. A smaller secondary spawning period occurs in February and March. • Recruitment is highly variable due to environmental factors. • The movements of pearl oyster larvae prior to settlement on the seabed are dictated to by wave action, prevailing winds and currents. The currents off Eighty Mile Beach result in alongshore dispersion. • Spawning of oysters off Eighty Mile Beach has been predicted to be concentrated mostly between 8-15 metre water depths with smaller contributions of spawn from deeper water, resulting in recruitment locally and alongshore. • Larvae on WA's north-west shelf are predominantly transported alongshore less than 30 kilometres, however some as far as 60 kilometres.	Suspension feeders - particulate organic matter / nutrients	Sustainable	Benzie and Smith (2006) Condie *et al*. (2006) Department of Fisheries (2015a) Department of Fisheries (2016) Fletcher *et al*. (2006) Hart and Friedman (2004) Hart *et al*. (2018) Hart *et al*. (2016) Johnson and Joll (1993) Wada and Tëmkin (2008) Miller (2019)

Species	Distribution and habitat	Stock structure, reproduction and recruitment	Food / Prey	Stock Status	References
Australian scampi *Metanephrops australiensis*	• Scampi live on the seabed in deep continental slope waters. • They are usually found on Globigerina ooze (deep sea muds rich in the shells of planktonic organisms) at depths of 420-500 metres.	• Timing of spawning is uncertain but is thought to occur annually and studies of similar species suggest that spawning occurs in September-October.	Other crustaceans, fish and squid	Sustainable	Australian Fisheries Management Authority (2018) Harte and Curtotti (2018)
Banana prawn *Penaeus indicus, Penaeus merguiensis*	• Inhabit coastal waters over muddy and sandy seabed. • Banana prawns are widely distributed within tropical and subtropical waters. • White banana prawns are typically found in water depths of 16-25 metres. • Redleg banana prawns are found in deeper waters of 35-90 metres, however they are schooling species and can occasionally form dense aggregations near the surface.	• The biological stock structure of banana prawn is uncertain. • Prawn spawning occurs in shallow coastal waters near estuaries. • Prawn nursery areas in the fisheries in the Pilbara region are located in and around Nickol Bay, Depuch Island, Fortescue river mouth and the De Grey river mouth.	Small bivalve molluscs, crustaceans, polychaete worms, and foraminifera	Sustainable	Australian Fisheries Management Authority (2018) Department of Fisheries (2004) Kangas (2018) Larcombe *et al*. (2018) Sporer *et al*. (2015)
Western king prawn *Penaeus latisulcatus*	• Western king prawns are distributed throughout the Indo-West Pacific. • Inhabit coastal waters over muddy and sandy seabed.	• The biological stock structure of western king prawn is uncertain. • Prawn spawning occurs in shallow coastal waters near estuaries.	Small bivalve molluscs, crustaceans, polychaete worms, and foraminifera	Sustainable	Australian Fisheries Management Authority (2018) Department of Fisheries (2004) Kangas (2018) Sporer *et al*. (2015)
Brown tiger prawn *Penaeus esculentus, Penaeus semisulcatus*	• Tiger prawns are endemic to Australian coastal waters, occurring in Northern Australia from Shark Bay to NSW. • Tiger prawns are found in depths up to 200 metres. • Adults are typically found over coarse sediments. Adult grooved prawns are found in fine mud sediments. Juveniles are found in shallower waters.	• The biological stock structure of brown tiger prawn is uncertain but there is some genetic evidence of separation of brown tiger prawn stocks from the east and west coasts of Australia. • Prawn spawning occurs in shallow coastal waters near estuaries.	Small bivalve molluscs, crustaceans, polychaete worms, and foraminifera	Sustainable	Australian Fisheries Management Authority (2018) Department of Fisheries (2004) Kangas (2018) Noell *et al*. (2018) Sporer *et al*. (2015)



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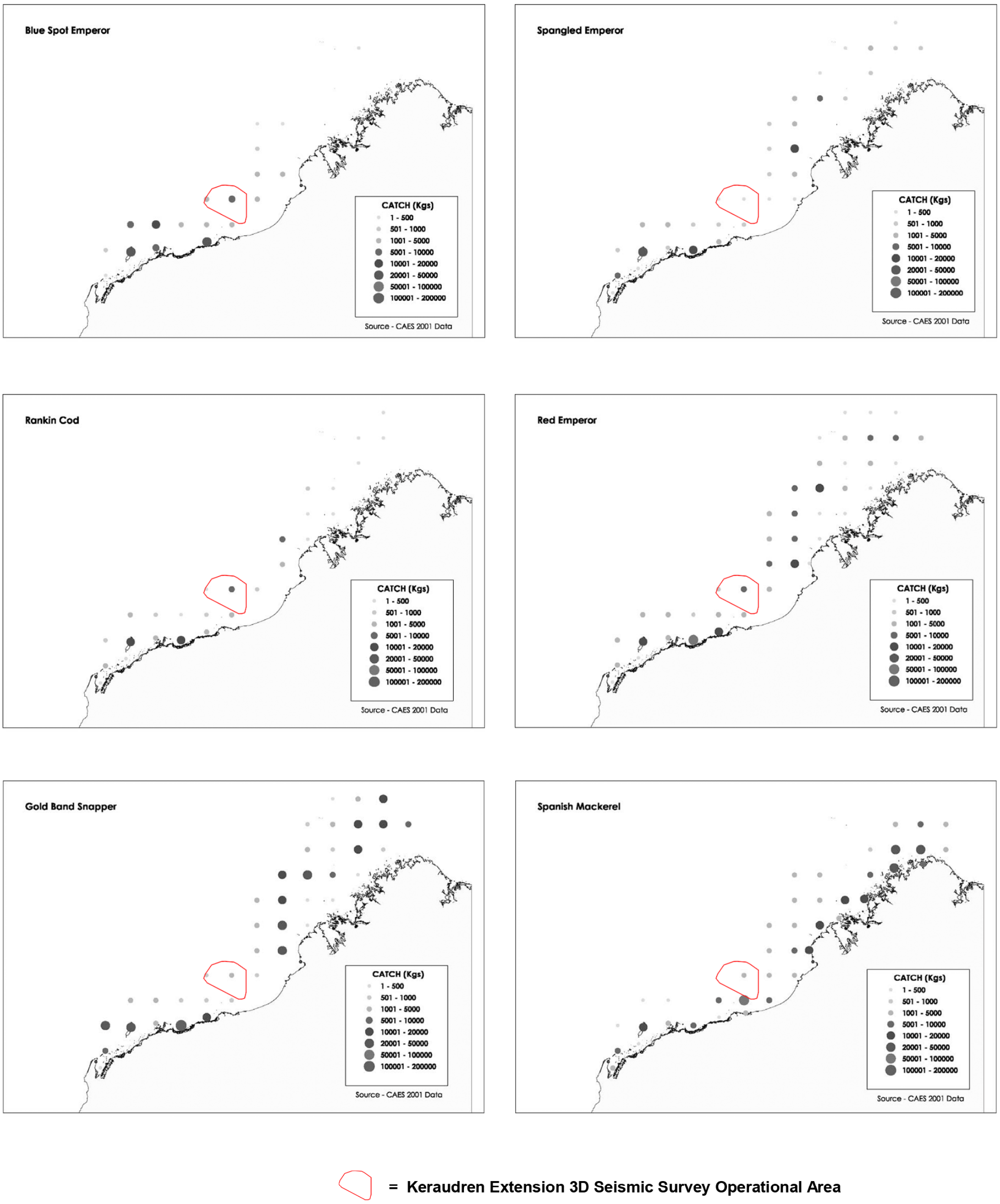
SPATIAL DISTRIBUTION OF CATCH PER UNIT EFFORT (CPUE) FOR INDEX SPECIES OF NORTH WESTERN AUSTRALIA SCALEFISH RESOURCES (2004-2008)

Figure 3-17: Spatial distribution of catch per unit effort for index species of the North Coast Demersal Scalefish Resources (2004-2008 data)



Source: Newman, S.J., Hyndes, G.A., Penn, J.W., Mackie, M.C., Stephenson, P.C. (2014) *Review of generic no-take areas and conventional fishery closure systems and their application to the management of tropical fishery resources along north-western Australia*

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SPATIAL DISTRIBUTION OF KEY COMMERCIAL FISH SPECIES CAUGHT ACROSS NORTH WESTERN AUSTRALIA (2001 CAES DATA)

Figure 3-18: Spatial distribution of key commercial fish species caught across north western Australia based on 2001 catch and effort statistics (CAES)

3.2.4.4 Other Socio-Economic Receptors

Other socio-economic considerations, such as shipping (**Figure 3-19**), recreational fishing, oil and gas industry, tourism, and cultural heritage, submarine cables and defence activities, in relation to the operational area and EMBA are summarised in **Table 3-11**. More detailed descriptions of socio-economic considerations are provided in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**).

Table 3-11: Socio-economic receptors within the EMBA

Value/Sensitivity	Description	Operational area Presence	Relevant events within the operational area	Relevant events within the EMBA
Shipping	The operational area overlaps two designated shipping fairways (**Figure 3-19**) servicing Port Hedland. Commercial shipping using NWS waters includes iron ore carriers, oil and LNG tankers and other vessels proceeding to or from the ports of Dampier, Port Walcott, Port Hedland, Barrow and Varanus islands, and Onslow. Large cargo vessels carrying freight bound or departing from Fremantle also transit along the WA coastline heading north and south in deeper waters.	✓	<u>Planned</u> Interaction with marine users Spill response operations	<u>Planned</u> Spill response operations <u>Unplanned</u> Marine gas oil released from a vessel collision within the operational area
Recreational and charter boat fishing	Consultation for the previous Keraudren 3D MSS has confirmed that no charter boats operate out of Port Hedland. Similarly, consultation with Recfishwest identified that recreational fishing often occurs around the Port Hedland port marker buoys. In consultation with the Port Hedland Game Fishing Club and Port Hedland Volunteer Marine Rescue, it was identified that recreational fishing activity may occur 50 nautical miles offshore, with some locals targeting game fish up to the 50 m water depth and the area surrounding Bedout Island. Therefore, no interaction with recreational fishers is anticipated in the operational area, but may occur in EMBA. Within the North Coast bioregion as a whole, recreational fishing is experiencing growth, with a distinct seasonal peak in winter when the local population increases significantly. Increased recreational fishing has also been attributed to those involved in the construction or operation of developments within the region.	x	None	<u>Planned</u> Spill response operations Noise emissions <u>Unplanned</u> Marine gas oil released from a vessel collision within the operational area
Indigenous, subsistence or customary fishing	Indigenous marine users or customary fishing could occur in the operational area. However, no interactions with traditional fishers has been recorded during previous activities conducted by Santos in the operational area.	x	None	None
Oil and gas activities	The area of the NWS is a major oil and gas hub in Australia, with several companies operating on the NWS. The Activity occurs in a particularly isolated	x	None	None

Value/Sensitivity	Description	Operational area Presence	Relevant events within the operational area	Relevant events within the EMBA
	area of the NWS with respect to the main oil and gas operational and exploratory fields. There are currently no existing facilities in the operational area. The nearest operating facility is Woodside's Angel oil field and associated infrastructure, located approximately 280 km from the operational area. Exploration activity, such as seismic surveys and exploration drilling, could occur within and surrounding the operational area over the life of this EP.			
Tourism	Santos was advised during consultation for the previous Keraudren 3D MSS that there is no offshore tourism industry that operates from Port Hedland, unlike other North West towns like Exmouth and Broome. A low level of recreational diving may occur in the waters surrounding Bedout Island.	x	None	<u>Planned</u> Spill response operations Noise emissions <u>Unplanned</u> Marine gas oil released from a vessel collision within the operational area
Cultural heritage	A search of the online aboriginal heritage Inquiry system was undertaken along shoreline areas within the EMBA from the Montebello Islands, along the coastline to Broome and then north to the Lacepede Islands. The search identified 30 registered aboriginal heritage sites protected under the *Aboriginal Heritage Act 1972* as potentially occurring along the coastal margins of the EMBA. These sites may include artefacts, engraving sites or other ceremonial sites; however, are not likely to be impacted in a spill scenario. The listed sites, mapping and supporting reports are provided in **Appendix C**. Another search of the online aboriginal heritage inquiry system in the same shorelines areas identified 11 other heritage places in the EMBA. These sites may include water source, or mythological uses. Similarly, these sites are not likely to be impacted in a spill scenario. The listed sites, mapping and supporting reports are provided in **Appendix C**. One identified 'other Heritage place' is Bedout Island, which is located 96 km north-east of Port Headland and 42 km south-west of the operational area,	x	None	None

Value/Sensitivity	Description	Operational area Presence	Relevant events within the operational area	Relevant events within the EMBA
	within the EMBA. The Island is a nature reserve and an Important Bird Area (IBA) as classified by BirdLife International (2018), supporting significant breeding colonies of seabirds. There are no historic shipwrecks or sunken aircraft (older than 75 years) located within the operational area. There are however 25 historic shipwrecks located in the EMBA, the closest being the Twin Screw Steamer (1912), 30 kilometres south-west of the operational area. There is also one sunken aircraft located in the EMBA off Eighty Mile Beach, the Dornier Do-24 X-36 (1942), located approximately 130 kilometres south-east of the operational area.			
Communications	Two optical submarine telecommunication cables traverse the operational area, the JASURAUS system that connects Port Hedland to Jakarta (outside of the ramp-up zone), and the North West Cable System (NWCS) (overlapping the ramp-up zone) which connects offshore oil and gas facilities in the Browse, Bonaparte and Carnarvon Basins to onshore locations. The cable system overlaps the operational area as shown in **Figure 3-20**.	✓	Planned Noise emissions	Planned Noise emissions
Defence	No designated defence areas overlap the operational area as shown in **Figure 3-21**. The nearest RAAF bases are the Curtin RAAF base located approximately 404 km north-east and the Learmonth RAAF base located approximately 590 km south-west. Additionally, there are two training and practice areas located near the Learmonth Base, approximately 370 km (training area) and 520 km (practice area) south-west of the operational area. These overlap with the most western portion of the EMBA.	x	None	Unplanned Marine gas oil released from a vessel collision within the operational area Spill response operations

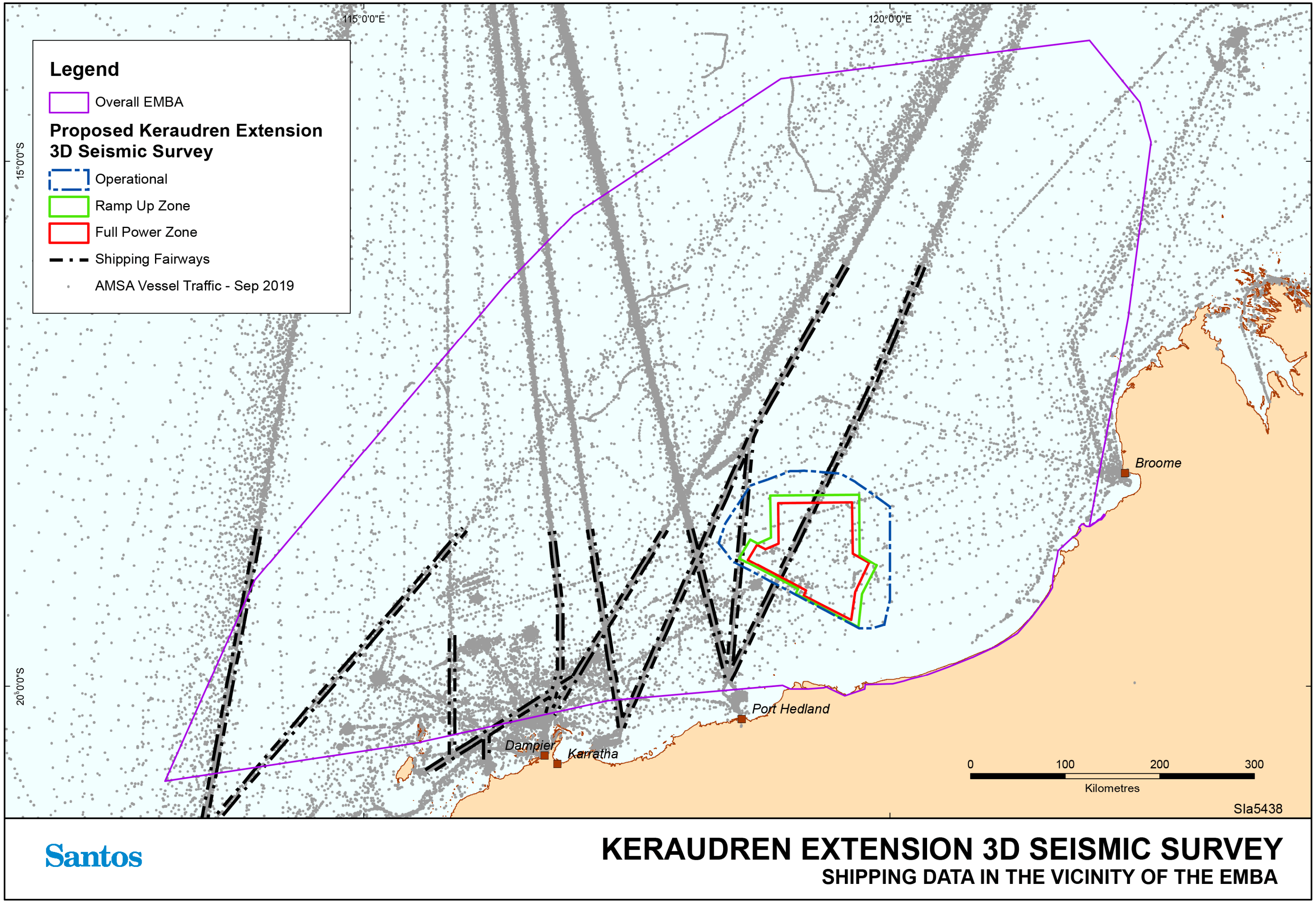

Figure 3-19: AMSA vessel traffic and shipping fairways within the EMBA

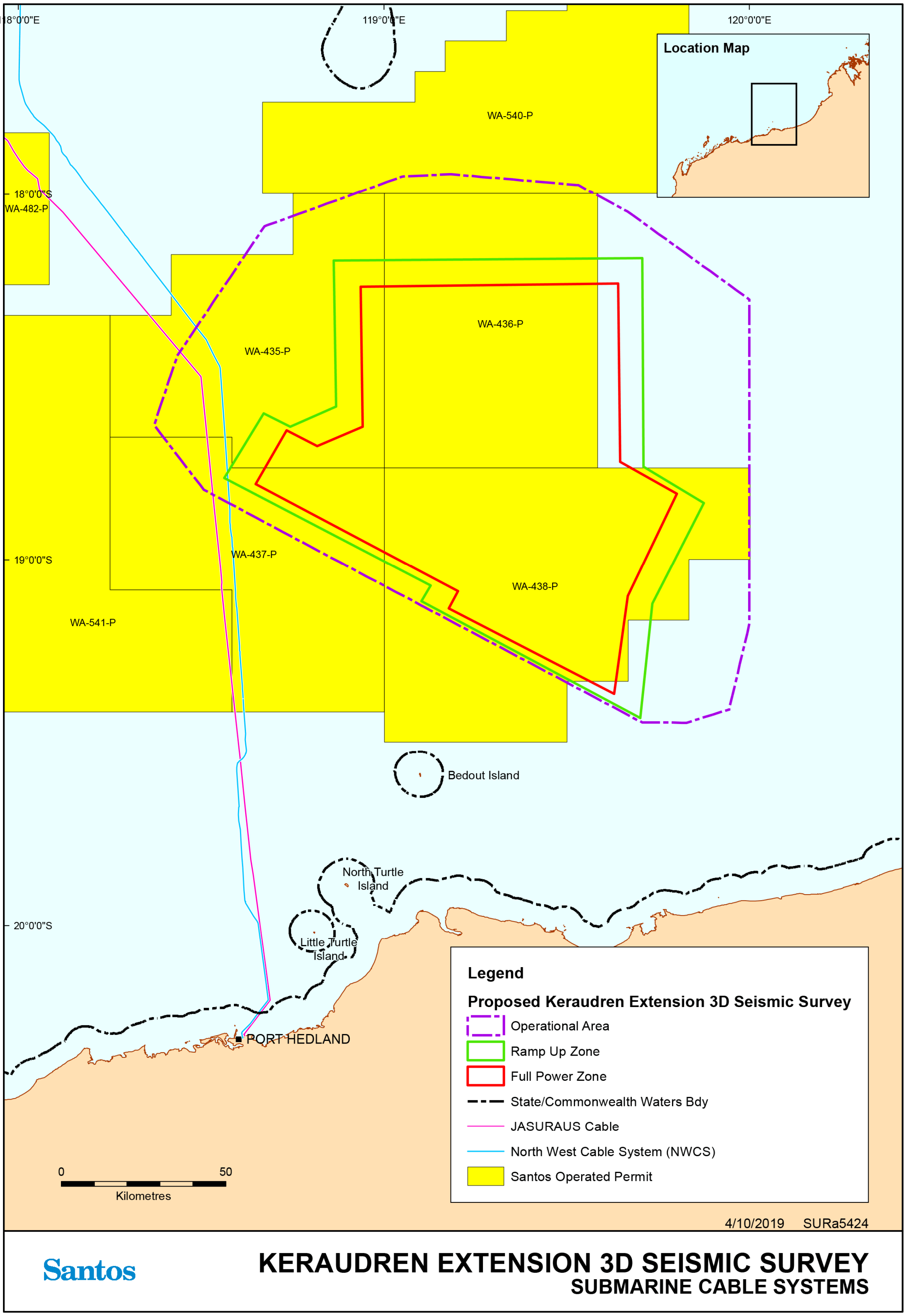

Figure 3-20: Location of the North West Cable System and JASURAUS cable

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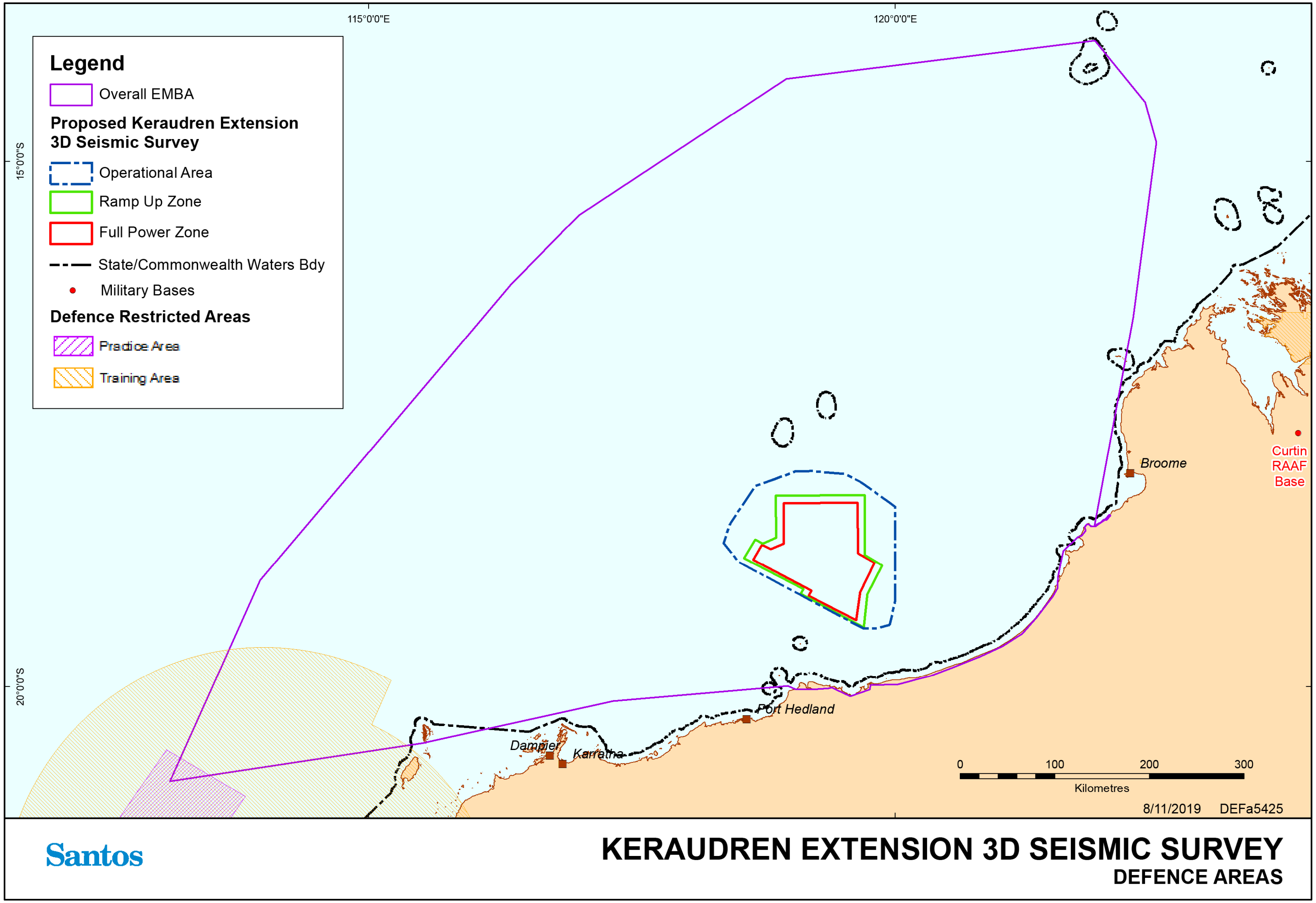

Figure 3-21: Defence areas in the vicinity of the operational area

3.2.5 Periods of Peak Sensitivity or Activity

Timing of peak sensitivity or activity for threatened species and other relevant, significant sensitivities is provided in **Table 3-12.**

Table 3-12: Periods of peak sensitivity or activity windows of sensitivity for the EMBA

Categories	Receptors (critical life cycle stages)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Activity timing													
Physical environment and habitats	Coral (spawning periods)												
	Macroalgae	Growing			Shedding fronds					Growing			
	Other benthic habitats												
	All shoreline habitats												
Protected / significant areas	Protected Areas												
Commercial fish species	Goldband snapper peak spawning												
	Pink snapper peak spawning (Rare within North Coast Bioregion and overlap with this survey)												
	Rankin cod peak spawning												
	Red emperor peak spawning												
	Spanish mackerel peak spawning												
	Pearl oyster spawning												
	Bluespotted Emperor												
	Dusky whaler pupping[6]	May occur throughout year											
	Whiskery shark pupping[7]												
	Blacktip shark (Australian) pupping												
	Sandbar shark pupping												
	Gummy shark pupping	Peak pupping periods unknown											
	Fish – other species	Timing of spawning activity varies between species											
	Sharks												

Categories	Receptors (critical life cycle stages)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Activity timing													
Threatened and migratory Marine Fauna	Whale shark – level of activity for the EMBA, not region		Aggregations at Ningaloo Coast					Post-aggregation foraging and migration					
	Marine Mammals												
	Humpback whale (migration at Port Hedland - Broome)[5]												
	Pygmy blue whale migration				Northern							Southern	
	Marine Reptiles												
	Hawksbill turtles resident adult and juveniles[1]	Widespread throughout NW Shelf waters, highest density of adults and juveniles over hard bottom habitat (coral reef, rocky reef, pipelines etc.)											
	Hawksbill turtle (mating aggregations[1])												
	Hawksbill turtle (nesting and internesting[1])												
	Hawksbill turtle (hatching[1])												
	Flatback turtles (resident adult and juveniles[1])	Widespread throughout NW Shelf waters, increased density over soft bottom habitat 10 – 60m deep, post hatchling age classes and juveniles spread across shelf waters											
	Flatback turtle (mating aggregations[1])												
	Flatback turtle (nesting and internesting[1])												
	Flatback turtle (hatching[1])												
	Green turtles (resident adult and juveniles[1])	Widespread throughout the NW Shelf waters, highest density associated with seagrass beds and macro algae communities, high density juveniles in shallow waters off beaches, amongst mangroves and in creeks											
	Green turtle (mating aggregations[1])												
	Green turtle nesting and internesting[1])												
	Green turtle (hatching[1])												
	Loggerhead turtles (resident adult and juveniles[1])	Widespread throughout the NW Shelf waters, increased density associated with soft bottom habitat supporting their bivalve food source, juveniles associated with nearshore reef habitat											
	Loggerhead turtle (mating aggregations[1])												

Categories	Receptors (critical life cycle stages)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Activity timing													
	Loggerhead turtle (nesting and internesting[1])												
	Loggerhead turtle (hatching[1])												
	Leatherback turtles												
	Seabirds												
	Lesser frigatebird breeding												
	Brown booby breeding												
	Tern breeding												
Conservation Dependent Fauna	Southern Bluefin Tuna												
	Scalloped Hammerhead Shark (East Coast)												
Socioeconomic receptors	**Commercial Managed Fisheries**												
	North West Slope Trawl Fishery												
	State Managed Fisheries												
	Pearl Oyster Managed Fishery												
	Mackerel Managed Fishery[4]												
	All other fisheries												
	Oil and gas												
	Shipping												
	Tourism/recreational[4]												
	Communications	NWCS and JASUARUS cable presence											
	Peak activity, presence reliable and predictable	[1] Information provided by K. Pendoley and DoEE 2017											

Categories	Receptors (critical life cycle stages)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Activity timing													
	Lower level of abundance/activity/presence	[2] No activity in NW Marine Region											
	Activity not occurring	[3] No recent activity in Australia											
	Activity can occur throughout year	[5] Location and Estimated Period of Humpback Whale activity in WA (DMP, 2003)											
		[6] Last, P.R.; Stevens, J.D. (2009). Sharks and Rays of Australia (second ed.). Harvard University Press. pp. 269–270.											
		[7] Simpfendorfer, C. & Unsworth P. (1998) Reproductive biology of the whiskery shark, *Furgaleus macki*, off south-western Australia. *Marine and Freshwater Research* 49(7) 687 - 793											

4. Stakeholder Consultation

OPGGS(E)R 2009 Requirements
Regulation 9AB
If the Regulator’s provisional decision under regulation 9AA is that the environment plan includes material apparently addressing all the provisions of Division 2.3 (Contents of an environment plan), the Regulator must publish on the Regulator’s website as soon as practicable: (a) the plan with the sensitive information part removed; and (b) the name of the titleholder who submitted the plan; and (c) a description of the activity or stage of the activity to which the plan relates; and (d) the location of the activity; and (e) a link or other reference to the place where the accepted offshore project proposal (if any) is published; and (f) details of the titleholder’s nominated liaison person for the activity. Note: If the plan is a seismic or exploratory drilling environment plan, the Regulator must also publish an invitation for public comment on the plan: see regulation 11B.
Regulation 16
16 The environment plan must contain the following: (b) a report on all consultations under regulation 11 A of any relevant person by the titleholder, that contains: (i) a summary of each response made by a relevant person; and (ii) an assessment of the merits of any objection or claim about the adverse impact of each activity to which the environment plan relates; and (iii) a statement of the titleholder’s response, or proposed response, if any, to each objection or claim; and (iv) a copy of the full text of any response by a relevant person.

4.1 Summary

Santos has been active in the Bedout Sub-basin since exploration drilling activities commenced in 2014, and up until 2019 has drilled nine wells in permits WA-435-P and WA-437-P including Phoenix South 1, 2 and 3 wells, Roc-1 and Roc-2 wells, Dorado-1, 2 and 3 wells and Roc South-1 well. Additional exploration activity included the Keraudren 3D MSS completed by Santos in July 2019.

With this history, Santos is familiar with local community stakeholders and other users of the marine environment in the region.

Stakeholders (**Table 4-1**) were informed of activities covered in this EP via several channels of engagement commencing in October 2019, including:

- Santos’ *Quarterly Consultation Update* distributed to the company’s wider stakeholder cohort;
- Keraudren Extension 3D MSS Stakeholder Consultation package distributed to identified stakeholders;

- Keraudren Extension 3D MSS Additional Information for Commercial Fishers package distributed to identified fishing licence holders;
- A notice placed on the Santos website advising of the Keraudren Extension 3D MSS and EP public comment period;
- A notice placed in *The Australian*, *West Australian* and *Pilbara News* newspapers advising of the Keraudren Extension 3D MSS and EP public comment period; and
- Email notice sent to all relevant stakeholders advising of the Keraudren Extension 3D MSS and EP public comment period.

Based on Santos' experience with the Keraudren 3D MSS conducted in 2019, and from subsequent stakeholder feedback and regulator discussions, the primary stakeholder issues of concern for this activity are:

- Potential impact of seismic on marine receptors, specifically commercial fish stocks (addressed in **Section 6.2**); and
- The level of potential industry seismic activity in the region over the next few years (addressed in **Section 6.3**).

Santos has considered all stakeholder responses and assessed the merits of all objections and claims about the potential impact of the proposed seismic survey. A summary of Santos' response statements to the objections and claims is provided in **Table 4-2.**

Santos considers that consultation with relevant stakeholders has been adequate to inform the development of this EP. Notwithstanding this, Santos recognises the importance of ongoing stakeholder consultation and notification and these are described in **Table 8-3.**

4.2 Stakeholder Identification

Santos understands retaining a broad licence to operate depends on the development and maintenance of positive and constructive relationships with a comprehensive group of stakeholders in the community, government, non-government, other business sectors and other users of the marine environment. Fostering effective consultation between Santos and relevant stakeholders is an important part of this process.

Santos began the stakeholder identification process for this EP with a review of its stakeholder database, including stakeholders consulted for other recent activities in the area and specifically the Keraudren 3D MSS. The list of stakeholders was then reviewed and refined based on the defined operational area **(refer to Section 2.3)**, the EMBA **(refer to Section 3.1)** and the relevance of the stakeholder according to Regulation 11A of the OPGGS (E) Regulations and NOPSEMA Bulletin #2 *Clarifying statutory requirements and good practice consultation* (November, 2019). More specifically, stakeholders for this EP were identified through the following:

- Regular review of legislation applicable to petroleum and marine activities;
- Identification of marine user groups and interest groups active in the area (e.g., commercial fisheries, other oil and gas producers, merchant shipping, etc.);
- A request for the most recent Department of Primary Industries and Regional Development (DPIRD) FishCube data (**Section 3.2.4.2**).
- Updated fishing licence holder contact details, from these identified fisheries, as provided by DPIRD;
- Utilisation of the WAFIC Oil and Gas consultation services to advise on 'relevant' commercial fisheries and fishers, and to review and distribute fishery-specific consultation material;
- Discussions with identified stakeholders to identify other potentially impacted persons;

- Active participation in industry bodies and collaborations (e.g., APPEA, AMOSC, NERA); and
- Records from previous consultation activities in the area, including previous Bedout Basin drilling activities and Keraudren 3D MSS.

Currently identified stakeholders and an assessment of their relevance under the OPGGS (E) Regulations for the purposes of consultation for this activity are listed in **Table 4-1.**

Table 4-1: Assessment of relevance of identified stakeholders for the proposed activity

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
Commonwealth government departments/agencies		
Australian Hydrographic Office (AHO)	Considered relevant persons under Regulation 11A(1) (a)	The AHO is the part of the Commonwealth DoD responsible for maintaining and disseminating nautical charts, including the distribution of Notice to Mariners. The operational area is in commonwealth waters.
Australian Maritime Safety Authority (AMSA)	Considered relevant persons under Regulation 11A(1) (a)	AMSA is the statutory and control agency for maritime safety and vessel emergencies in Commonwealth Waters. AMSA is a relevant agency when proposed offshore activities may impact on the safe navigation of commercial shipping in Australian waters. The operational area is in commonwealth waters.
Department of Defence (DoD)	Considered relevant persons under Regulation 11A(1) (a)	DoD is a relevant agency where the proposed activity may impact operational requirements; encroach on known training areas and/or restricted airspace, or when nautical products or other maritime safety information is required to be updated. The operational area is in commonwealth waters.
Australian Fisheries Management Authority (AFMA)	Considered relevant persons under Regulation 11A(1) (a)	AFMA is responsible for managing Commonwealth fisheries and is a relevant agency where the activity has the potential to impact on fisheries resources in AFMA managed fisheries. The operational area intersects with commonwealth managed fisheries.
Department of Agriculture and Water Resources (DAWR) – Biosecurity (marine pests)	Considered relevant persons under Regulation 11A(1) (a)	The DAWR (marine pests) has primary policy and regulatory responsibility for managing biosecurity for incoming goods and conveyances, including biosecurity for marine pests. The Department is the relevant agency where an offshore activity has the potential to transfer marine pests between installations and mainland Australia. The operational area is in commonwealth waters.
Department of Agriculture and Water Resources (DAWR) – Fisheries	Considered relevant persons under Regulation 11A(1) (a)	DAWR (fisheries) has primary policy responsibility for promoting the biological, economic and social sustainability of Australian fisheries. The Department is the relevant agency where the activity has the potential to negatively impact fishing operations and / or fishing habitats in Commonwealth waters. The operational area intersects with commonwealth managed fisheries.
Department of Agriculture and Water Resources (DAWR) – Biosecurity (vessels, aircraft and personnel)	Considered relevant persons under Regulation 11A(1) (a)	DAWR (vessels and aircraft) has inspection and reporting requirements to ensure that all conveyances (vessels, installations and aircraft) arriving in Australian territory comply with international health regulations and that any biosecurity risk is managed. The department is the relevant agency where the titleholder's activity involves: • the movement of aircraft or vessels between Australia and offshore petroleum activities either inside or outside

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
		Australian territory • the exposure of an aircraft or vessel (which leaves Australian territory not subject to biosecurity control) to offshore petroleum activities.
Director of National Parks (DoNP)	Considered relevant persons under Regulation 11A(1) (a)	The DNP is the statutory authority responsible for administration, management and control of Commonwealth marine reserves (CMRs). The Director of National Parks is a relevant person for consultation where: • the activity or part of the activity is within the boundaries of a proclaimed Commonwealth marine reserve; • activities proposed to occur outside a reserve may impact on the values within a Commonwealth marine reserve; and / or • an environmental incident occurs in Commonwealth waters surrounding a Commonwealth marine reserve and may impact on the values within the reserve. The operational area is adjacent to commonwealth marine reserves.
State government departments / agencies		
Department of Transport (DoT)	Considered relevant persons under Regulation 11A(1) (b)	DoT is the control agency for marine pollution emergencies in State waters.
Department of Primary Industries and Regional Development (DPIRD)	Considered relevant persons under Regulation 11A(1) (b)	DPIRD is responsible for managed West Australian State fisheries. The operational area intersects with state managed fisheries.
Department of Biodiversity, Conservation and Attractions (DBCA)	Considered relevant persons under Regulation 11A(1) (b)	DBCA is a relevant State agency responsible for the management of State marine parks and reserves and protected marine fauna and flora. The operational area is adjacent to state marine reserves.
Department of Mines, Industry Regulation and Safety (DMIRS)	Considered relevant persons under Regulation 11A(1) (c)	Department responsible for the management of offshore petroleum in the adjacent State waters.
Other interested parties		
Vocus Communications	Considered relevant persons under Regulation 11A(1) (d)	Vocus Communications is the operator of the North West Cable System (NWCS) which forms a key component to one of Australia's largest nationwide fibre optic networks. The cable system intersects with the survey operational area.
Telstra	Considered relevant persons under Regulation 11A(1) (e)	Telstra operate the Jasuarus Cable, a telecommunications table connecting Port Hedland to Jakarta. From previous engagement with Telstra, Santos understands this cable was decommissioned in 2012 and is no longer used, though remains in situ. The cable system intersects with the survey operational area.
Neighbouring operators / exploration companies		
3D Oil Ltd	Considered relevant persons under Regulation 11A(1) (e)	3D Oil is listed as the titleholder of an adjacent petroleum permit WA-527-P.
Carnarvon Petroleum Ltd	Considered relevant persons under Regulation 11A(1) (d)	Carnarvon Petroleum is listed as the titleholder of an adjacent petroleum permit WA-521-P.

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
Inpex Browse E&P P/L	Considered relevant persons under Regulation 11A(1) (e)	Inpex is listed as the titleholder of a nearby petroleum permit WA-533-P.
Pathfinder Energy Ltd	Considered relevant persons under Regulation 11A(1) (e)	Pathfinder Energy is listed as the titleholder of nearby petroleum permits WA-487-P and WA-479-P.
Equinor Australia BV	Considered relevant persons under Regulation 11A(1) (e)	Equinor is listed as the titleholder of nearby petroleum permit WA-542-P.
PGS	Considered relevant persons under Regulation 11A(1) (e)	This company was consulted as a potentially interested seismic acquisition / multiclient seismic company.
Searcher Seismic	Considered relevant persons under Regulation 11A(1) (e)	This company was consulted as a potentially interested seismic acquisition / multiclient seismic company.
Polarcus	Considered relevant persons under Regulation 11A(1) (e)	This company was consulted as a potentially interested seismic acquisition / multiclient seismic company.
Shearwater	Considered relevant persons under Regulation 11A(1) (e)	This company was consulted as a potentially interested seismic acquisition / multiclient seismic company.
TGS	Considered relevant persons under Regulation 11A(1) (e)	This company was consulted as a potentially interested seismic acquisition / multiclient seismic company.
Industry bodies		
Western Australian Fishing Industry Council (WAFIC)	Considered relevant persons under Regulation 11A(1) (e)	WAFIC is the peak industry body representing the interests of the WA commercial fishing, pearling and aquaculture sector. The operational area intersects with several State-managed fisheries.
Commonwealth Fisheries Association (CFA)	Considered relevant persons under Regulation 11A(1) (e)	The CFA was engaged as a representative body for Commonwealth fisheries. The operational area intersects with several Commonwealth-managed fisheries. The CFA is also listed on the AFMA website as a contact for petroleum operators to use when consultation with fishing operators is required.
Marine Tourism WA (MTWA)	Considered relevant persons under Regulation 11A(1) (e)	MTWA represents the charter sector in WA. DPIRD has indicated charter fishing may occur within the proposed area of activity. MTWA is identified as being able to assist in reaching its membership to inform them of survey timing should this be requested.
Pearl Producers Association (PPA)	Considered relevant persons under Regulation 11A(1) (e)	The PPA is the peak representative organisation of The Australian South Sea Pearling Industry. PPA membership includes all *Pinctada maxima* pearl oyster licensees that operate within the Australian North-west Bioregion. The PPA has previously informed Santos the region nearby 80 Mile Beach is of high interest to the pearling industry.
Recfishwest	Considered relevant persons under Regulation 11A(1) (e)	Recfishwest is the peak body representing recreational fishers in WA. DPIRD has indicated recreational fishing may occur within the proposed area of activity. Recfishwest is identified as being able to assist in reaching its membership to inform of survey timing should this be requested.

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
WA Professional Shell Fisherman's Association	Not considered relevant persons under Regulation 11A for the purposes of this activity	Industry association representing professional shell fishermen. The fishery overlaps the proposed operational area however no fishing effort is expected within the area due to the water depth. Confirmed in consultation with WAFIC. Therefore, the functions, interests and activities of the shell fishermen will not be affected. Provided initial consultation pack as a courtesy.
Australian Southern Bluefin Tuna Industry Association (ASBTIA)	Considered relevant persons under Regulation 11A(1) (e)	ASBTIA represents the Australian SBT industry. ASBTIA is also listed on the AFMA website as a contact for petroleum operators to use when consultation with Commonwealth fishing operators is required.
Community / Port Hedland		
Town of Port Hedland	Considered relevant persons under Regulation 11A(1) (e)	Port Hedland is the nearest community to Santos' Bedout Basin petroleum permits. The Town of Port Hedland is the local government body for the region.
Shire of East Pilbara	Not considered relevant persons under Regulation 11A for the purposes of this activity	The Shire of East Pilbara North West Ward covers a patch of shoreline between Port Hedland and 80 Mile Beach which includes Cape Keraudren. Santos is of the view that the shire's functions, interests and activities will not be affected. Provided initial consultation pack as a courtesy.
Pilbara Port Authority	Considered relevant persons under Regulation 11A(1) (e)	Pilbara Ports Authority manages port land at Dampier, Port Hedland, Ashburton and Cape Preston East, and facilitates the development of land and leases to support port-related industries. Port Hedland is the nearest port to the activity.
Port Hedland Chamber of Commerce and Industry (PH CCI)	Not considered relevant persons under Regulation 11A for the purposes of this activity	The Port Hedland CCI is a member driven organisation providing information, professional services and support for businesses in the local Port Hedland area. Santos is of the view that the CCI's functions, interests and activities will not be affected. Provided initial consultation pack as a courtesy.
Port Hedland Game Fishing Club (PHGFC)	Considered relevant persons under Regulation 11A(1) (e)	The PHGFC was identified as a potentially relevant stakeholder for Keraudren 3D MSS. DPIRD has also indicated recreational fishing may occur within the proposed area of activity. PHGFC is identified as being able to assist in reaching its membership to inform of survey timing should this be requested.
Port Hedland Volunteer Marine Rescue (PHVMR)	Not considered relevant persons under Regulation 11A for the purposes of this activity	The PHVMR was identified as a potentially relevant stakeholder for Keraudren 3D MSS. Santos is of the view that the groups functions, interests and activities will not be affected by the proposed activity. Provided initial consultation pack as a courtesy.
Port Hedland Yacht Club	Not considered relevant persons under Regulation 11A for the purposes of this activity	The PHYC was identified as a potentially relevant stakeholder for Keraudren 3D MSS. Santos is of the view that the club's functions, interests and activities will not be affected by the proposed activity. Provided initial consultation pack as a courtesy.
Port Hedland Seafarers Centre	Not considered relevant persons under Regulation 11A for the purposes of this activity	Port Hedland Seafarers Centre operates Harbour Tours of the Port Hedland Port with members of the public, on a Seafarers Launch Service Boat. Discussions with this group for Keraudren 3D MSS confirmed they operated only within the harbour and were not a relevant stakeholder. Provided initial consultation pack as a courtesy.
Department of Planning Land and Heritage (Hedland)	Not considered relevant persons under Regulation 11A	Suggested as potentially relevant stakeholder in previous consultation with the Port Hedland CCI. DPLH Hedland undertakes key activities relating to land use planning, the land supply chain, land administration and asset management, all

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
	for the purposes of this activity	aspects of heritage, and Aboriginal lands and heritage. Santos is of the view that the department's functions, interests and activities will not be affected by the proposed offshore activity. Provided initial consultation pack as a courtesy.
GT Diving	Considered relevant persons under Regulation 11A(1) (e)	Suggested as potentially relevant stakeholder with information regarding recreational diving activities offshore Port Hedland. Identified as being able to assist in reaching recreational divers to inform of survey timing should this be requested.
80 Mile Beach Caravan Park	Not considered relevant persons under Regulation 11A for the purposes of this activity	Suggested as potentially relevant stakeholder in previous consultation with the Town of Port Hedland. The proposed operational area is approximately 146 km offshore from the 80 Mile Beach Caravan Park. Santos is of the view that the business' functions, interests and activities will not be affected by the proposed offshore activity. Provided initial consultation pack as a courtesy.
De Grey Station	Not considered relevant persons under Regulation 11A for the purposes of this activity	De Grey Station is a pastoral lease, now a cattle station approximately 80 km east of Port Hedland on the mouth of the De Grey River in the Pilbara. Santos is of the view that the station's functions, interests and activities will not be affected by the proposed offshore activity. Provided initial consultation pack as a courtesy.
Pardoo Station	Not considered relevant persons under Regulation 11A for the purposes of this activity	Pardoo Station is a pastoral lease, formerly a sheep station, and now a cattle station approximately 120 kilometres east of Port Hedland and 121 kilometres north of Marble Bar. Santos is of the view that the station's functions, interests and activities will not be affected by the proposed offshore activity. Provided initial consultation pack as a courtesy.
Care for Hedland	Considered relevant persons under Regulation 11A(1) (e)	Port Hedland-based Non-government Organisation (NGO). Focused primarily on turtle conservation, with an interest in whales. Identified as relevant given the location of the survey in relation to biologically important areas for turtles, and humpback whale migration pathways. Santos has chosen to consult with as part of informing good environmental management practices.
BHP Corporate Affairs Port Hedland	Not considered relevant persons under Regulation 11A for the purposes of this activity	BHP Corporate Affairs in Port Hedland was identified as a potentially relevant stakeholder given their local knowledge and understanding of the local stakeholder groups. Santos is of the view that the business' functions, interests and activities will not be affected by the proposed offshore activity. Provided initial consultation pack as a courtesy.
Commercial fisheries – state managed		
Mackerel Managed Fishery (Area 2)	Considered relevant persons under Regulation 11A(1) (d)	Based on a review of DPIRD FishCube data (**Section 3.2.4.2)** and consultation with WAFIC, the Mackerel Managed Fishery (Area 2) boundary overlaps the proposed operational area. Further, there has been recorded fishing effort in, and near, the operational area. There are 22 licences in Area 2 of this fishery held by ten licence holders.
Pilbara Line Fishery	Considered relevant persons under Regulation 11A(1) (d)	Based on a review of DPIRD FishCube data (**Section 3.2.4.2**) and consultation with WAFIC, the Pilbara Line Fishery boundary overlaps the proposed survey operational area. Further, there has been recorded fishing effort in, and near, the operational area. There are nine licenses in this fishery held by seven licence holders.

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
Pilbara Trap Managed Fishery	Considered relevant persons under Regulation 11A(1) (d)	Based on a review of DPIRD FishCube data (**Section 3.2.4.2**) and consultation with WAFIC, the Pilbara Trap Managed Fishery boundary overlaps the proposed operational area. Further, there has been recorded fishing effort in, and near, the area. There are six licenses in this fishery held by two licence holders.
Pilbara Fish Trawl Interim Managed Fishery	Considered relevant persons under Regulation 11A(1) (d)	Based on a review of DPIRD FishCube data (**Section 3.2.4.2**), and consultation with WAFIC, the Pilbara Fish Trawl Interim Managed Fishery boundary overlaps the proposed operational area. Further, there has been recorded fishing effort in the area. There are 11 licenses in this fishery held by four licence holders.
Nickol Bay Prawn Fishery	Not considered relevant persons under Regulation 11A for the purposes of this activity	Based on a review of DPIRD FishCube data (**Section 3.2.4.2**) and consultation with WAFIC, the Nickol Bay Prawn Managed Fishery boundary overlaps the proposed operational area. However, recorded fishing effort is well clear of the area and no intersection with licence holders is expected. Santos is of the view that fishing licence holder's functions, interests and activities will not be affected by the proposed activity. Fishers provided an initial consultation pack as a courtesy.
Pearl Oyster Managed Fishery	Considered relevant persons under Regulation 11A(1) (e)	Based on a review of DPIRD FishCube data (**Section 3.2.4.2**) and consultation with WAFIC, the Pearl Oyster Managed Fishery boundary overlaps the proposed survey operational area. Santos has decided to consult with the industry association (PPA) given previous concerns about seismic surveys, water depth and pearl oyster stocks.
Pilbara Crab Managed Fishery	Considered relevant persons under Regulation 11A(1) (e)	WAFIC has advised that this fishery is potentially active, and its boundary overlaps the proposed operational area, therefore the licence holders in the fishery are potentially affected parties to this activity and their targeted resource. While most fishing is inshore (less than 50 m) the fishers may venture into deeper waters. WAFIC identified one fisher for consultation.
WA North Coast Shark	Not considered relevant persons under Regulation 11A for the purposes of this activity	The boundaries of this fishery overlap the proposed operational area; however this fishery is currently closed to protect the breeding grounds of the resource which support the two southern shark fisheries. Confirmed in consultation with WAFIC. Santos is of the view that fishing licence holder's functions, interests and activities will not be affected by the proposed activity.
West Coast Deep Sea Crustacean	Not considered relevant persons under Regulation 11A for the purposes of this activity	The boundaries of this fishery overlap the proposed operational area however there has been no fishing effort within the operational area. Confirmed in consultation with WAFIC. Santos is of the view that fishing licence holder's functions, interests and activities will not be affected by the proposed activity.
Marine Aquarium	Not considered relevant persons under Regulation 11A for the purposes of this activity	The boundaries of this fishery overlap the proposed operational area however no fishing effort has been recorded in the area due to water depth. Confirmed in consultation with WAFIC. Santos is of the view that fishing licence holder's functions, interests and activities will not be affected by the proposed activity.
Commercial Fisheries – commonwealth managed		
North West Slope Trawl	Considered relevant persons under Regulation 11A(1) (e)	WAFIC has advised that this fishery is potentially active, and its boundary overlaps the proposed operational area. WAFIC recommended consultation focus only on the overlap between the fishery border and the operational area (vessel turning zone

Stakeholder	Relevant to Activity	Relevance / Reason for Engagement
		only) and identified three fishers for consultation in addition to the CFA.
Western Tuna and Billfish (Commonwealth managed)	Considered relevant persons under Regulation 11A(1) (e)	WAFIC has advised that this fishery is potentially active, and its boundary overlaps the proposed operational area. WAFIC identified one commercial tuna fisherman in WA waters for consultation and advised this fisher has requested all seismic consultation material.
Southern Bluefin Tuna fishery	Not considered relevant persons under Regulation 11A for the purposes of this activity	The boundaries of this fishery overlap the proposed operational area however no fishing effort has been recorded in the area. Consultation has been undertaken with WAFIC and ASBITA, but no fishing licence holders.
Western Skipjack Tuna Fishery	Not considered relevant persons under Regulation 11A for the purposes of this activity	The boundaries of this fishery overlap the proposed operational area, however based on the AFMA website and WAFIC advice this fishery is currently not active. Santos is of the view that fishing licence holder's functions, interests and activities will not be affected by the proposed activity.

4.3 Stakeholder Consultation

The approach to stakeholder consultation for this EP follows the process adopted by Santos for all its EPs, and specifically the earlier Keraudren 3D MSS EP. Some modifications to this approach have been made based on feedback from WAFIC, commercial fishers and NOPSEMA. These include:

- Providing more detailed information to commercial fishers, targeted to their fishery, in the initial consultation packs;
- Engaging WAFIC to assist in the review and distribution of commercial fisher consultation material;
- Refinements to the stakeholder identification process to clearly identify and maintain current lists of 'relevant' persons, and
- Clearly documenting and tracking notification commitments to relevant persons.

Key stakeholders were contacted by phone or meeting prior to providing the *Keraudren Extension 3D MSS Stakeholder Consultation* package to increase activity awareness and to encourage two-way communication. Stakeholders, wherever possible, were provided personal emails with information tailored to their functions, interests and activities, including outlining why they have been identified as a relevant stakeholder.

The consultation package contains details such as an activity summary, location map, coordinates, water depth, distance to key regional features, vessel exclusion zone details and estimated timing and duration. This consultation package outlined potential risks and impacts together with a summary of proposed management control measures. For simplicity, the consultation package represented the seismic full power and ramp-up zones as one zone, labelled the 'survey area'. Stakeholders were encouraged to provide feedback on the proposed activity.

Individual fishing licence holders, as identified through DPIRD data and in consultation with WAFIC, were provided the *Keraudren Extension 3D MSS Stakeholder Consultation* package *and Keraudren Extension 3D MSS Additional Information for Commercial Fishers* package by email (and one by post).

Commercial fishers were provided additional information which included:

- Maps and information relevant to a specific fishery;
- Information about the timing and duration of the survey;

- An environmental sensitives chart showing the proposed survey window to reduce risks to spawning key indicator fish species;
- Information on operational area access and concurrent operations, and
- Information on commercial fishery payment (make good) claims.

The intent of providing this level of information early in the consultation process was to facilitate each party proceeding with their business in a safe and efficient manner, and without loss or conflict, by minimising the extent of interruption by the seismic survey activities on commercial fishing operators' activities to the lowest practicable level. Where this is unavoidable, to mitigate the effects of the interruptions, and where commercial fishers may potentially incur additional cost and/or loss, Santos and commercial fishers to then proceed to an equitable 'make good' process. Santos invited commercial fishers to make comment on the make good process.

Santos has also been mindful of the potential for other seismic surveys to be conducted in the Bedout Sub-basin in coming years. Hence, Santos approached other relevant oil and gas operators and seismic survey service providers to discuss their plans and potential stakeholder issues, specifically the commercial fisheries.

Stakeholders were afforded at least six weeks to review consultation packs, although Santos accepted stakeholder feedback after this period.

A summary of the stakeholder consultation and Santos' assessment of stakeholder comments is outlined in **Table 4-2**. Full transcripts between Santos and stakeholders are provided in the *Keraudren Extension 3D Marine Seismic Survey Environment Plan Sensitive Stakeholder Information Report* (SO-91-BI-20006.03) as a confidential submission to NOPSEMA.

In relation to stakeholder consultation Santos is of the opinion that Regulation 10A of the OPGGS(E) Regulations has been met.

Table 4-2 Consultation summary for activity

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
Commonwealth departments/agencies		
Australian Hydrographic Office (AHO)	AHO was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. AHO acknowledged receipt of information on 10 October 2019. Santos emailed AHO on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.AHO acknowledged receipt of information on 6 January 2020. No further response received to date.	AHO notification requirements, as requested by AMSA and DoD, are addressed in Table 8.3. Santos will address any comments from this stakeholder should they arise in the future.
Australian Maritime Safety Authority (AMSA)	AMSA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. AMSA responded on 10 October 2019 advising the Master should notify AMSA's Joint Rescue Coordination Centre (JRCC) for promulgation of radio-navigation warnings at least 24-48 hours before operations commence. JRCC will also need to be advised when operations start and end. Santos should contact the AHO at no less than four working weeks before operations, with details relevant to the operations. The AHO will promulgate the appropriate Notice to Mariners (NTM), which will ensure other vessels are informed of activities. Santos responded to AMSA on 14 November 2019 confirming AMSA's comments will be taken into consideration in the drafting of the EP. Santos emailed AMSA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	AMSA's requirements are addressed in **Table 8-3**, CM-1. Santos will address any additional comments from this stakeholder should they arise in the future.
Department of Defence (DoD)	DoD was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. The DoD responded on 4 November 2019 advising they had no objections to the proposed activities and requested continued liaison with AHS, to ensure the AHS is notified three weeks prior to the actual commencement of activities. Santos responded to DoD on 13 November 2019 confirming DoD comments will be taken into consideration in the drafting of the EP.	DoD's requirements are addressed in **Table 8-3**, CM-1. Santos will address any additional comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	Santos phoned DoD on 9 December 2019 to confirm their notification requirements because they differed slightly from advice received from AMSA: • DoD – ensure the Hydrographic Service (AHS) is notified three weeks prior to commencement of activities at datacentre@hydro.gov.au. • AMSA – ensure the Australian Hydrographic Office (AHO) is notified no less than four working weeks before operations commence at datacentre@hydro.gov.au. In discussion with DoD it was confirmed: • Operators can refer to AHO or AHS, although there was now a preference for AHO. • Acknowledged the different notification requirements and suggested the earliest notification possible was always preferred. Agreed Santos would include a notification requirement to the AHO of no less than four working weeks before operations commenced to satisfy both requirements. Santos emailed DoD on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	
Australian Fisheries Management Authority (AFMA)	AFMA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos sent a follow-up email on 10 December 2019 inviting comment. AFMA responded on 11 December 2019 advising AFMA was unable to comment on individual proposals, however, it was important to consult with all fishers who have entitlements to fish within the proposed area. This can be done through the relevant fishing industry associations or directly with fishers who hold entitlements in the area. AFMA provided guidance on where to find this information. Santos responded on 11 December 2019 thanking AFMA for the information. Santos emailed AFMA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	Santos has assessed the impact to fish and commercial fisheries in **Sections 6.1 and 6.2.** Santos will address any additional comments from this stakeholder should they arise in the future.
Department of Agriculture and Water Resources (DAWR) – Biosecurity (vessels, aircraft and personnel)	The department was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. The department responded on 18 October 2019 providing advice on the Australian Government's biosecurity requirements. In summary, the department advised:	The department's requirements are addressed in **Table 8-3**, CM-51. Santos will address any additional comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	• It is our understanding that your intended operating practices may expose domestic conveyances (support vessels and aircraft) to interactions with the survey vessel which may pose an unacceptable level of biosecurity risk. Where domestic conveyances become exposed through interactions with persons, goods or conveyances outside Australian territory they automatically become subject to biosecurity control upon their return. If the department concludes that the level of biosecurity risk associated with the survey vessel is low, within the meaning of the Biosecurity (Exposed Conveyances – Exceptions from Biosecurity Control) Determination 2016 (the Determination), an exposed conveyance may be eligible for an exception from biosecurity control. • For exposed conveyances to be assessed as low risk, the offshore installation must demonstrate that it meets the requirements set out in the Determination. To have risk status assessed, offshore installation projects must apply to the department at least one month prior to project commencement. The department will work with installation representatives to assess the biosecurity risk of the installation and associated support conveyances (vessels and aircraft). Note: To be eligible, an exposed conveyance must meet all circumstances as outlined in section 6 of the Determination. • Please review the department's Offshore Installations webpage and associated Offshore Installations Biosecurity Guide which provides specific biosecurity information for operators of offshore installations and notify the department where your project which may have conveyance interactions with Australian territory, or to discuss a biosecurity assessment, email seaports@agriculture.gov.au. • Please also review Australian ballast water and biofouling requirements and pre-arrival reporting using MARS. Santos responded to the department on 18 November 2019 confirming DAWR requirements on biosecurity will be taken into consideration in the drafting of the environment plan. Santos emailed the department on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	
Department of Agriculture and Water Resources	The department was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019.	Santos will address any comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
(DAWR) – Biosecurity (marine pests)	Santos emailed the department on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Management of invasive marine pest species is addressed in **Section 7.7**.
Department of Agriculture and Water Resources (DAWR) – Fisheries	The department was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. The department acknowledged receipt of information on 11 October 2019. Santos sent a follow-up email on 9 December 2019 inviting comment. Santos emailed the department on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Santos has assessed the impact to fish and commercial fisheries in **Section 6.1 and 6.2**. Santos will address any comments from this stakeholder should they arise in the future.
Director of National Parks (DNP)	The Director of National Parks (DNP) was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. DNP responded on 18 October 2019 seeking clarification on the survey distances from Australian Marine Parks. Santos responded on 21 October 2019 clarifying the distances and providing a revised consultation pack for the DNP. DNP responded on 8 November 2019 advising: • Based on the material provided, the planned activities do not overlap any Australian Marine Parks and that the operational area of the seismic survey is approximately 5 km, 20 km and 85 km from Eighty Mile Beach, Argo-Rowley Terrace and Mermaid Reef marine parks respectively. Therefore, there are no authorisation requirements from the DNP. • To assist in the preparation of an EP for petroleum activities that may affect Australian marine parks, NOPSEMA has worked closely with Parks Australia to develop and publish a guidance note that outlines what titleholders need to consider and evaluate. In preparing the EP, you should consider the Australian marine parks and their representativeness. In the context of the management plan objectives and values, Santos should ensure that the EP: ○ identifies and manages all impacts and risks on Australian marine park values (including ecosystem values) to an acceptable level and has considered all options to avoid or reduce them to as low as reasonably practicable.	DNP requirements are addressed in **Section 8.12**. Santos has addressed DNP emergency notification requirements in Section 5 of the OPEP. Santos will address any additional comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	○ clearly demonstrates that the activity will not be inconsistent with the management plan. • The North West Management Plan (management plan) came into effect on 1 July 2018 and provides further information on values for Eighty Mile Beach, Mermaid Reef and Argo-Rowley Terrace marine parks. Australian marine park values are broadly defined into four categories: natural (including ecosystems), cultural, heritage and socio-economic. Information on the values for the marine parks is also located on the Australian Marine Parks Science Atlas. • Due to the close proximity of the operational area to Eighty Mile Beach Marine Park, please make sure Santos is aware of the ecological significance of this area, and note the specific values of the marine park which include (but are not limited to): ○ Shallow shelf habitats, including, terraces, banks and shoals; ○ Diverse benthic and pelagic fish communities; ○ Threatened, migratory, marine and cetacean species, including Humpback whales; Seabirds; Marine turtles; and Sawfish. DNP confirmed they did not require further notification of progress made in relation to this activity unless details regarding the activity change and result in an overlap with or new impact to a marine park, or for emergency responses. In the case of an emergency response, the DNP should be made aware of oil/gas pollution incidences which occur within a marine park or are likely to impact on a marine park as soon as possible. Notification should be provided to the 24-hour Marine Compliance Duty Officer Santos responded on 14 November 2019 advising the DNP comments will be taken into consideration in the drafting of the EP. Santos emailed DNP on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	
State Government Departments		
Department of Transport (DoT)	DoT was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. DoT responded on 10 October 2019 advising if there is a risk of a spill impacting State waters from the proposed activities, please ensure that the department is consulted as	Santos will provide DoT information requested as per the Department of Transport Offshore Petroleum Industry Guidance Note – Marine Oil

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	outlined in the Department of Transport Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (September 2018). Santos responded on 13 November 2019 confirming the department's requirements will be taken into consideration in the drafting of the EP. DOT was provided a copy of the Keraudren Extension 3D Marine Seismic Survey OPEP, and a copy of the Keraudren Extension 3D Marine Seismic Survey OPEP DoT Consultation Package via email on 19 December 2019. DOT responded on 13 January 2020 advising, given the information that has been provided, detailing the low risk to State waters, a full review of the OPEP has not been deemed necessary. DOT requested an accepted version of the OPEP for their records once finalised. Santos responded on 15 January 2020 confirming a copy of the accepted version of the OPEP would be provided. Santos emailed DOT on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	Pollution: Response and Consultation Arrangements (September 2018), prior to submission of the EP. Santos will address any additional comments from this stakeholder should they arise in the future.

Department of Primary Industries & Regional Development (DPIRD)	DPIRD FishCube data and commercial fishing licence holder information was requested on 24 September 2019 to identify relevant commercial fishing stakeholders.
	The department was copied in on an email from WAFIC to Santos on 2 October 2019 in which WAFIC provided advice to Santos on the fisheries deemed relevant for consultation for the Keraudren Extension 3D MSS.
	Santos emailed DPIRD on 3 October 2019 seeking to discuss the proposed seismic activity and DPIRD requirements.
	DPIRD was provided the Keraudren Extension 3D MSS Stakeholder Consultation package from Santos via email on 10 October 2019.
	DPIRD provided comments to Santos via letter on 2 December 2019. The letter stated that:
	• DPIRD considers themselves a 'relevant person'.
	• The operational area exists in, or in close proximity to, the following fisheries:
	    ○ Mackerel Managed Fishery.
	    ○ Marine Aquarium Fish Managed Fishery.
	    ○ Nickol Bay Prawn Managed Fishery.
		All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and fishers (recreational, chart and commercial) are discussed in **Section 6.1 and 6.2**.
		Guidance statement on undertaking seismic surveys in Western Australian waters is considered in **Section 6.2.**
		Santos has consulted with WAFIC, Recfishwest and commercial fishers as described in **Section 4**.
		Spawning periods are listed in **Section 3.2.4.3**and strategies to reduce risks are described in **Section 6.2**. The key strategy is to restrict the timing of the survey to minimise overlap with key fish species spawning periods. It is not possible to avoid all fishing spawning.
		Sound intensity and survey timing are described in **Section 2**. Santos intends to complete the survey as

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	○ Pilbara Crab Managed Fishery. ○ Pilbara Fish Trawl (Interim) Manage Fishery. ○ Pilbara Trap Managed Fishery. ○ Pilbara Line Managed Fishery. ○ Customary, recreational and charter fishing. • Seismic surveys have the potential to affect fish populations and the operations of fishers who harvest these resources, with reference to *Guidance statement on undertaking seismic surveys in Western Australian waters*. • Santos should initiate and maintain ongoing consultation with WAFIC, Recfishwest and directly with fishers. • Spawning grounds and nursery areas for key fish species are considered in the development of the EP, and that strategies are developed to mitigate possible impacts of survey activities in these areas. • DPIRD data indicates that the following spawning dates for key fish species in the area, Goldband Snapper Oct-May, Red Emperor Sept-June, Rankin Cod Jun-Dec, Mar; Blue Spotted Emperor Jul-Mar, and Giant Ruby Snapper Dec-Apr. • Seismic surveys may alter fish behaviour during spawning and pre-spawning periods, this Santos should employ strategies to mitigate possible impacts, including soft starts for every start-up, and minimise sound intensity and exposure time of surveys. • There is a biosecurity risk and that in accordance with the Fish Resources Management Regulations 1995, Regulation 176(1), all vessels and immersible equipment must minimise this risk; and vessels should be 'clean' before each voyage. • Suspected or confirmed presence of any organisms listed in the WA Prevention List for Introduced Marine Pests and any other organism that appears to have clear negative impacts or invasive characteristics, must be reported within 24 hours to the Department by email or telephone. Santos to ensure they remain up to date with any changes to the list, and that this information is forwarded directly to all vessel operators associated with the survey. • Department requests that all potential impacts to fisheries, fish and fish habitat described in their letter are acknowledged in the final EP and strategies undertaken by Santos to mitigate or minimise these impacts are defined.	efficiently as possible thereby minimising fish sound exposure time. Sound limitation is provided for as CM-15, **Table 8-3**. Soft start procedures are provided for as CM-11, **Table 8-3**. Biosecurity risk controls as required under the Fish Resources Management Regulations are provided for as CM-49, **Table 8-3**. Santos will review the WA Prevention List for Introduced Marine Pests prior to each survey stage as described in **Section 7.7**; and Santos commits to forward this list to vessel operators as provided for as CM-49. Santos will address any additional comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	Santos responded to DPIRD on 10 December 2019 acknowledging that DPIRD is a ‘relevant person’ for the purposes of this activity and confirmed that all potential impacts to fisheries, fish and fish habitat described in DPIRD’s letter of 2 December 2019 have been addressed in the EP, including strategies undertaken by Santos to mitigate or minimise these impacts (refer assessment of stakeholder objections and claims). Santos emailed DPIRD on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	
Department of Biodiversity and Conservation Attractions (DBCA)	DBCA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. DBCA responded on 22 October 2019 confirming that based on the information provided, DBCA has no comments to provide in relation to its responsibilities under the Biodiversity Conservation Act 2016 and the Conservation and Land Management Act 1984. Santos responded 13 November 2019 acknowledging response. Santos emailed DBCA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	Santos will address any additional comments from this stakeholder should they arise in the future.
Department of Mines, Industry Regulation and Safety (DMIRS)	DMIRS was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. DMIRS responded on 28 October 2019. DMIRS noted the activities are regulated by NOPSEMA under the provisions of the OPGGS(E)R and does not require any further information at this stage. Requested Santos continue to send commencement and cessation notifications to DMIRS. Santos responded 13 November 2019 acknowledging response. Santos emailed DMIRS on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	The department’s notification requirements are addressed in **Table 8-3**. Santos will address any additional comments from this stakeholder should they arise in the future.
Other stakeholders		
Telstra	Telstra were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos emailed Telstra on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Santos will address any comments from this stakeholder should they arise in the future.

<table>
<tr><th>Stakeholder</th><th>Summary of stakeholder and titleholder correspondence, and any objections and claims made</th><th>Assessment of stakeholder objections and claims</th></tr>
<tr><td>Vocus Communications</td><td>Vocus Communications were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019.
Vocus responded on 21 November 2019 requesting that Cable Protection Committee Recommendation No.8 Procedure is followed during offshore seismic survey work and all care is taken to avoid any contact or other disturbance of the NWCS system.
Santos responded on 9 December 2019 advising:
• Santos will comply with the International Cable Protection Committee Recommendation No.8, Procedure to be followed whilst offshore seismic work is being undertaken in the vicinity of active submarine cable systems. Santos also confirmed that the pressure waves emitted from the seismic activity will be below the required 2.0 bar.
• Santos acknowledges the advice from Vocus to avoid any contact or other disturbance of the NWCS system; and
• Vocus' comments will be addressed in the EP.
Santos emailed Vocus on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.</td><td>Vocus communications requirements are addressed in Section 6.1..
Santos will address any additional comments from this stakeholder should they arise in the future.</td></tr>
<tr><td colspan="3">Other operators</td></tr>
<tr><td>3D Oil Ltd</td><td>3D Oil were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues.
Santos emailed 3D Oil on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.
No formal response received to date.</td><td>Santos will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Carnarvon Petroleum Ltd</td><td>Carnarvon Petroleum were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues.
Santos emailed Carnarvon Petroleum on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.</td><td>Santos will address any comments from this stakeholder should they arise in the future.</td></tr>
</table>

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	No formal response received to date.	
Inpex Browse E&P P/L	Inpex were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed Inpex on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Equinor Australian BV	Equinor were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed Equinor on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Pathfinder Energy P/L	Pathfinder were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed Pathfinder on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
PGS	PGS were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed PGS on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
Searcher Seismic	Searcher Seismic were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed Searcher Seismic on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Polarcus	Polarcus were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed Polarcus on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Shearwater	Shearwater were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed Shearwater on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
TGS	TGS were provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 19 November 2019. Santos acknowledged the potential for other seismic surveys to be conducted within the Bedout Sub-Basin and invited discussion on these surveys, and any associated stakeholder issues. Santos emailed TGS on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No formal response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Fishing bodies		

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
Western Australian Fishing Industry Council (WAFIC)	Santos met with WAFIC on 2 October 2019 to discuss the proposed Keraudren Extension 3D MSS and WAFIC's fee for service work to assist with the identification of relevant fisheries and communication with individual fishers. WAFIC responded via email on 2 October 2019 outlining commercial fishing environment plan engagement categorisation for the proposed Keraudren Extension 3D MSS. In summary, WAFIC identified the following fisheries are potentially active and their legal boundaries overlap the proposed Keraudren Extension 3D Seismic Survey operational area, therefore they are potentially affected parties to this activity and to their targeted resource. Accordingly, consultation must take place with these identified fisheries and representative bodies: • North West Slope Trawl (Commonwealth managed). Consultation re fishing activity will focus on the overlap between the fishery border and the operational area (i.e. vessel turning zone only) • Western Tuna and Billfish (Commonwealth managed). There is one active operator in WA who has requested all seismic consultation • Commonwealth Fisheries Association • Mackerel Managed Fishery Area 2 Pilbara • Nickol Bay Prawn Managed Fishery (subject to FishCube information). • Pearl Oyster Managed Fishery. All engagement is via the PPA. • Pilbara Crab Managed Fishery. • Pilbara Fish Trawl Interim Managed Fishery • Pilbara Line Fishery – all Pilbara waters • Pilbara Trap Managed Fishery • WAFIC • DPIRD (Fisheries) During week of 7 October 2019, Santos consulted with WAFIC on content for consultation materials for commercial fishers. On Tuesday 8 October 2019, Santos emailed finalised copies of the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers packages to WAFIC to send to licence holders in agreed fisheries. WAFIC, on behalf of Santos, sent the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for	Santos acknowledges WAFICs support and guidance in the identification of relevant and potentially affected commercial fishers. All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1**and **6.2**. Santos has limited the survey window to 6 months of the year to minimise the survey overlap with key commercial indicator fish species spawning months, as well as whale migration periods. Spawning periods are listed in **Section 3.2.4.3**and strategies to reduce risks are described in **Section 6.2**. The key strategy is to restrict the timing of the survey to minimise overlap with key fish species spawning periods. It is not possible to avoid all fishing spawning. Santos acknowledges the potential for commercial fishers to be interrupted by the proposed seismic survey and is proposing the following to minimise such interruptions: • Commercial fishing and seismic survey vessels to operate concurrently. • Commercial fishing vessels respect Santos' requested 3 nm exclusion (safety) zone around the seismic vessel. • Seismic survey vessel respect reasonable requests to avoid active fishing vessels. • Santos commits to ongoing engagement with commercial fishers before, during and after the seismic survey. Specifically, to provide advanced notification of a proposed survey so that

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims

	Commercial Fishers package to relevant licence holders in agreed fisheries on 9 October 2019.
	WAFIC was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers packages via email on 10 October 2019.
	Santos emailed WAFIC on 13 November 2019 to follow-up on the consultation material and any feedback received. Santos follow-up phone call to WAFIC on 13 November 2019.
	WAFIC phoned Santos on 19 November 2019 confirming no comments to date from individual fishers on the consultation pack and that WAFIC comments would be submitted shortly. Santos offered to meet to discuss, however WAFIC declined due to time constraints.
	Santos email to WAFIC on 22 November 2019 seeking to meet to discuss Santos' proposed activities in the Bedout Basin, and those of the industry more broadly. Santos noted the potential for a number of seismic surveys to be conducted in the Bedout Basin in coming years and proposed to discuss these surveys with WAFIC and any associated issues for commercial fishers.
	WAFIC provided written comment to Santos on the Keraudren Extension Seismic survey on 27 November 2019. Below is a summary of the comments made by:
	• WAFIC appreciated Santos efforts to provide information bespoke to commercial fisheries overlapping the operational area and for engaging WAFIC to ensure the information was commercial fishing focussed and was sent in a timely manner to all licence holders direct in each identified potential affected fishery.
	• WAFIC stressed that almost always, commercial fishing licence holders are the only "relevant and potentially affected parties" to this and other offshore EPs.
	• WAFIC notes that the survey will potentially disrupt commercial fishing activities and the commercial fishing resource, at a potential cost / loss to fishers and a potential short/medium/long term impact on the key indicator species of these commercial fisheries.
	  ○ Pilbara Trawl potential overlap of 20.22% of recent historical catch data.
	  ○ Pilbara Trap potential overlap of 13.33% of recent historical catch data.
	  ○ Other fisheries under 2%.
		commercial fishers have time to plan their operations.
		• Santos commits to developing vessel communication and operational protocols with commercial fishers who continue to fish in the operational area during a seismic survey.
		• Santos will honour evidence-based payment claims for commercial fishers who due to the seismic survey decide to fish elsewhere or experience a temporary loss of catch.
		Santos agrees to change survey vessel sail lines to avoid commercial fishing vessels if it is feasible to do so, but respectfully requests open and advanced communication between the seismic survey and commercial fishing vessel and to be provided with a reasonable opportunity to complete the survey in a timely and efficient manner. Santos commits to working with relevant commercial fishers on this matter prior to survey commencement.
		Santos acknowledges the potential for commercial fishers to be interrupted by seismic surveys over multiple years. Santos has:
		• requested to meet with WAFIC and commercial fishers to discuss the issue of concurrent and successive seismic surveys, and potential ways to minimise risks to the fishery and commercial fishers
		• committed to complete the survey as soon as possible within the available operating window, and.
		• in recognition of the potential disruptions to commercial fishers, Santos has offered a 'make good' payment process to ensure commercial fishers are no worse off as a result of the survey.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims

	• WAFIC query the effectiveness and transparency of the consultation process when it appears it is the availability of a vessel which will determine the schedule, not the least possible impact to commercial fishing activities and the commercial fishing resource.
	• WAFIC note that Santos plans to split the survey over multiple stages between 2020 and 2022, and potentially 2023 and express concern at the impact (interruptions) this will have in fishing operations.
	• WAFIC seek confirmation that the survey operator will agree to change the survey schedule if communication with commercial fishing vessels in the region notes they are on a strong fishing patch and do not want to move.
	• WAFIC note the potential for commercial fishing operations to be continually disrupted over multiple years by the Santos and other proposed and or confirmed seismic surveys operating over this same broad region over the same fisheries.
	• WAFIC notes the two to three months each year impact on the peak and or extended spawning of some key indicator species of commercial fishers overlapping the survey operational area.
	• WAFIC holds significant concern that like other seismic proponents Santos is not acknowledging or recognising cumulative impacts
	  ○ Either on the resource;
	  ○ Or that fact that there is / will be potentially other multiple seismic surveys also operating in 2020, 2021 and 2022 - not overlapping each other – but over the same commercial fisheries / commercial fishing resource.
	  ○ This is unacceptable to commercial fishers, we do not believe that this is safe to an As Low As Reasonably Practicable (ALARP) level for commercial fishing operations and the commercial fishing resource.
	• WAFIC acknowledges Santos' compensation process, noting:
	  ○ Santos has offered to cover the accounting costs for fishers to coordinate and sort their historical catch records and costs etc., thank you.
	  ○ Santos has confirmed proven loss of catch compensation.
	  ○ Santos has confirmed proven displacement compensation costs.
	• While WAFIC appreciates Santos' commitment to compensation, WAFIC note that Santos has set the compensation rules.
	• WAFIC queries apparent differences in the compensation process adopted by Santos for the Bethany seismic survey and the Keraudren Extension 3D MSS.
		Santos has in place several measures to address WAFIC's concerns to minimise the impact of seismic activity on commercial fisheries:
		• Spawning periods are listed in **Section 3.2.4.3**of the EP and strategies to reduce risks are described in **Section 6.2**. DPIRDs *Guidance statement on undertaking seismic surveys in Western Australian waters* is considered in **Section 6.2**.
		• Sounds intensity and survey timing are described in **Section 2**. Santos intends to complete the survey as efficiently as possible thereby minimising fish sound exposure time.
		• Sound limitation is provided for as CM-15, **Table 8-3**.
		• Soft start procedures are provided for as CM-11, **Table 8-3**.
		Santos' 'compensation' framework is based on the premise that no commercial fisher should be worse off as a result of the survey. The framework will be included in the Keraudren Extension 3D MSS EP. Providing evidence is 'reasonable' to support a claim that a commercial fisher is worse off then Santos would make a commensurate payment. The level of evidence required has not been defined so that claims can be considered on a case-by-case basis. Should there be any issues with the evidence, assessment or payment amount, Santos will, in consultation with the commercial fishing licence holder, engage an independent relevant expert to determine the issue. In addition, Santos is offering a means for commercial fishers to claim for their time spent progressing a make good payment claim. The process for making a claim and the claim limitations

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims

	• WAFIC seeks an explanation as to why Santos is, in effect, proposing to transfer all potential risks and impacts as a result of this and other Santos seismic surveys to the commercial fishing sector?
	• North-west Slope Trawl – the survey does not overlap the fishing areas but does it overlap the target specie scampi. Scampi cannot move away from the seismic source at any great speed. Has Santos identified key sensitivities for the target scampi species?
	• What processes does Santos have in place to quantitatively assess any potential damage to fish stocks, fish spawn, the food chain such as plankton etc. due to the impact of the K2 seismic survey activity?
	  ○ Does Santos plan to do any bespoke pre-survey up-to-date environment assessments, covering commercial fishing key indicator species, stock assessments, the food chain etc.?
	  ○ If Santos is not planning on doing any bespoke pre-survey stock etc. assessments what science are you using to have a complete understanding of the baseline marine environment prior to the commencement of a seismic survey?
	  ○ If you are not planning on completing any bespoke pre seismic survey fish stock etc. surveys, should there be any negative impacts on commercial fishing activity / commercial fishing resource necessitating assessment and potential make good arrangements, what science are you relying on to understand the pre and post seismic survey potential environmental impacts? How will this science be used within the make good framework should post survey impacts become evident?
	• Has Santos identified other seismic surveys planned to occur in the same region over the same fisheries in 2020, 2021 and 2022?.
	• What other proposed or confirmed seismic surveys are in place / proposed over the same /similar areas (overlapping the same fisheries)?
	• Can Santos assure fishers that there will not be multiple seismic surveys taking place throughout one calendar year over their fishing activity areas and fish spawning areas.
	• It is not ALARP to commercial fishers and the resource to have multiple surveys over the same fisheries throughout one and consecutive calendar years.
		will be discussed with WAFIC on acceptance of the EP. Santos expects the claim amount to be capped, to be for reasonable expenses not normally incurred by commercial fishers and be itemised with evidence to support any claim.
		Santos is open to suggestions from WAFIC and commercial fishers on how the 'make good' framework could be made 'fairer and more reasonable'.
		WAFIC's inference that Santos offered compensation for potential impacts on fish resources for the Bethany seismic survey is incorrect. Santos' EP commitment that commercial fishing licence holders will be no worse off related to relocation expense payments and loss of catch payments, both of which were reviewed by an independent third party for the survey in question. Santos' Keraudren Extension 3D MSS also provides for relocation expense payments and loss of catch payments, and for third party review.
		Santos acknowledges the potential risk to fisheries and commercial fishers and is committed to the following:
		• Preparing an EP underpinned by the most current and available commercial fishing catch data and information from the commercial fishing sector, government fishery reports and scientific literature.
		• Limiting the survey window to 6 months of the year, thereby avoiding part of the peak and extended spawning of key indicator species.
		• Honouring an evidence-based make good payment framework that is underpinned by the

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	• WAFIC requests that, in the published EP that Santos advises WAFIC where in the EP they have addressed all the above issues and mitigation details. Issues raised deemed not part of the environment plan but still requiring feedback, please provide follow-up documentation. • The sheer number of consultations and concurrent seismic survey consultations and actual survey activity taking place has made the position of commercial fishing operators untenable. We will also be seeking legislative support for our industry via the Australian Senate seismic inquiry. Santos responded to WAFIC on 3 December 2019 addressing the comments made (refer to assessment of stakeholder objections and claims). Santos and WAFIC conducted a telephone meeting on 11 December to discuss the Santos response to WAFIC's comments. As requested by WAFIC, Santos emailed WAFIC on 11 December 2019 additional comments to close out the discussions and actions required to enable the EP to be submitted for public comment. The email reiterated previous commitments made to commercial fishers as detailed in consultation packages and in the reply to WAFIC on 3 December 2019. On behalf of Santos, WAFIC emailed active licence holders in the Pilbara Trap and Pilbara Trawl fisheries on 20 December 2019 reiterating Santos' previous commitments made to commercial fishers and inviting feedback. The following information was emailed: • Santos is committed to concurrent operations with commercial fishers so fishers can continue to fish. • Santos confirms it will provide daily lookahead plans to keep fishing vessels informed of the survey progress and vessel location. • Santos confirms that wherever possible it will instruct the survey vessel to avoid fishing vessels in the operational area, so long as sufficient forward advice is received. • Santos will take fishers advice on the communication lines between the survey vessel and fishing vessels, including establishment of dedicated radio channels. • Santos confirms there is an evidenced based 'make good' claim process in place and will make payments for equipment damage, displacement costs and/or loss of catch.	principle that no commercial fishing licence holder will be worse off as a result of the survey. According to the Commonwealth Department of Agriculture, the scampi fishery aligns with the 200 m isobath. Neither the survey ramp-up or full power zone extend to this water depth. Santos is not aware of any key sensitives for the target scampi species that may be affected by the proposed seismic survey, however, would appreciate any additional information if known by WAFIC or commercial fishers. Information on the North-west Slope Trawl fishery will be presented in the EP. Santos' ongoing assessment of the fishery and make good payments will be based on the following information: • Annual assessment of DPIRD FishCube data for each fishery. • Assessment of supplementary fishery catch data provided by commercial fishers. • DPIRD stock assessment reports. • Expert advice from marine and fishery scientists, including AIMS and DPIRD. Santos' assessment of future seismic activity in the Bedout Basin in contained in **Section 6.2** of the EP. Santos recognises that a potential aggregate programme of future seismic surveys is of concern to commercial fisheries stakeholders and has requested to meet with WAFIC to discuss ways in which the potential risks to the fishery and commercial fishers can be managed. Santos commits to advising WAFIC where the issues they have raised are addressed in the EP and providing feedback on all issues raised.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	• Santos will provide administrative support to licence holders for agreed bookkeeping costs, to support licence holders in any compensation claim process, should it be required. • Santos is offering a means for commercial fishers to claim for their time spent progressing a make good claim, should it be required. To be agreed between individual fishers. • Santos will communicate with other seismic survey vessels in the Pilbara demersal fishery in an effort to minimise interference with commercial fishers. Santos emailed WAFIC on 2 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	Santos will continue open dialogue with WAFIC to ensure any additional comments from this stakeholder are addressed.
Commonwealth Fisheries Association (CFA)	The CFA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (Commonwealth Fisheries) via email on October 10, 2019. Santos sent a follow-up email on 10 December 2019 inviting comment. Santos emailed CFA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from this stakeholder should they arise in the future.
Pearl Producers Association (PPA)	The PPA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for the Pearl Oyster Managed Fishery) via WAFIC on 9 October 2019. Santos also provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Pearl Oyster Managed Fishery) via email on 10 October 2019. Santos sent a follow-up email on 10 December 2019 inviting comment. Santos emailed PPA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from this stakeholder should they arise in the future.
Australian Southern Bluefin Tuna Industry Association (ASBTIA)	ASBITA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (Commonwealth Fisheries) via email on 10 October 2019.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	ASBTIA responded on 10 October 2019, confirming it is very unlikely that this survey would impact SBT purse-seine fishing activities and the area does not overlap what is to the best of their current knowledge the spawning area for SBT. Santos responded 13 November 2019 acknowledging ASBITA's comments. Santos emailed ASBTIA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	Santos will address any additional comments from this stakeholder should they arise in the future.
Recfishwest	Recfishwest was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos emailed Recfishwest on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. Recfishwest responded on 6 January 2020 advising it is unlikely that this activity will impact recreational fishers given it takes place over 140km from shore.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from this stakeholder should they arise in the future.
Marine Tourism WA (MTWA)	MTWA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos emailed MTWA on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Community/Port Hedland		
Town of Port Hedland (TOPH)	TOPH was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on October 10, 2019. Santos sent a follow-up email on 10 December 2019 inviting comment. TOPH responded on 10 December 2019 asking to meet with Santos to discuss the potential Dorado project. Santo responded on 11 December 2019 confirming a briefing will be arranged with the TOPH as soon as convenient for all parties. Santos emailed TOPH on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS.	Santos will address any comments from this stakeholder should they arise in the future.
Pilbara Ports Authority	The Pilbara Ports Authority was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019.	Santos will address any comments from this stakeholder should they arise in the future.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	Santos emailed the Pilbara Ports Authority on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	
Port Hedland Game Fishing Club (PHGFC)	The PHGFC was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos emailed PHGFC on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Santos will address any comments from this stakeholder should they arise in the future.
Care for Hedland	Care for Hedland was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos emailed Care for Hedland on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Santos will address any comments from this stakeholder should they arise in the future
GT Diving (Port Hedland)	GT Diving was provided the Keraudren Extension 3D MSS Stakeholder Consultation package via email on 10 October 2019. Santos emailed GT Diving on 3 January 2020 providing notification of the Public Comment Period for the Keraudren Extension 3D MSS. No response received to date.	Santos will address any comments from this stakeholder should they arise in the future
Commonwealth Managed Fisheries		
Western Tuna and Billfish Fishery (One identified relevant fisher)	This licence holder was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for North West Slope Trawl and Western Tuna and Billfish Fisheries) via WAFIC on 9 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from this stakeholder should they arise in the future.
North West Slope Trawl (Three identified relevant fishers)	These licence holders were provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for North West Slope Trawl and Western Tuna and Billfish Fisheries) via WAFIC on 9 October 2019.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**.

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
	Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	Santos will address any comments from these stakeholders should they arise in the future.
State managed fisheries		
Mackerel Managed Fishery (Area 2) (Ten identified relevant fishers)	These licence holders were provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Mackerel Managed Fishery (Area 2)) via WAFIC on 9 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from these stakeholders should they arise in the future.
Pilbara Line Fishery (Seven identified relevant fishers).	These licence holders were provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Pilbara Line Fishery) via WAFIC on 9 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from these stakeholders should they arise in the future.
Pilbara Trap Managed Fishery (Two identified relevant fishers).	These licence holders were provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Pilbara Trap Managed Fishery) via WAFIC on 9 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from these stakeholders should they arise in the future.
Pilbara Fish Trawl Interim Managed Fishery (Four identified relevant fishers)	These licence holders were provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Pilbara Fish Trawl Interim Managed Fishery) via WAFIC on 9 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from these stakeholders should they arise in the future.
Pilbara Crab Managed Fishery	This licence holder was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and

Stakeholder	Summary of stakeholder and titleholder correspondence, and any objections and claims made	Assessment of stakeholder objections and claims
(One identified relevant fisher)	Commercial Fishers package (for Nickol Bay Prawn and Pilbara Crab Managed Fisheries) via WAFIC on 9 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from this stakeholder should they arise in the future.
Pearl Oyster Managed Fishery	The PPA was provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Pearl Oyster Managed Fishery) via WAFIC on 9 October 2019. Santos also provided the Keraudren Extension 3D MSS Stakeholder Consultation package and Keraudren Extension 3D MSS Additional Information for Commercial Fishers package (for Pearl Oyster Managed Fishery) via email on 10 October 2019. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.	All listed fisheries are described in **Section 3.2.4.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Section 6.1** and **6.2**. Santos will address any comments from these stakeholders should they arise in the future.

4.4 Public Comment

NOPSEMA published the Keraudren Extension 3D MSS EP for public comment between 20 December 2019 to 19 January 2020. No public comments were received.

Santos placed notices on its website and in *The Australian*, *West Australian* and *Pilbara News* newspapers, and emailed relevant stakeholders, advising of the Keraudren Extension 3D MSS and EP public comment period.

4.5 Ongoing Consultation

Stakeholder consultation for this activity will be ongoing and Santos will work with stakeholders before, during and after the activity. Should new stakeholders be identified (**Section 4.1**), they will be added to the stakeholder database and included in all future correspondence as required, including activity-specific notifications.

Santos, as a marine user, understands there will be the need to interact and communicate with other marine users to ensure mutual and individual stakeholder goals are met. Santos has identified the need for ongoing engagement with the fishing industry, as committed to in **Section 8.6.**

To this end, Santos commits to the following ongoing stakeholder consultation process:

- Prior to commencement of each seismic survey stage, Santos will notify all relevant stakeholders listed, or as revised, in **Table 4-2.** The notification will include information on survey timing, vessel movements and vessel details.
- Prior to the commencement of any seismic survey stage in 2021 or 2022, Santos will review and revise the relevant stakeholders listed in **Table 4-2**. The latest DPIRD data and consultation with WAFIC will help inform the review.
- Upon completion of each seismic survey stage, Santos will provide a cessation notification to the relevant stakeholders listed, or as revised, in **Table 4-2**. The final cessation notification will advise stakeholders that the survey has ended.
- All relevant stakeholders listed in **Table 4-2**, will receive a copy of Santos' Quarterly Consultation Update (see **Section 4.5**) as a supplement to keep them informed of upcoming activities, including the Keraudren Extension 3D MSS. This consultation will cease once the survey has ended.
- Up to date knowledge of stakeholders will be managed as described in **Section 8.7.**

Where practicable and if available, Santos will endeavour to use the WAFIC consultation services to help distribute survey notifications to relevant commercial fishers.

4.6 Quarterly Consultation Update

Activities covered under this EP will be included in Santos' *Quarterly Consultation Update* until they can be listed as a 'completed activity', with updates scheduled for approximately March, June, September and December annually.

The Keraudren Extension 3D MSS was included in Santos' Quarterly Consultation Update distributed on October 23, 2019. No comment regarding the seismic survey was received in response to this consultation. This document is provided in **Appendix F**.

The Quarterly Consultation Update is circulated to a broad group of Santos stakeholders, including many of the stakeholders identified in **Table 4-2**. Santos will ensure all relevant stakeholders identified in **Table 4.2** receive future copies of the update.

If stakeholders request additional information or raise concerns on any activity listed in a Quarterly Consultation Update, a dialogue with these stakeholders can continue during or post the preparation of an EP and will be recorded for future reference. Santos commits to respond and address any comments to the satisfaction of both parties and keep any consultation on file during and post acceptance of an EP.

4.7 Addressing Consultation Feedback

Santos' Consultation Coordinator is available before, during and after the activity to ensure opportunities for stakeholders to provide feedback are available.

Santos will maintain records of all stakeholder consultation related this this EP and activity.

4.8 Stakeholder-related Control Measures, Performance Outcomes and Standards

Control measures and performance outcomes and standards for stakeholder consultation are included in **Section 8.6.**

If, in stakeholder consultation, a change to any control measure or activity outlined in this EP is required, Santos will undertake an internal assessment using the management of change process (**Section 8.10**).

5. Impact and Risk Assessment Terminology

Common terms applied during the impact and risk assessment process, and used in this EP, are defined in **Table 5-1**. For a more comprehensive listing of the terms and definitions used in environmental impact and risk assessment, refer to Santos' *Environmental Risk Identification and Analysis Procedure (EA-91-IG-004)*.

Table 5-1: Impact and risk assessment terms

Name	Definition
Acceptable level of impact or risk	Determined for both impacts and risks. The acceptable level of planned impacts is in part determined by the severity (consequence) of the impact following control measures being implemented. The acceptable level of unplanned impacts is in part determined from its risk ranking following control measures being implemented. For both impacts and risks, the acceptable level is also determined from a demonstration of the ALARP principle, consistency with the Environmental Management Policy, consistency with all applicable legislation, consistency with the principles of Ecologically Sustainable Development (ESD) as defined under the EPBC Act, and consideration of relevant stakeholder consultation when determining control measures.
ALARP	As Low As Reasonable Practicable The ALARP principle is that the residual impacts and risk shall be `as low as reasonably practicable'. It has particular connotations as a route to reduce impacts and risks when considering law, regulation and standards. For an impact or risk to be ALARP it must be possible to demonstrate that the cost involved in reducing the impact or risk further would be grossly disproportionate to the benefit gained. The ALARP principle arises from the fact that infinite time, effort and money could be spent on the attempt of reducing a risk to zero. It should not be understood as simply a quantitative measure of benefit against detriment. It is more a best common practice of judgement of the balance of impact or risk and environmental/societal benefit.
Aspect	Element of an organisation's activities or products or services that can interact with the environment.
EMBA	Environment that may be affected by planned or unplanned events.
Environment	The environment (physical, biological and socio-economic) within the spatial extent over which the planned Activity will occur.
Environmental consequence	The severity of an impact in terms of its adverse effects on the environment.
Environmental impact	Any change to the environment, whether adverse or beneficial, wholly or partly resulting from the planned Activity.
Environmental risk	Applies to unplanned events. Risk is a function of the likelihood of the unplanned event occurring and the severity (consequence) of the environmental impact that arises from that event.
Grossly disproportionate	Where the sacrifice (cost and effort) of implementing a control measure to reduce impact or risk, grossly exceeds the environmental benefit to be gained.
Hazard	A situation with the potential to cause harm.
Likelihood	Probability of an unplanned event occurring.
Non-routine planned event	An attribute of the planned Activity that results in some level of environmental impact and may occur or will occur infrequently during of the planned Activity.
Planned Activity	The Activity to be undertaken including the services, equipment, products, assets, personnel, timing, duration and location.
Receptor	A feature of the environment that may have environmental, social and/ or economic values.

Name	Definition
Routine planned event	An attribute of the planned Activity that results in some level of environmental impact and will occur continuously or frequently through the duration of the planned Activity.
Unplanned event	An event that results in some level of environmental impact and may occur despite preventative safeguards control measures in place. An unplanned event is not intended to occur during the Activity.

5.1 Summary of the Environmental Impact and Risk Assessment Approach

5.1.1 Overview

Santos' risk management framework is consistent with the requirements of *AS/NZS ISO 31000 Risk Management – Guidelines* (2018). The key steps are illustrated in **Figure 5-1**.

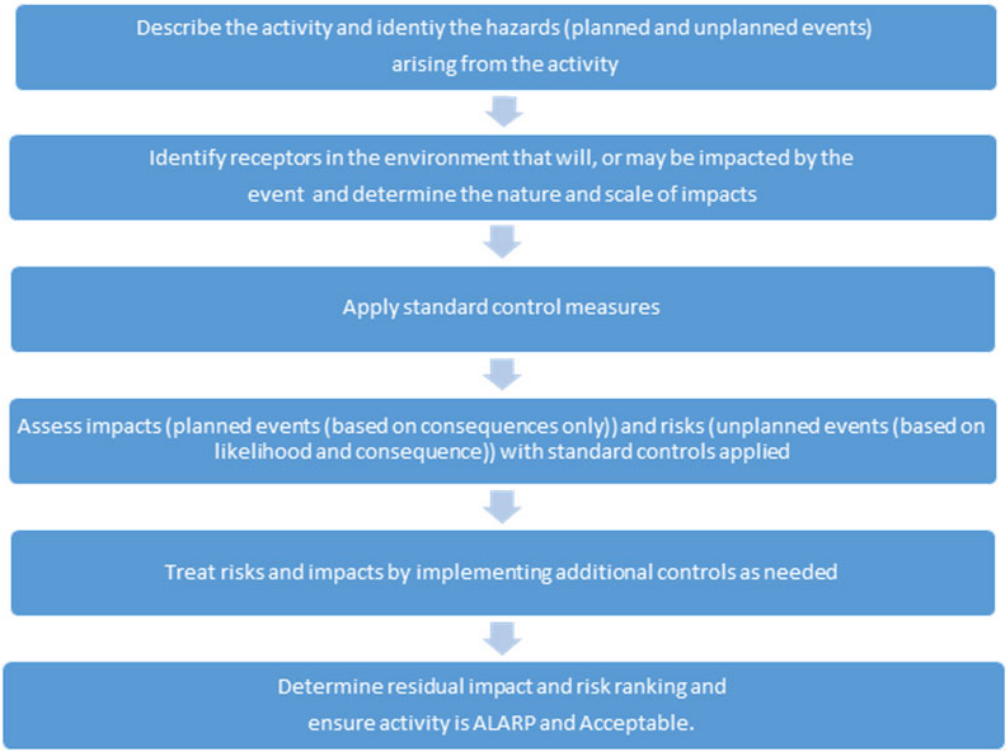


Figure 5-1: Environmental impact and risk assessment process

The Santos' *Environmental Risk Identification and Analysis Procedure* (EA-91-IG-004) includes consideration of the following key areas in an impact and risk assessment:

- Description of the Activity (including location and timing);
- Description of the environment (potentially affected by both planned and unplanned activities);
- Identification of relevant persons;
- Identification of legal requirements ('legislative controls') that apply to the Activity;
- the Environmental Management Policy (**Figure 1-1**);
- Principles of Ecologically Sustainable Development (ESD); and
- Santos acceptable levels of impact and risk.

5.1.2 Describe the Activity and Hazards (Planned and Unplanned Events)

The Activity is described in **Section 2** of this plan. An assessment against the Activity was undertaken and the environmental events identified. The outcome of this assessment is detailed in the relevant sub-sections of **Sections 6** and **7**. A summary of the environmental events identified for the Activity are:

- Interactions with other marine users;
- Light emissions;
- Noise emissions (vessel, helicopter and seismic discharges);
- Planned operational discharges;
- Atmospheric emissions;
- Spill response operations;
- Fuel oil release from vessel collision (surface);
- Minor hydrocarbon release;
- Hazardous and non-hazardous release – liquid;
- Hazardous and non-hazardous release – solid;
- Marine fauna collisions; and
- Introduction of invasive marine species (IMS).

5.1.3 Determine the Nature and Scale of Impacts and Identify Receptors that Will or May Be Impacted

The extent of actual or potential impacts from each planned or unplanned event is assessed using, where required, modelling (e.g. seismic sound source and hydrocarbon spills) and scientific reports. The duration of the event is also described including the potential duration of any impacts should they occur. Receptors identified as potentially occurring within impacted area(s) are detailed in **Sections 6** and **7**. Determine the Impact Consequence Level and Risk Rankings (on the basis that all control measures have been implemented)

This step looks at the causal effect between the aspect/hazard and the identified receptor. Impact mechanisms and any thresholds for impacts are determined and described, using scientific literature and modelling where required. Impact thresholds for different critical life stages are also identified where relevant.

The consequence level of the impact is then determined for each planned and unplanned event based on the severity of the impact to relevant receptors within the following categories:

- Threatened/migratory/local fauna;
- Physical environment/habitat;
- Threatened ecological communities;
- Protected areas; and
- Socio-economic receptors.

This process determines a consequence level, based on set criteria for each receptor category, and takes into consideration the duration and extent of the impact, receptor recovery time and the effect of the impact at a population, ecosystem or industry level.

For unplanned events, a risk ranking is also determined using an assessment of the likelihood (likelihood ranking) of the event as well as the consequence level of the potential impact should that event occur.

Impacts to social and economic values are also considered based on existing knowledge and feedback from stakeholder consultation. From Santos' historic and ongoing consultation with stakeholders, it is evident that the social and economic values in the region are of interest.

The process and definitions supporting the consequence, likelihood and risk ranking determination are included within the *Environmental Risk Identification and Analysis Procedure* (EA-91-IG-00004). The Santos consequence matrix and risk matrix are provided in **Appendix G**.

The EMBA is defined in the relevant section using, where available, modelling, scientific reports or any additional justification. The level of information required to determine the impact or risk assessment is dependent on nature and scale.

5.1.4 Describe the Environmental Performance Outcomes, Environmental Performance Standards and Measurement Criteria

For each planned and unplanned event, a set of Environmental Performance Outcome(s), Environmental Performance Standards and Measurement Criteria are identified. The definitions of the performance outcomes, standards and measurement criteria are consistent with the OPGGS(E)R.

5.1.5 Evaluating the Acceptable Level of Impact and Risk

Santos considers an impact or risk associated with the proposed Activity to be of an acceptable level if the following criteria are met:

- The consequence of a planned event is ranked as A (negligible) or B (minor); or a risk of impact from an unplanned event is ranked low to medium;
- An assessment has been completed to determine if further information/studies are required to support or validate the consequence assessment;
- Assessment and management of risks has addressed the principles of ESD, as defined in Section 3A of the EPBC Act:
    - a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;
    - b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
    - c) the principle of inter-generational equity - that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
    - d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision making;
    - e) improved valuation, pricing and incentive mechanisms should be promoted.
- Demonstration that the acceptable levels of impact and risks have been informed by relevant species recovery plans, threat abatement plans and conservation advice;
- Legal and regulatory requirements are met;
- Control measures and performance standards are consistent with the Santos Environmental Management Policy;

- Control measures and performance standards are consistent with industry standards and best practice guidance;
- Control measures and performance outcomes and standards are consistent with stakeholder expectations; and
- Proposed control measures have been demonstrated to reduce the impact or risk to ALARP.

5.1.6 Evaluating if Impacts and Risks are ALARP

For planned and unplanned events, an ALARP assessment is undertaken to demonstrate that the standard control measures adopted reduce the impact (consequence level) or risk to as low as reasonably practicable (ALARP). This process relies on demonstrating that further potential control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. If this cannot be demonstrated, then further control measures are adopted. The level of detail included within the ALARP assessment is based upon the nature and scale of the potential impact or risk. For example, more detail is required for a risk ranked as `medium' compared to a risk ranked as `low'.

5.1.7 Non-credible Events

The following unplanned events were deemed not credible scenarios and are not discussed further in this section:

Hydrocarbon spill due to vessel grounding

Vessel grounding can occur due to a loss of propulsion or to navigational error resulting in the vessel running aground in shallow areas. Vessel grounding and subsequent fuel tank rupture was not considered a credible scenario for this Activity since the operational area is situated in deep water and there are no chartered reefs or islands that could pose a grounding hazard in the operational area.

Loss of well control

There are no existing wellheads present in the operational area. All exploration wells have been plugged and abandoned and cut off at seabed. Hence, there is no potential for loss of well control due to an unplanned vessel interaction.

Seabed disturbance

Anchoring is not planned during the Activity and therefore seabed disturbance from anchoring is not credible.

6. Environmental Assessment for Planned Events

OPGGS(E)R 2009 Requirements
Regulation 13. Environmental assessment.
Evaluation of environmental impacts and risks (5) The environment plan must include: a) details of the environmental impacts and risks for the Activity; b) an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk; and c) details of the control measures that will be used to reduce the impacts and risks of the Activity to as low as reasonably practicable and an acceptable level. (6) To avoid doubt, the evaluation mentioned in paragraph (5)(b) must evaluate all the environmental impacts and risks arising directly or indirectly from: a) all operations of the Activity; and b) potential emergency conditions, whether resulting from accident or any other reason. *Environmental performance outcomes and standards* (7) The environment plan must: a) set environmental performance standards for the control measures identified under paragraph (5)(c); b) set out the environmental performance outcomes against which the performance of the titleholder in protecting the environment is to be measured; and c) include measurement criteria that the titleholder will use to determine whether each environmental performance outcome and environmental performance standard is being met.

Santos' environmental assessment identified six potential sources of environmental impacts associated with planned events for this Activity. The consequence rankings resulting from the environmental assessment are summarised in **Table 6-1**. A comprehensive risk and impact assessment for each of the planned events, and subsequent control measures proposed by Santos to reduce the risk and impacts to ALARP and acceptable levels are detailed in the following sub-sections.

Table 6-1: Summary of the consequence level rankings for hazards associated with planned activities

Hazard	Final consequence ranking
Interactions with other marine users	B – Minor
Noise emissions	B – Minor
Cumulative and additive seismic impacts	B – Minor
Light emissions	A – Negligible
Planned operational discharges	A – Negligible
Atmospheric emissions	A – Negligible

6.1 Interaction with Other Marine Users

6.1.1 Description of Event

Aspect	Interactions with other marine users through undertaking the Activity. The presence of vessels in the operational area could potentially inhibit or be an inconvenience to marine user groups such as commercial shipping and commercial fishing. For commercial fishing licence holders, the level of interaction could lead to temporary displacement. The presence of vessels and the towed streamers could pose a collision risk (refer to **Section 7.1**).
Extent	Operational area
Duration	For the duration of the Activity, as described in **Section 2**.

6.1.2 Nature and Scale of Environmental Impacts

Santos has identified the following stakeholders as potential marine users of the operational area: commercial fishers, recreational fishers and divers, commercial shipping, and other petroleum-related vessels. These users maybe temporarily impacted by the physical presence of the seismic vessel. The potential effects of noise from the seismic survey on marine users, specifically commercial fishers, is addressed in **Section 6.2** and **6.3**.

Commercial Fishers

Commercial fishers have been identified as a relevant stakeholder and are considered to be the main marine user with potential to be materially affected by the proposed seismic survey. Based on a review of fisheries overlapping the operational area (**Section 3.2.4.1**), analysis of FishCube data (**Appendix E**) and through consultation with fishing stakeholders (**Section 4**) five WA-managed fisheries and one Commonwealth-managed fishery have been identified as having the potential for fishing in the operational area and therefore the potential for interference:

- Mackerel Managed Fishery (Area 2) (WA).
- Pilbara Fish Trawl (Interim) Managed Fishery (WA).
- Pilbara Line Fishery (WA).
- Pilbara Trap Managed Fishery (WA).
- Specimen Shell Managed Fishery (WA).
- North West Slope Trawl Fishery (Cwlth).

Potential impacts to commercial fisheries caused by a seismic vessel in the operational area range from operational inconveniences (e.g. maneuvering around the seismic vessel) to temporary loss of access to fishing areas (i.e. displacement). Displacement could result in reduced catches and income, or increased costs to operate elsewhere (i.e. relocation costs).

A summary of the current fishery zones and closures, depth range of activity, historical fishing effort data, fishing methods and consultation feedback (refer to **Section 3**) for relevant fisheries is provided in **Table 3-9**.

While the boundaries of several other fisheries overlap the operational area, no fishing effort in the operational area has been identified through consultation (**Section 3**) and review of historical fishing data as evidenced in **Appendix E.** No pearl oyster licence holders are known or expected to dive in the operational area due to the water depth (i.e. greater than 40 m); hence, displacement is not expected.

Mackerel Managed Fishery (MMF) (Area 2)

Analysis of FishCube data (**Appendix E**) shows that the area of fishery effort[5] in the Pilbara region of the MMF (Area 2) covers 51,848 km^2 for the ten-year period between 2009 and 2018. The operational area overlaps with 2,439 km^2 (5%) of this fished area. Fishing effort is restricted to the southern portion of the operational area in water depths less than 60 m (approximately 12 % of the total operational area). During stakeholder consultation for the Keraudren 3D MSS it was corroborated that fishers typically operate in water depths less than 60 m.

FishCube data also shows that the number of fishing vessels operating in the 10 nm blocks intersecting the operational area in the last ten years was generally limited to just one or two vessels. However, three vessels fished in a single CAES block (191193, refer to **Appendix E**) located in the most southern part of the operational area. In the past 10 years, 91 days of fishing effort has been recorded within this block (i.e. average of 9 days per year) (**Appendix E**). Further examination of FishCube data showed that this block was fished by one or two vessels in 2014 and 2016 to 2018, and three vessels in 2015. In 2015, 13 days of fishing was recorded. Total fishing days in the other years cannot be determined due to FishCube data limitations.

Based on consultation with fishery stakeholders from the Keraudren 3D MSS, at least one licence holder is active in the operational area. Santos was also advised that the southern portion of the operational area (where fishing blocks overlap) comprises important fishing areas for at least one fisher (which are fished each year). This information is consistent with the FishCube data analysis.

An assessment of the number of 10 nm CAES blocks fished each month over the past five years (2009 to 2018) showed that fishing vessels were present in the fishery all year round (**Figure 6-1**). The highest number of CAES blocks with active fishing vessels occurred between May to September. The number of fishing days per month could not be determined based on FishCube data limitations. This is consistent with previous assessments conducted by the WA DPIRD (or former Department of Fisheries; Mackie *et al*. 2010). The proposed timing of the Keraudren Extension 3D MSS (February to July) overlaps the first half of the main fishing period, although the seismic survey vessel will acquire data in the southern parts of the operational area (in shallower waters where mackerel fishers may be encountered) for only a small proportion of the total survey duration (in the order of one to two weeks).

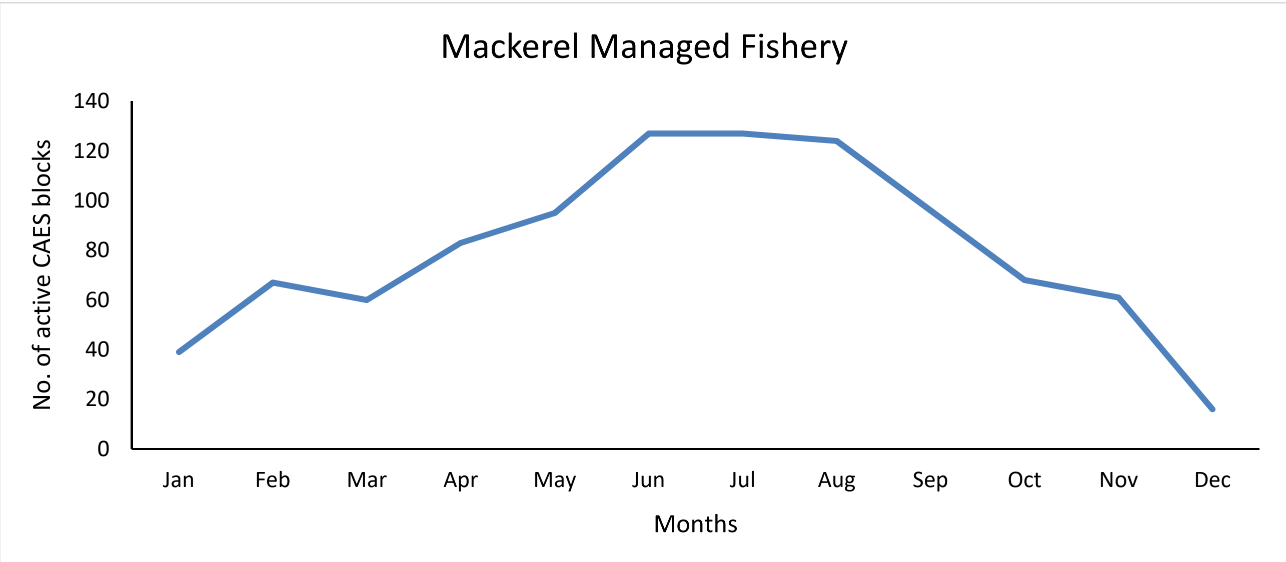


Figure 6-1: Total number of active 10 nm CAES blocks per month for the MMF between 2014 to 2018

It is noted that the MMF operate throughout the nearshore waters of the Pilbara and the vessel and gear types make them relatively mobile. Fishing effort is distributed along the Pilbara coast, with areas of significant effort located off Eighty Mile Beach, Port Hedland, Dampier, and near Barrow Island and the

Montebello Islands (**Appendix E**). Alternative fishing grounds are available to MMF fishers, including other sites near to the operational area, during the period when the seismic survey vessel is operating in these waters.

Based on a review of available data, MMF fishing vessels may potentially experience operational inconvenience or area displacement during the period when the seismic vessel is acquiring data in the southern part of the operational area. However, such interactions are expected to be infrequent and short term in the order of days to weeks.

Pilbara Fish Trawl Interim Managed Fishery (PFTIMF)

Analysis of FishCube data (**Appendix E**) shows that the area of fishery effort[5] is 23,058 km^2 for the period between 2009 and 2018. Fishing effort occurs throughout nearly the entire area open and available to trawling. The operational area overlaps with 6,310 km^2 (27%) of the area of fishing effort. Three vessels were active in the fishery in 2014, 2015, 2016, while 4 vessels were active in 2018. The FishCube data shows that three or four vessels fished in 10 nm CAES blocks in the operational area each year between 2014 and 2018.

FishCube data for the total number of fishing days in 10 nm CAES blocks that intersect the operational area (for blocks where at least three vessels have fished, and data is available) was 3,463 days between 2009 to 2018. This equates to an averaged 346 days of fishing per year across the operational area. Given the absence of data for at least three fishing blocks (183194, 183195 and 191191) the total number of recorded fishing days within the operational area would have been slightly higher. The total number of recorded fishing days within the operational area from 2009 to 2018 equates to approximately 20% of the total number of recorded fishing days across the entire fishery.

FishCube data between 2014 to 2018 for the 10 nm CAES blocks that intersect the operational area (for blocks where at least three vessels have fished and data is available) shows that fishing days per block ranged from 7 days (recorded in 2014) to 54 days (recorded in 2014).

The areas of greatest historical fishing effort in the fishery are in Area 1 and Area 2, located over 400 km southwest of the operational area, and closest to the home ports of the fishers (Exmouth and Point Samson near Karratha) (refer to Figure E4 in **Appendix E**).

An assessment of the number of 10 nm CAES blocks fished each month over the past five years (2014 to 2018) showed that fishing vessels were consistently present in the fishery all year round (**Figure 6-2**). The number of fishing days per month could not be determined based on FishCube data limitations. Fishing vessel presence fluctuated throughout the year, with peaks in March and November. The proposed seismic survey extends across the March peak.

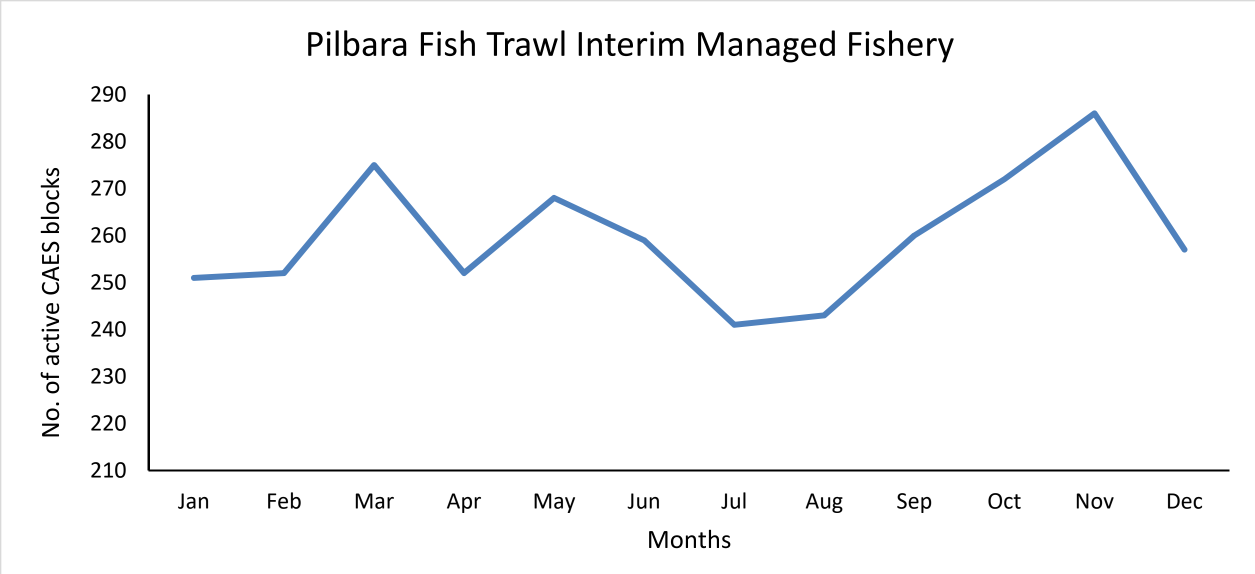


Figure 6-2: Total number of active 10 nm CAES blocks per month for the PFTIMF between 2014 to 2018

FishCube data showed that up to four vessels were active in this fishery in 2018. Two trawl fishing companies are understood to operate across the entire fishery. Therefore, temporary operational inconvenience or area displacement may be experienced by at least two commercial fishing licence holders, between February and July.

Pilbara Line Fishery

The available FishCube data indicates a low level of fishing activity in relation to the Pilbara Fish Trawl Interim Managed Fishery (mentioned above).

Analysis of FishCube data (**Appendix E**) shows that the area of fishery effort[5] is 146,414 km^2 for the period between 2009 and 2018. The operational area overlaps with 8,802 km^2 (6%) of the area of fishing effort. However, FishCube data for the Pilbara Line Fishery was only available in 60 nm CAES block resolution. As such, the area of fishing effort and overlap may be overestimated, as these large blocks represent fishing that will have likely occurred at more discrete locations. Most of the operational area has not been fished in the last ten years (refer to Figure E5 in **Appendix E**).

In addition, less than three vessels have fished in the waters of the operational area from 2009 to 2018. Greater effort is located to the west of the operational area, and closest to the home ports of the fishers (Exmouth and Point Samson near Karratha) (refer to Figure E5 in **Appendix E**).

Figure 6-3 indicates a low level of fishing vessel presence within January and February, increasing in March and remaining relatively consistent for the remainder of the year. The number of fishing days per month could not be determined based on FishCube data limitations. The reason for the reduced effort in January and February has not been confirmed with relevant fishing stakeholders. However, the fishery is expected to be active in the region to some degree throughout the proposed months of the Keraudren Extension 3D MSS, February to July.

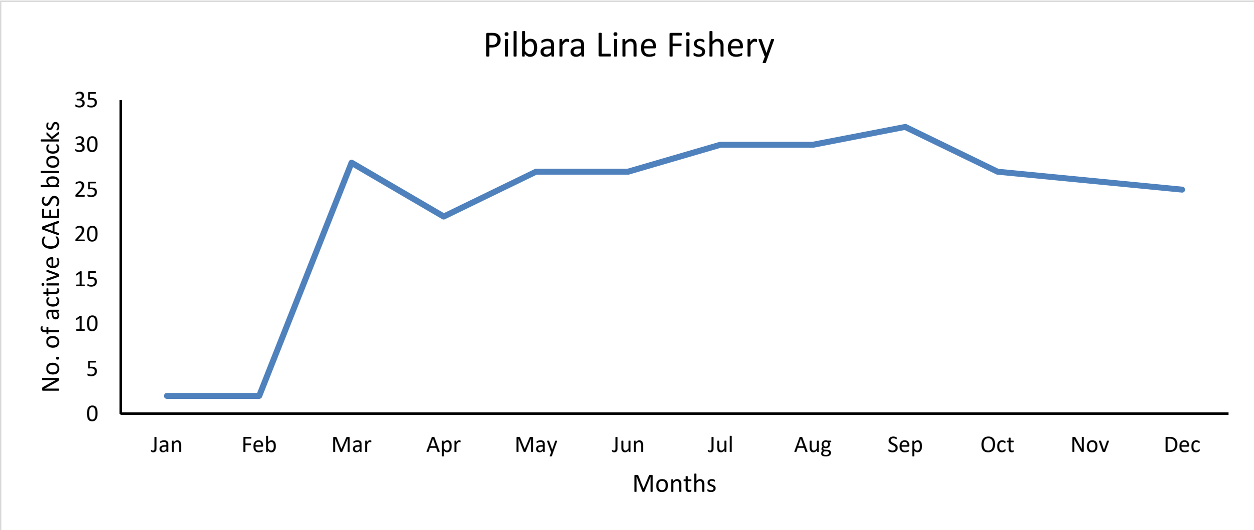


Figure 6-3: Total number of active CAES blocks per month for the PLF between 2014 to 2018

Santos understands that for the 2018/2019 season there are nine fishing licences, held by seven operators. Temporary operational inconvenience or area displacement from part of the operational area may be experienced by some of these operators between February and July but given the lower levels of fish catch and effort, interactions are less likely than for the trawl fishery.

Pilbara Trap Managed Fishery

The available FishCube data indicates a low level of fishing activity in relation to the Pilbara Fish Trawl Interim Managed Fishery (mentioned above).

Analysis of FishCube data (**Appendix E**) shows that the area of fishery effort[5] was 86,006 km^2 for the period between 2009 and 2018. The operational area overlaps with 19,691 km^2 (28%) of the area of fishing effort. However, FishCube data for the Pilbara Trap Managed Fishery was only available in 60 nm CAES block resolution. As such the area of fishing effort and overlap may be overestimated, as these large blocks represent fishing that will have likely occurred at more discrete locations.

An assessment of the number of 10 nm CAES blocks fished each month over the past five years (2014 to 2018) showed that fishing vessels were consistently present in the fishery all year round (**Figure 6-4**). The number of fishing days per month could not be determined based on FishCube data limitations.

[5] Note the area of fishing effort has been calculated by Santos based on FishCube data for the past ten years (2009 to 2018). The area of fishing effort is not the same as the total fishery licence area or management area boundary, which for most cases is much larger.

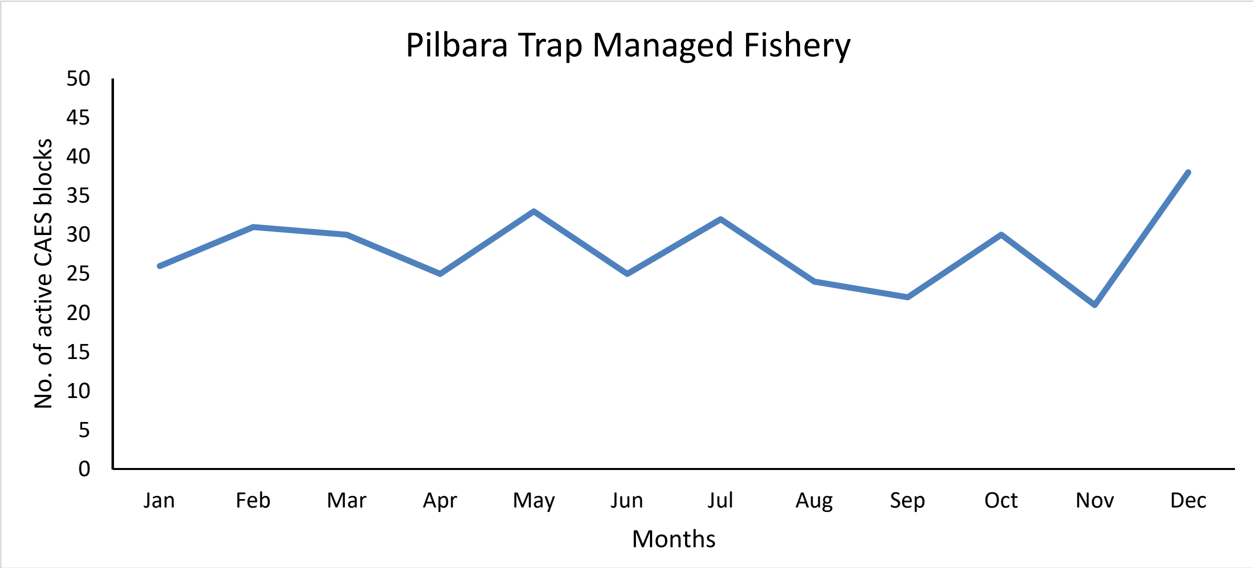


Figure 6-4: Total number of active CAES blocks per month for the PTMF between 2014 to 2018

FishCube data suggests that one or two vessels have operated over fishing blocks overlapping the operational area over the past five years. Temporary operational inconvenience or area displacement from part of the operational area may be experienced by at least one commercial fishing licence holder, between February and July.

Specimen Shell Managed Fishery

Analysis of FishCube data (**Appendix E)** shows that the areas of fishery effort[5] over the West Australian coast was 43,321 km^2 for the period between 2009 and 2018. The operational area overlaps with 14,532 km^2 (34%). FishCube data for the fishery was only available in 60 nm CAES block resolution. As such, the area of fishing effort and overlap is likely to be overestimated.

Stakeholder consultation with WAFIC and the Specimen Shell Industry Association for the previous Keraudren 3D MSS confirmed that fishing effort in offshore waters near the operational area would have been undertaken from a boat using an ROV (used by a single licence holder in the fishery) and that seismic survey activities in these waters should not impact upon routine specimen shell collecting activities. Therefore, interactions are not expected.

North West Slope Trawl Fishery

FishCube data is not available for Commonwealth-managed fisheries. Fishing effort in the fishery is known to occur along the northern edge of the operational area in water depths greater than 200 m. Typically, effort is concentrated along the continental slope offshore from the Pilbara region, in the Rowley Shoals area and north-east towards and around Scott Reef. However, the main target species of the fishery (scampi) more commonly occur at depths of 420 m to 500 m, as corresponds with the Special Purpose (Trawl) Zone of the Argo-Rowley Terrace AMP. Therefore, this fishery may be operating in waters further north and outside of the operational area.

The number of vessels involved in the fishery has been one or two vessels each year since 2008/2009. Two vessels were active in the fishery during the 2016-17 fishing season over 114 days of fishing effort (refer to **Section 3.2.4**). Temporary operational inconvenience or area displacement from part of the operational area may be experienced by these vessels if they are operating in the same northern part of the operational area at the same time as the survey.

Recreational Fishers and Divers

Santos has not identified any charter boats operating out of Port Hedland (**Section 3.2.4.4**), and there is no identified offshore tourism industry within or near the operational area.

Recreational activities such as boating, snorkelling, diving, and fishing activities are more likely to occur in shallower waters around Bedout Island (approximately 45 km from the operational area). Hence, the seismic vessel is not expected to encounter recreational boats within the deeper, offshore waters of the operational area.

Commercial Shipping

Shipping traffic data from AMSA indicates cargo and local offshore support vessel traffic may be encountered within the operational area. Traffic is largely confined to two designated shipping fairways servicing Port Hedland. Shipping using NWS waters includes iron ore carriers, LNG and oil tankers and other vessels proceeding to or from the ports of Dampier, Port Walcott, Port Hedland, Barrow Island, Varanus Island and Onslow. Large cargo vessels carrying freight bound or departing from Fremantle, transit along the WA coastline heading north and south in deeper waters.

Given the seismic survey vessel will be towing the streamer array, maneuverability will be limited, and commercial vessels may be required to change course. Should commercial vessels need to deviate from planned routes to avoid the seismic vessel, this may slightly increase transit times and fuel consumption. As the operational area is in open waters with no grounding or navigational hazards, it is not likely that any such deviation would increase the potential for vessel collision or grounding.

Petroleum Industry

The area of the NWS is a major oil and gas hub in Australia, with several companies operating on the NWS. The Activity occurs in a particularly isolated area of the NWS with respect to the main oil and gas operational and exploratory fields. There are currently no existing facilities in the operational area. The nearest operating facility is Woodside’s Angel oil field and associated infrastructure, located approximately 280 km from the operational area.

The operational area overlaps primarily Santos operated petroleum titles, and small areas of vacant acreage. Santos has been active in these permits since exploration drilling commenced in 2014, and has since drilled, and subsequently plugged and abandoned, nine exploration wells.

Exploration activity, such as seismic surveys and exploration drilling, could occur within and surrounding the operational area over the life of this EP (refer to **Section 6.2**).

6.1.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes (EPOs) relating to this event include:

- Information available to regulatory authorities and marine users directly affected by planned activities (EPO-1);
- No unplanned interactions with commercial fishers (EPO-18); and
- Commercial fishing licence holders are no worse off as a result of the seismic survey (EPO-19).

The Control Measures considered for this Activity are shown below with Environmental Performance Standards and Measurement Criteria for the EPOs described in **Section 8.6.1.**

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-1	Maritime Notices - Notices to Mariners (NTM) and AUSCOAST warnings	Ensures other marine users are aware of the presence of the seismic survey vessel, and the relatively slow speed and restricted manoeuvrability.	Costs associated with the personnel time in issuing notifications and closing out queries and responses.	**Adopted** – Benefits considered to outweigh negligible costs. Maritime requirement to issue marine notices.
CM-2	Stakeholder consultation	Ensures other marine users, such as commercial fishers, are aware of upcoming seismic survey operations so they can plan their business accordingly.	Limited additional costs to Santos. Stakeholders time required to review consultation material and communicate with Santos.	**Adopted** – Benefits considered to outweigh negligible costs. Important control to ensure other marine users are aware of upcoming seismic activities and potential business disruptions. Provides an opportunity for Santos and stakeholders to discuss additional ways of minimising on-water interference and business disruptions.
CM-3	Exclusion zone established to reduce potential for collision or interference with other marine user activities.	Requested 3 nm (5.6 km) exclusion zones around the seismic vessel and trailing streamers prevents other vessels from getting too close and causing damage to equipment of either party.	No additional costs to Santos. Other marine users may be temporarily excluded from small areas, disrupting their activities.	**Adopted** – The requested exclusion of other marine users is temporary. Marine users will still be able to access the operational area. Normal navigation at sea process whereby shipping vessels avoid navigational risks. Hence, the safety benefits to all marine users outweighs any potential costs.
CM-4	Navigation equipment and procedures	Reduces the risk of collisions with other marine users.	Negligible costs of acquiring and operating navigation equipment, as required by maritime law.	**Adopted** – The safety benefits of having navigation equipment and procedures outweighs any cost. This is a maritime requirement.
CM-5	Support vessel in place during the Activity to reduce potential for collision or interference with other marine users	Identifies and communicates with approaching third-party vessels to ensure exclusion (safety) zone is observed, preventing potential interaction or interference.	Additional costs of contracting a support vessel.	**Adopted** – The safety benefits from having a support vessel during the Activity to assist with managing third-party vessels outweighs the cost.

CM-6	Constant bridge watch	Crew of support vessels and the seismic vessel will maintain constant bridge watch, including for third party vessels which may be approaching or enter the exclusion zone.	No additional costs.	**Adopted** – No additional costs. This is a maritime requirement.
CM-7	Vessels fitted with AIS systems and radars	Reduces risk of impact from vessel collisions.	Negligible as the seismic vessel should be fitted with AIS.	**Adopted** – The safety benefits of having AIS outweigh any costs. This is a maritime requirement.
Additional control measures				
N/A	No seismic acquisition in known mackerel fishing grounds in peak mackerel fishing period (May to Sept)	Minimise displacement of mackerel fishing vessels from known fishing area.	Limiting the seismic survey window to February to April means the survey will need to be acquired over multiple years. As such the data will not be available when required by Santos.	**Not Adopted** – Avoiding this area between May and July would require multiple years of seismic surveys and prevent Santos from acquiring the data in a timely manner. MMF fishing vessels may potentially experience operational inconvenience or area displacement during the period when the seismic vessel is acquiring data in the southern part of the operational area. Santos has committed to ensure that fishers are no worse off as a result of the survey.
N/A	No seismic acquisition in Pilbara Demersal Scalefish Fisheries (Trap, Line and Trawl)	Minimises displacement of trap, line and trawl fishing vessels from known fishing areas.	The operational area overlays all three fisheries. Survey objectives would not be met.	**Not Adopted** – Fishing activities occurs all year round, there is no obvious time to schedule the survey to avoid fishing operations. Survey objectives would not be met.
CM-8	Concurrent operations planning with relevant commercial fishers	As legitimate users of the marine environment, concurrent operations planning (including establishment of communication protocols between the seismic vessel and the fishing vessels) will minimise fisher displacement while allowing Santos to meet its seismic survey objectives.	Concurrent operations planning will require fisher's time to discuss communication protocols, plan vessel movement patterns, etc. It is, however, possible that concurrent operations are simply not practicable i.e. fishing and seismic methods and	**Adopted** – There are no apparent reasons why commercial fishing vessels and seismic survey vessels cannot co-exist, providing the requested exclusion (safety) zone around the seismic vessel is observed.

			vessel movements are not operationally compatible.	Santos also agrees to change survey vessel sail lines to accommodate commercial fishers requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey and commercial fishing vessel and providing Santos is afforded a reasonable opportunity to complete the survey in a timely and efficient manner. Santos commits to working with relevant commercial to enable fair and reasonable concurrent operations.
CM-9	Commercial fishery payment claims (further details are provided in **Section 8.6.2**)	Should relevant commercial fishers be displaced from their normal fishing areas because of the physical presence of the seismic vessel then Santos is prepared to consider financial payments so that commercial fishers are not worse off as a result of the seismic survey. Evidenced-based compensation models are not new to seismic surveys in Australia.	For Santos to accept a payment claim, fishers will need to provide enough evidence to demonstrate displacement. This will require fisher's time and effort. Santos is prepared to invest the time to assess the merits of all claims. Fishing licence holders new to fishing areas overlapping the operational area may have difficulty evidencing displacement.	**Adopted** – Santos is prepared to assess the merits of all payment claims if commercial fishers can provide evidence of displacement. This process will apply unless commercial agreements are made with fishing licence holders.
N/A	Limiting the survey to one calendar year	Avoids consecutive years of potential interference with commercial fishers. Potentially a more cost-effective way to acquire the survey, given only one mobilisation/demobilisation.	A window of at least five months is required to complete the full survey. Due to survey time limitations adopted by Santos to minimise risks to Pilbara commercial fisheries and migrating humpback whales, only 6 months of the year is available to acquire the survey. Hence, the survey could not be acquired in full in 2020 as environmental approvals will be incomplete and a suitable seismic sources vessel is not available. That	**Not Adopted** – Santos intends to acquire the data as quickly and efficiently as possible. The same amount of time is required to acquire the full survey regardless if the survey is acquired over one or more years, hence, the commercial fisher interaction risks are not considered to be materially different. There are several external factors that may impact Santos' ability to meet a commitment to

			said, Santos may have an opportunity to acquire part of the survey in 2020 (May to July). The full survey could potentially be acquired in 2021 subject to environmental approvals and vessel availability (and operability as linked to weather etc.). At this point in time 2022 is considered a contingency year should the full survey not be acquired in 2020-2021.	acquire the survey in one year, including vessel availability and operability. For this reason, the additional control measure has been rejected.

6.1.4 Impact and Consequence Ranking

<table>
<tr><th>Receptor</th><th>Consequence Level</th></tr>
<tr><td colspan="2">Interaction with other marine users</td></tr>
<tr><td>Threatened / Migratory Fauna</td><td rowspan="4">N/A – related to socio-economic receptors only.</td></tr>
<tr><td>Physical Environment/ Habitat</td></tr>
<tr><td>Threatened ecological communities</td></tr>
<tr><td>Protected Areas</td></tr>
<tr><td>Socio-economic receptors</td><td>In accordance with Santos' environmental assessment procedure and consequence ranking criteria (EA-91-IG-00004), the consequence of the seismic vessel interfering with or displacing other marine users is considered to be 'Minor' (B ranking) – Detectable but insignificant short-term loss of value of the local industry. This assumes the implementation of all proposed control measures.
The justification for this consequence assessment is:
Marine users will still be permitted to enter the seismic survey operational area providing the requested exclusion (safety) zone around the seismic vessel is observed.
Any interactions or displacements will be limited to between 1 February and 31 July (i.e. temporary and within a defined period).
Santos is prepared to invest the time and resources to plan and manage concurrent operations with relevant commercial fishers who wish to continue fishing in the operational area during the seismic survey. Santos agrees to change survey vessel sail lines to accommodate commercial fishing activities, if it is feasible to do so.
Significant alternative fishing areas outside of the operational area are available for commercial fisheries who decide to fish elsewhere.
Santos believes that commercial fishers should not be financially disadvantaged from its seismic operation. Hence, Santos is prepared to consider evidence-based payment claims should commercial fishing licence holders be displaced from the operational area during the seismic survey.
Santos commits to ongoing engagement with commercial fishers before, during and after the seismic survey.
Commercial Fisheries
Through consultation Santos understands that several commercial fishing licence holders are concerned about seismic surveys (refer to Section 4).
The seismic survey has the potential to impact upon multiple commercial fisheries, including the Mackerel Managed Fishery (Area 2) (WA), Pilbara Fish Trawl (Interim) Managed Fishery (WA), Pilbara Line Fishery (Condition) (WA), Pilbara Trap Managed Fishery (WA), Specimen Shell Managed Fishery (WA) and North West Slope Trawl Fishery (Cwlth). Fishers will be able to continue to access the operational area during the survey and Santos is prepared to operate concurrently with fishers. Santos has requested a 3 nm exclusion zone around the seismic vessel and streamers for safety reasons. An exclusion zone is standard practice for a seismic vessel and no concerns about the size of the exclusion zone have been raised by fishers during consultation (Section 4).
Nonetheless, due to the physical presence of the seismic vessel and requested safety exclusion zone, fishers' normal operations maybe temporarily disrupted. Fishers may be displaced or may choose to avoid parts of, or the entire, operational area. This maybe for the duration of the seismic survey or for a part of the survey. If alternative</td></tr>
</table>

Receptor	Consequence Level
	fishing grounds outside of the operational area are not available, then this may result in a loss of catch and financial income. If alternative fishing grounds are available but are more expensive to fish, then this may increase operating costs. Santos understands that all potentially affected fishers have access to alternative fishing areas. Santos recognizes that additional engagement with potentially affected fishers is necessary to determine effective ways of operating concurrently, and/or to determine and evidence any commercial impacts (e.g. relocation costs) of temporary displacement. Santos commits to continued engagement with relevant fishers (refer to **Section 4**) and to assessing the merits of all evidence-based displacement payment claims (refer to **Section 8.6.2**). Santos considers there to be enough information available to understand the nature and scale of potential impacts to commercial fishers, and to assess impact consequence. Ongoing engagement with commercial fishers will be used to validate the below impact assessment. *Mackerel Managed Fishery (Area 2)* Consultation feedback has confirmed that at least one individual mackerel fisher has the potential to be temporarily displaced from part of the operational area. Analysis of FishCube data suggests that extensive alternative fishing grounds are available outside of the operational area, with approximately 51,848 km^2 of total fishing effort for the period between 2009 and 2018. The operational area overlaps with 2,439 km^2 (5%) of the total area of historical fishing effort. One fisher has claimed that the southern portion of the operational area (up to 60 metres in water depth) represents an important fishing area, which is fished each year peaking in May to August (based on consultation during the previous Keraudren 3D MSS). Santos commits to continued engagement with the identified mackerel fisher to reduce temporary operational disruptions to a level that is acceptable and ALARP. *Pilbara Fish Trawl Interim Managed Fishery* Consultation feedback has confirmed that two operators who hold or lease all the trawl fishery licences have the potential to be temporarily displaced from the operational area. Additionally, one of the fishers has identified potential displacement from a fishing area adjacent to the operational area due to the seismic survey vessel 'obstructing' the trawl vessel's path (based on consultation during the previous Keraudren 3D MSS). Analysis of FishCube data suggests that while large areas of alternative fishing grounds are available outside of the operational area, the operational area does overlap a reasonable proportion of the fishery area of effort (27% or 6,310 km^2 of the fishing effort for the period between 2009 and 2018). One fisher has claimed that trawl fishing Area 4 and Area 5 are important fishing grounds for their operation, and that there is year-round fishing effort in these areas (based on consultation during the previous Keraudren 3D MSS). Based on current knowledge about this fishery, it is possible that two operators may be disrupted during the seismic survey. Santos commits to continued engagement with the identified trawl fishers to reduce temporary operational disruptions to a level that is acceptable and ALARP. *Pilbara Line Managed Fishery* Based on a review of FishCube Data and consultation with WAFIC, Pilbara Line Managed Fishery boundary overlaps the operational area and there has been recorded fishing effort in, and near, the operational area. Analysis of FishCube data shows that the area of fishery effort over the West Australian coast is 86,006 km^2 for the period between 2009 and 2018. The operational area overlaps with 19,691 km^2 (23%) of the area of fishing effort. Based on current knowledge about this fishery, fisher displacement impacts should be negligible. *Pilbara Trap Managed Fishery*

Receptor	Consequence Level
	Consultation feedback has confirmed that trap fishers are relevant and potentially affected commercial fishers, and that at least one individual trap fisher has the potential to be temporarily displaced from the operational area. Analysis of FishCube data suggests that extensive alternative fishing grounds are available outside of the operational area. Analysis of FishCube data shows that the area of fishery effort over the West Australian coast was 146,414 km^2 for the period between 2009 and 2018. The operational area overlaps with 8,802 km^2 (6%) of the area of fishing effort. Based on current knowledge about this fishery, fisher displacement impacts should be negligible. *Specimen Shell Managed Fishery* Consultation feedback has confirmed that seismic survey activities within the operational area should not impact upon routine specimen shell collecting activities. Fishing effort in offshore waters near the operational area would have been undertaken from a boat using an ROV. Analysis of FishCube data shows that the areas of fishery effort over the West Australian coast was 43,321 km^2 for the period between 2009 and 2018. The operational area overlaps with 14,532 km^2 (34%). There have been no claims by fishers and there is no evidence that the operational area represents an important or unique area for specimen shell collection. Based on current knowledge about this fishery, fisher displacement impacts should be negligible. *North West Slope Trawl Fishery* Consultation with WAFIC has indicated that trawl fishers are not likely to fish within the operational area, however, the fishery resource (i.e. scampi) could be affected by the proposed seismic survey (refer to **Section 6.2**). Fishing effort is known to be concentrated along the northern edge of the operational area in water depths greater than 200 m. There have been no claims by fishers and there is no evidence that the operational area represents an important or unique fishing area for fishing effort. Based on current knowledge about this fishery, fisher displacement impacts should be negligible. *Other Marine Users* Other marine users will not be restricted from entering the operational area. However, given the low manoeuvrability and slow speed of the seismic vessel, it is possible that third party commercial vessels may be required to deviate from planned routes to avoid the seismic vessel and trailing streamers. Since the seismic vessel will be continually moving, potential displacement from any one location within the operational area will be temporary and negligible. Santos has not identified through consultation any tourism activity in the operational area or surrounds. Recreational fishers and divers may be present at Bedout Island and surrounding waters; however, they will not be displaced by the seismic vessel. It is unlikely indigenous users of the marine environment or traditional fishers will be present within the operational area. AMSA require a high level of communication during the Activity (Marine Notices, NTM, AUSCOAST warnings), therefore, reducing the likelihood of interaction with other sea users (e.g. private leisure craft, etc.).
Overall worst-case consequence	B – Minor

6.1.5 ALARP Evaluation

No alternative options to the use of a seismic vessel is possible in order to undertake the Activity. Alternative options to the survey design have been assessed by Santos. In regard to survey design options that affect other marine users, Santos has attempted to optimise the survey to minimise the operational area size and seismic survey duration, and defined a set window during which the seismic survey will be completed (i.e. 1 February to 31 July). A further reduction in the size of the operational area may be possible once the seismic survey vessel has been determined and sail lines finalised. The survey window is 'booked ended' by spawning periods of commercially important fish species and the humpback whale peak migration period (July onwards) (refer to **Section 6.2**).

Santos intends to acquire the data as quickly and efficiently as possible. The same amount of time is required to acquire the full survey regardless if the survey is acquired over one or more years, hence, the commercial fisher interaction risks are not considered to be materially different. There are several external factors that may impact Santos' ability to meet a commitment to acquire the survey in one year, including vessel availability and operability. For this reason, Santos is not committing to complete the survey in one calendar year.

Additional control measures aimed at avoiding commercial fisheries were identified but not adopted on the grounds that the fisheries overlap either the entire or significant parts of the operational area (refer to **Section 3.2.4.1**).

Stakeholders have been informed of the proposed seismic activity as detailed in **Section 3**. Santos is committed to continued engagement with relevant stakeholders, with a focus on commercial fishers as active users of the operational area. It is through this process the potential operational interference to commercial fishers will be further defined and mitigated to a level that is as low as reasonably practicable.

Santos has agreed to change survey vessel sail lines to accommodate commercial fishers requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey and commercial fishing vessel, and providing Santos is afforded a reasonable opportunity to complete the survey in a timely and efficient manner. Santos commits to working with relevant commercial to enable fair and reasonable concurrent operations.

Santos has made a commitment to consider evidence-based compensation payments should commercial fishers be displaced during the seismic survey. Santos considers it to be appropriate for any commercial agreements with commercial fishers to be managed outside of the environmental approval process.

The exclusion zone requested by Santos around the seismic vessel and streamers in the operational area is 3 nm (5.6 km), as detailed in stakeholder notifications issued by Santos. While this exclusion zone may temporarily displace marine users, it is required to ensure the safety of the seismic vessel and third-party vessels. Requested exclusions zones are standard industry practice and Santos has not received any specific objection to the size of the exclusion zone.

The assessed residual consequence for this potential impact is 'Minor' and cannot be reduced without compromising seismic survey objectives. The data is required in a timely manner to inform Santos permit area relinquishment strategy (refer to **Section 1.1**). Additionally, without the detailed data this survey will acquire future Bedout Sub-basin exploration and development activity may be significantly affected resulting in potentially higher capital expenditure on drilling, and delays to drilling programs and any field developments.

Therefore, the proposed control measures for marine user interaction are considered appropriate to manage the consequence to ALARP.

6.1.6 Acceptability Evaluation

Is the consequence ranked as A or B?	Yes – B (Minor).
Is further information required in the consequence assessment?	No – Sufficient information is available to understand the nature and scale of potential impacts, and to assess impact consequence. Ongoing engagement with commercial fishers

	will be used to validate the impact assessment and ensure the proposed control measures are effectively implemented.
Are performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes - Management consistent with COLREGS, *Safety of Life at Sea* (SOLAS) 1974 and *Navigation Act 2012*.
Are performance standards consistent with the Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance standards consistent with stakeholder expectations?	Yes – Control measures and associated performance standards have been included to address stakeholder concerns. Relevant stakeholders were sent details on Santos' proposed concurrent operations and commercial fishery payment claim protocols. Santos will continue to assess the merits of any stakeholder claims or objections on the proposed control measures and performance standards and will continue to engage with stakeholders as committed.
Are performance standards such that the impact or risk is considered to be ALARP?	Yes – Santos understands through consultation that some commercial fishers do not support seismic surveys have concerns regarding the impacts of seismic surveys on access to fishing grounds, catchability and fish stock. This is acknowledged, however, both commercial fishing and seismic operations are legitimate activities in offshore Commonwealth waters. Based on available information and the proposed control measures, Santos considers interference impacts to marine user to be at an acceptable level. To further reduce potential commercial impacts to a level that is ALARP, Santos commits to assess evidence-based payment claims from commercial fishing licence holders who claim to be affected by the seismic survey. Santos has made a commitment to ensure that commercial fishing licence holders are no worse off as a result of the seismic survey. If additional control measures are identified through ongoing engagement with commercial fishers, then Santos will assess the merits of these and communicate these assessments to stakeholders accordingly. This will ensure that impacts to commercial fishers remain acceptable and ALARP for the duration of the seismic survey.

6.2 Noise Emissions

6.2.1 Description of Event

Aspect	During the Activity noise will be generated through operation of: • Seismic source • Vessels; and • Helicopters. *Seismic source* The aspect considered to have the greatest potential impact is noise emitted from the seismic source array, comprising a series of airguns discharged in a pre-determined order, described in detail in the following sections. The seismic sources will be fired at regular intervals, producing pulses of high-intensity low-frequency sound. Seismic pulses typically have ~98% of the signal power in dominant frequencies less than 200 Hz; predominantly in the 10 to 200 Hz range (McCauley 1994), the useful range for seismic data imaging. *Vessels* The vessels will emit noise from propeller cavitation, thrusters, hydrodynamic flow around the hull, and operation of machinery and equipment. Typically, marine vessels produce low frequency sound (i.e. below 1 kHz) from the operation of machinery on-board; from hydrodynamic flow noise around the hull; and from propeller cavitation, which is typically the dominant source of noise (Ross 1987, 1993; cited in Skjoldal *et al*. 2009). Most sounds associated with vessels are broadband, though tones are also associated with the harmonics of the propeller blades (Ross 1987; 1993 cited in Skjoldal *et al*. 2009). The sound is continuous (non-impulsive) in nature but is modulated by propeller cavitation. McCauley *et al*. (1998) examined the noise from a 64-m, 2,600-tonne rig tender vessel underway, which had a broadband source level of 177 dB re 1µPa. Usually, the larger the vessel, or the faster a vessel moves, results in more noise (Richardson *et al*. 1995). Depending on the vessel, source levels can range from less than 160 dB (trawlers) to over 200 dB re 1µPa @1m (super-tankers) (Simmonds *et al*. 2004). Based on these measurements, it is expected that the size of vessels to be used during this Activity will emit sound in the order of 180 dB re 1µPa @1m or less, particularly given the slow speed (4.5 knots) at which the seismic survey vessel will be travelling for the majority of the survey. *Helicopters* Strong underwater sounds are detectable for only brief periods when a helicopter is directly overhead (Richardson *et al*. 1995). Sound emitted from helicopter operations is typically below 500 Hz and sound pressure in the water directly below a helicopter is greatest at the sea surface but diminishes quickly with depth. A significant proportion of the sound energy is lost due to reflection and attenuation at the air-water interface. Reports for a Bell 214 (regarded to be one of the noisiest), indicated that noise is audible in the air for four minutes before the helicopter passed over underwater hydrophones. The helicopter was audible underwater for only 38 seconds at 3-m depth and 11 seconds at 8-m depth (Greene 1985a; cited in Richardson *et al*. 1995). Noise levels reported for Bell 212 helicopter during fly-over is 162 dB re 1µPa and for Sikorsky-61 is 108 dB re 1µPa at 305 m (Simmonds *et al*. 2004). Helicopters will be used during the survey for crew change and in an emergency. It is expected that underwater sounds as a result of helicopter activity will only be detectable in the upper water column for very brief periods during landing and take-off.
Extent	Extent of underwater noise from vessels and helicopters is localised. The extent of underwater noise from the seismic based on modelling is described extensively below.
Duration	For the duration of the Activity as described in **Section 2**.

6.2.2 Nature and Scale of Environmental Impacts – Seismic Source

6.2.2.1 Background

Marine fauna use sound in a variety of functions, including social interactions, foraging, orientation, and responding to predators. Underwater noise can affect marine fauna in three main ways:

- Injury to hearing or other organs. Hearing loss may be temporary (temporary threshold shift (TTS)) or permanent (permanent threshold shift (PTS));
- Disturbance leading to behavioural changes or displacement of fauna. The occurrence and intensity of disturbance is highly variable and depends on a range of factors relating to the animal and situation; and
- Masking or interfering with other biologically important sounds (including vocal communication, echolocation, signals and sounds produced by predators or prey).

Receptors with the potential to be impacted by underwater noise include:

- Plankton consisting of fish, coral and invertebrate eggs and larvae;
- Benthic invertebrates;
- Fish;
- Sharks;
- Marine mammals (cetaceans and dugongs);
- Marine reptiles; and
- Seabirds.

The levels of acoustic exposure that may result in injury or behavioural changes in marine fauna is an area of increasing research. Due to differences in experimental design, methodology and units of measure, comparison of studies to determine likely sound exposure thresholds can be difficult. On assessment of the available science, thresholds have been defined for informing the impact assessment, and interpreting the numerical noise modelling. These are discussed for each receptor in **Appendix I** (Technical Appendix: Noise Impacts on Marine Fauna).

To understand the extent and magnitude of underwater acoustic noise that may result from the Keraudren seismic survey Santos commissioned JASCO Applied Sciences (JASCO) to model expected sound fields caused by the survey (Koessler and McPherson 2019; refer to **Appendix H** for full copy of the modelling report). It is best practice for seismic survey impact assessments to use underwater acoustic modelling to assess potential impacts to identified environmental and social receptors. The assessment is conducted by comparing modelled received underwater sound levels to defined noise effect criteria, as determined by scientific research and academic papers (refer to **Appendix I**), for the identified environmental and social receptors.

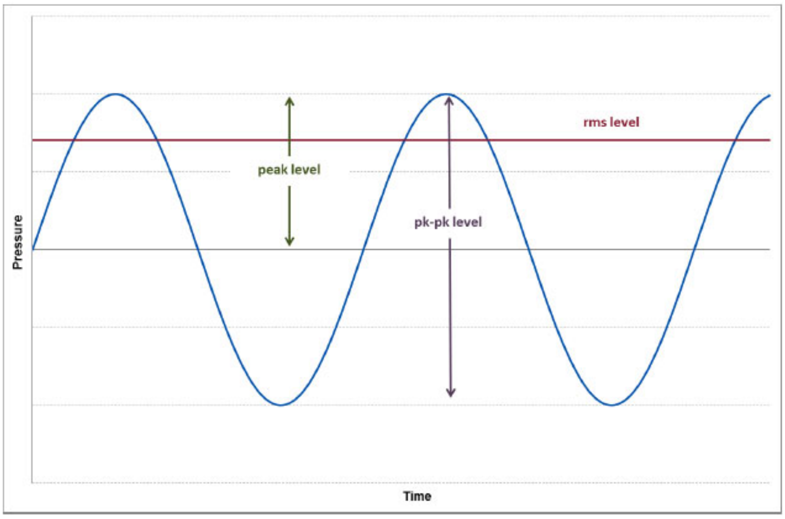
Although the relationship between received sound levels and impacts to marine species is the subject of ongoing research, the science underlying noise modelling is well understood (Farcas 2015).

6.2.2.2 Sound metric terminology

Given the multiple measures commonly used to express sound metrics, it's important to ensure any comparisons between specific sound level values are made using the same measures. These sound level metrics are summarised in **Table 6-1**.

Table 6-1: Sound Level Metrics Definitions

Source level	Source level (SL): The sound pressure level or sound exposure level measured 1 metre from a theoretical point source that radiates the same total sound power as the actual source. It is a theoretical value for a seismic source, because a seismic source is not a point source, but rather is made up of individual elements covering a defined area. Source level can be expressed as an SPL, SEL or PK. Unit: dB re 1 μPa^{2}m^2 or dB 1 μPa^{2}m^{2}s.
Impulse / Pulse	The terms used to refer to the discharge of a seismic source are impulse and pulse, therefore the terms used to describe a single discharge are per-impulse or per-pulse.
Peak pressure (PK)	Zero-to-peak sound pressure (PK), the greatest magnitude of the sound pressure during a specified time interval, unit: dB re 1 μPa. PK levels are modelled to assess mortality and potential

Impulsive sounds	mortal injury to fish, turtles, fish eggs and larvae. Refer to the below for graphical representation of PK. 
Peak-to-peak pressure (PK-PK) Impulsive sounds	Peak-to-peak sound pressure (PK-PK), is the sum of the peak compressional pressure (highest pressure variation) and the peak rarefactional (pressure lowest pressure variation) during a specified time interval, unit: dB re 1 µPa. PK-PK is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound. Refer to the above for graphical representation of PK-PK.
Sound pressure level (SPL) (also referred to as rms level)	The time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure over the duration of an acoustic event (i.e. the duration of a single seismic pulse); unit: dB re 1 µPa; because the SPL represents the effective sound pressure over the full duration of the acoustic event rather than the maximum instantaneous peak pressure (i.e. PK or PK-PK), it is regularly used to represent the effective or perceived loudness of a sound and to assess the potential for a behavioural response from marine fauna
Sound exposure level (SEL)	Sound exposure level (SEL), a measure related to the sound energy in one or more pulses, or the ratio of the time-integrated squared sound pressure to the specified reference value, unit: dB re 1 $\mu Pa^2 \cdot s$, and can be considered as a dose-type measurement. This measure recognises that the effects of sound are a function of exposure duration as well as maximum instantaneous peak pressure. The SEL metric integrates noise intensity over some period of exposure and is used as it allows exposure duration and the effect of exposure to multiple events to be taken into account. SEL is specified in terms of either per-impulse (per-pulse) or a defined accumulation period. The metrics determined for the defined accumulation period assume that a receptor remains stationary for the period. The accumulation period applied for this assessment is 24 hours, and therefore the SEL is referred to as either per-impulse SEL or SEL24h.
Particle motion metrics	Acoustic particle motion is defined as that motion caused by a sound wave of a given infinitesimal part of the medium relative to the medium as a whole, and it is an integral part of any sound field. Unlike pressure, particle motion is directional in nature and is typically described using three-dimensional vector notation. Particle motion levels can be expressed in a variety of units related to displacement, velocity, or acceleration. Acoustic particle velocity is the time derivative of particle displacement, and likewise acceleration is the time derivative of velocity. The particle velocity (v) is the physical speed of a particle in a material moving back and forth in the direction of the pressure wave. The particle acceleration (a) is the rate of change of the velocity with respect to time. Benthic invertebrates and many types of fish are sensitive only to particle velocity or acceleration rather than pressure, however limited measurements or data are available on the levels of particle motion that may result in effects. Some measurements are available from studies on bivalves, and therefore modelled particle motion values have been referenced for the impact assessment.

6.2.2.3 Noise effect criteria

During a seismic survey, new sound energy of finite duration is introduced into the environment with each pulse from the seismic source. For this assessment, the sound levels emitted into the marine environment have been modelled and are expressed using the above-mentioned sound metrics (i.e. SL, PK, SPL, SEL, etc.).

Whether the received noise levels injure or disturb marine fauna (i.e. have an effect) is an active research topic. The noise thresholds (i.e. the level that must be exceeded for an effect to occur) for sound-induced effects on marine fauna are described throughout **Section 6.2**, with additional detail provided in **Appendix H** and **Appendix I**.

Noise thresholds have been defined for both the per-pulse sound energy released, as well as the accumulated sound energy from multiple pulses that marine fauna is subjected to over a defined period of time. For recent regulatory assessments of seismic surveys, the period of total sound energy integration (i.e. accumulation) has been typically defined as 24 hours; hence, was the period used for modelling and in this assessment. For fish this period is based on available research (Popper *et al*. 2014) which found fish experiencing a temporary threshold shift (TTS) in hearing recovered to normal hearing levels within 18 to 24 hours, and for marine mammals the period is required to be either 24 hours or the length of the Activity, whichever is shorter (NMFS 2018).

Importantly, the 24-hour accumulated sound metric reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. More realistically, marine mammals and many fish (pelagic and some demersal) would not stay in the same location or at the same range for 24 hours. Popper *et al*. (2014) discuss the complications in determining a relevant sound exposure period of mobile seismic surveys, as the levels received by the receptor change between impulses due to the mobile source. For marine mammals and many fish, sound exposures at the closest point to the seismic source are the primary exposures contributing to a receptors accumulated level (Gedamke *et al*. 2011). Hence, thresholds based on a 24-hour exposure period are considered to be a conservative measure of potential effect.

6.2.2.4 Acoustic modelling

An acoustic modelling study was commissioned by Santos to aid in assessing the potential effects and impacts of the seismic source (**Appendix I**). The study was undertaken by JASCO, a specialist in the field of marine acoustics. A summary of the JASCO modelling is provided below and the full report is available in **Appendix H**.

JASCO designed the modelling study to take into consideration key survey factors, such as: the location of key environmental and social receptors, and the range of water depths across the survey area (full power zone and ramp-up zone). Eight standalone single impulse sites and two likely accumulated sound exposure scenarios for survey operations were defined (**Figure 6-5**), based upon the line plan options described in **Section 2.5.1**:

- Scenario 1 included two survey lines along the southern edge of the survey area, based on survey lines orientated 120/300 degrees, as per both line plan options 1 and 2 (**Section 2.5.1**). The scenario included five single impulse sites, representing a range of water depths between 38 m and 101 m, in proximity to the humpback whale migration BIA, turtle internesting habitats and other nearshore receptors.
- Scenario 2 included two survey lines in the northern part of the survey area, based on survey lines orientated 90/270 degrees, as per line plan option 1 (**Section 2.5.1**). The scenario included three single impulse sites, representing a range of water depths between 125 m and 157 m in the ancient coastline at the 125 m depth contour KEF and at a location within the planned survey acquisition that is closest in proximity to the pygmy blue whale migration BIA.

Scenario 1 is specifically relevant to sound levels that may occur in water depths relevant to the Mackerel Managed Fishery and nearshore waters accessed by the Pearl Oyster Fishery. Both scenarios consider the full range of water depths as a proxy for areas of interest to commercial fishers in the Pilbara Demersal Scalefish Fisheries.

It is noted that survey line plan option 2 (**Section 2.5.1**) includes lines in the northern part of the survey area that are orientated 120/300 degrees. However, the 90/270 degree scenario was selected for this impact assessment as this line orientation is more closely aligned parallel to the depth contours, therefore, providing an indication of the maximum sound propagation radii (broadside to the survey lines) towards both shallow water receptors and deep water receptors.

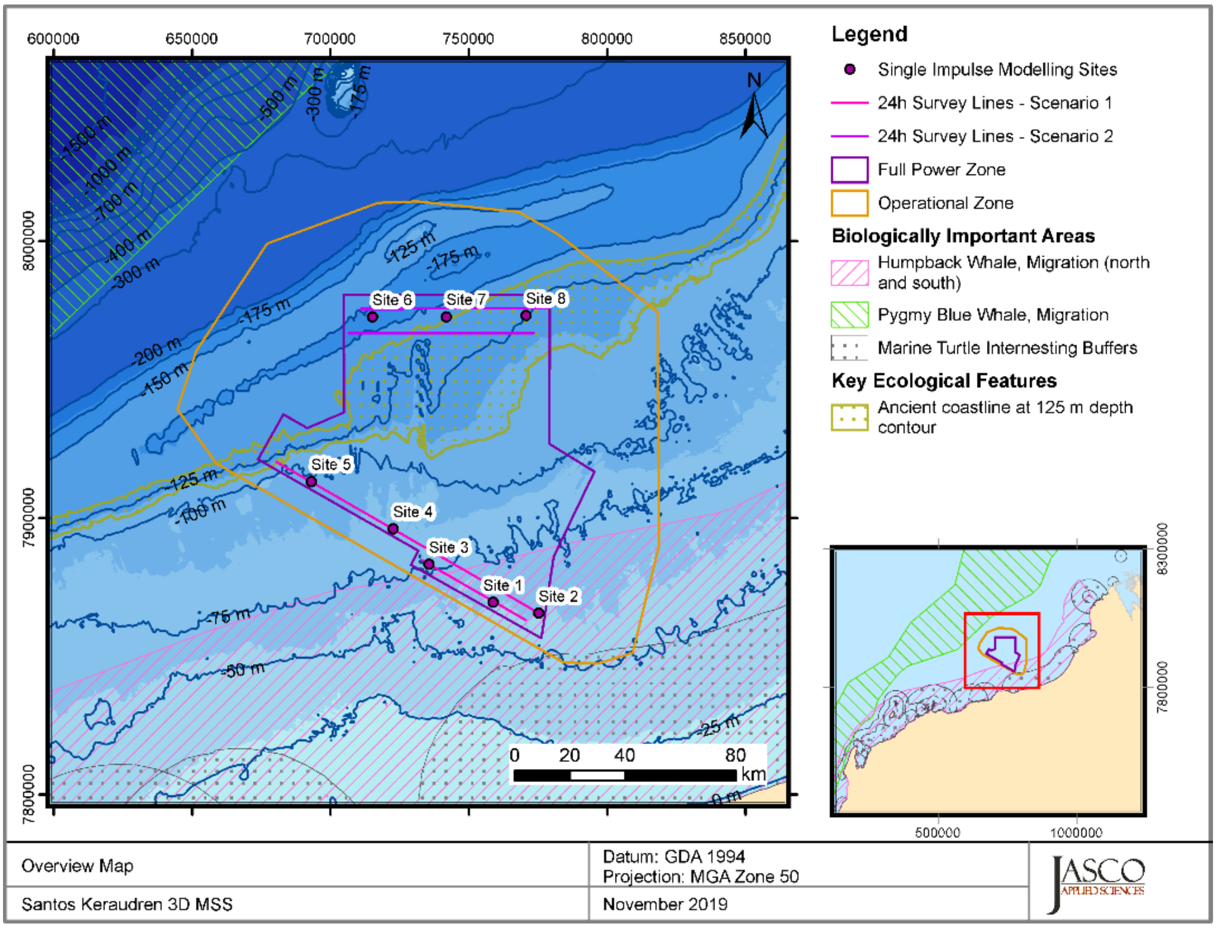


Figure 6-5: Location of modelling scenarios and sites with key receptors

The locations of these scenarios are considered representative of the range of water depths that will be covered during the Santos Keraudren Extension 3D MSS and the potential sound propagation characteristics that may arise at various locations within the survey area. It is acknowledged that seismic source or individual source elements may be infrequently discharged at or below full capacity elsewhere in the wider operational area for testing or maintenance purposes. The modelled single impulse sites are expected to produce sound fields of a similar order of magnitude to those expected elsewhere in operational area. Given the relatively short duration of these testing activities (typically in the order of minutes), the accumulated sound exposures from these activities is expected to be negligible in comparison to the modelled accumulated sound exposures arising from seismic acquisition in the survey area.

As described in **Section 2.5**, the Keraudren Extension 3D MSS may use a seismic source up to approximately 3,500 in^3 in total volume. JASCO's specialised Airgun Array Source Model (AASM), which accounts for the volumes of individual source elements within the array and the array geometry, was used to predict the acoustic signatures and spectra for six comparably sized source arrays under initial consideration for the survey (between 3,090 and 3,480 in^3). Out of these six source arrays, the single impulse received levels were evaluated to identify the loudest, worst case seismic source. This was determined to be a 3,260 in^3 source. Therefore, the loudest source was not necessarily the source with the largest total volume. The sound levels that propagate from the seismic source depend not only on volume, but the configuration and geometric layout of individual guns in the array. While the 3,480 in^3 source resulted in slightly greater levels in the vertical plane directly beneath the seismic source, the configuration and geometry of the 3,260 in^3 source, resulted in the greatest propagation of PK and SEL in the horizontal plane, away from the seismic source. This source, therefore, has the greatest potential for impacts over a greater distance and was selected as the worst-case of the source options for the purposes of the risk assessment.

Three complementary underwater acoustic propagation models were then used in conjunction with the selected modelled source to estimate sound levels over large distances. The modelling assumed that the seismic survey vessel sailed along the survey lines at ~4.5 knots, with a source point interval of 8.33 m, the most frequent source point interval that may be used during the survey, therefore producing the worst-case accumulated sound exposures.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL), zero-to-peak pressure levels (PK), peak-to-peak pressure levels (PK-PK), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL) as appropriate for different noise thresholds (**Figure 6-6**). Particle motion metrics were predicted at three of the modelling locations, in water depths of 38 m, 84 m and 137 m.

Contours of the modelled underwater sound fields have been computed, sampled either at the seafloor or as the maximum value over all modelled depths (maximum-over-depth; MOD) for each location in the modelled region. The modelled distances for each of the defined noise thresholds are computed from these contour maps. Two distances relative to the source are reported for each sound level:

1). R_{max}, the maximum range to the given sound level over all azimuths; and

2). $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded.

The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment. In some environments a sound level contour might have small anomalous isolated fringes in which case the literal use of R_{max} can misrepresent the area of the region exposed to such effects. In these instances, $R_{95\%}$ is considered more representative. In environments that have bathymetric features that affect sound propagation then the $R_{95\%}$ neglects to account for these and therefore R_{max} might better represent the region of effect in specific directions.

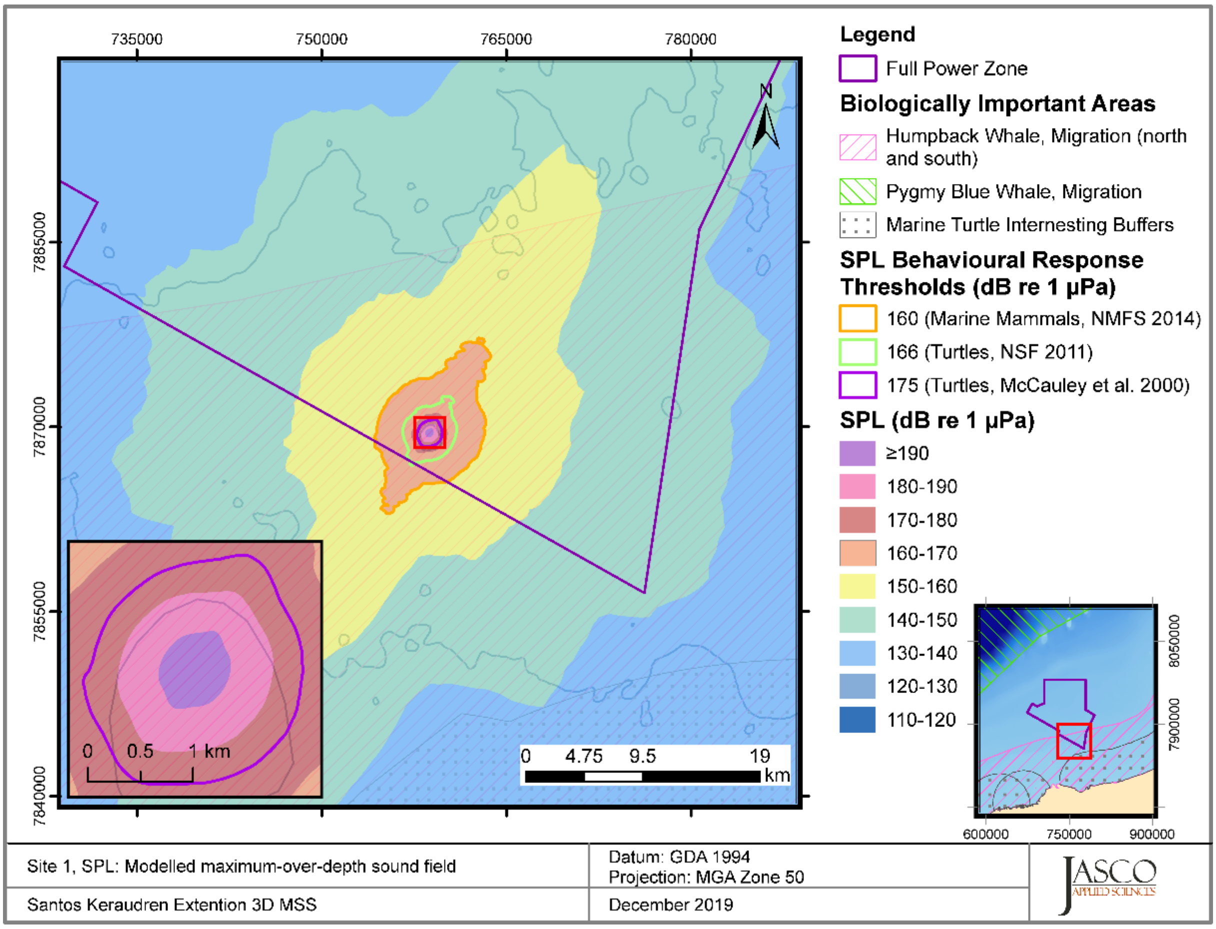


Figure 6-6: Sound level contour map showing unweighted maximum-over-depth per-pulse SPL results for the primary 3,260 in^3 seismic source (Scenario 1, site 1)

6.2.2.4.1 Model validation

Predictions from JASCO's Airgun Array Source Model (AASM) and propagation models (MONM-BELLHOP, FWRAM and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia and Australia (e.g. Hannay and Racca 2005, Aerts *et al*. 2008, Funk *et al*. 2008, Ireland *et al*. 2009, O'Neill *et al*. 2010, Warner *et al*. 2010, Racca *et al*. 2012a, Racca *et al*. 2012b, Matthews and MacGillivray 2013, Martin *et al*. 2015, Racca *et al*. 2015, Martin *et al*. 2017a, Martin *et al*. 2017b, Warner *et al*. 2017, MacGillivray 2018b, McPherson *et al*. 2018b, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modelling (including McCrodan *et al*. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin *et al*. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin *et al*. 2015, Austin and Li 2016, Martin and Popper 2016). The large number of measurement programs conducted by JASCO across a range of environments allows for a rigorous assessment of the performance of propagation models, and a process of continuous improvement to be in place.

All modelled assessment approaches contain an inherent level of uncertainty, which results from the individual uncertainty associated to each model input parameter. For some parameters, such as the airgun array sound source, there is little to no uncertainty when the airgun array is a standard type (MacGillivray 2018a, McPherson *et al*. 2018a), as is the case for this survey. The propagation models used in this study (listed above) are based on an understanding of the physics of sound propagation through the water. These models have been extensively tested during its development and use (as described above), with the aim to achieve predictions which match the results of measurement programs.

Uncertainty in the transmission models arise from the choice of parameter values, such as the sound speed profile and the geoacoustic parameters of the ocean bottom substrate. JASCO conducts a thorough analysis of available information to derive these parameters (Koessler and McPherson 2019), and where uncertainty exists, values which lead to a conservative estimation of the transmission loss are selected.

6.2.2.5 Plankton

6.2.2.5.1 Receptors

The following have been identified as areas where plankton may be of higher value:

- Whale shark foraging BIA;
- Pearl oyster broodstock area conservatively estimated to be out to 70 m water depth (based on consultation with Pearl Producers Association during the previous Keraudren 3D MSS); and
- Commercial fish eggs and larvae.

6.2.2.5.2 Impact pathways and sensitivities

Plankton is a collective term for all marine organisms that are unable to swim against a current. This group is diverse and includes phytoplankton (plants) and zooplankton (animals), as well as fish and invertebrate eggs and larvae. There is no scientific information on the potential for noise-induced effect in phytoplankton and no functional cause-effect relationship has been established. Noise-induced effects on zooplankton, such as copepods, cladocerans, chaetognaths and euphausiids, have been investigated in several sound exposure experiments. Parry *et al.* (2002) studied the abundance of plankton after exposure to airgun sounds but found no evidence of mortality or changes in catch-rate on a population-level.

The effects of impulsive sound on fish eggs and larvae were investigated in the context of offshore pile driving. Bolle *et al*. (2012) investigated the risk of mortality in common sole larvae by exposing them to impulsive stimuli in an acoustically well-controlled study. Even at the highest exposure level tested, at an SEL of 206 dB re 1 µPa^2·s (corresponding to 100 strikes at a distance of 100 m) no statistically significant differences in mortality was found between exposure and control groups.

Contrary to these results, McCauley *et al*. (2017) found that after exposure to airgun sounds generated with a single airgun (150 in^3) zooplankton abundance decreased and mortality in adult and larval zooplankton increased two- to three-fold when compared with controls. In this first, large-scale field experiment on the impact of seismic activity on zooplankton, a sonar and net tows were used to measure the effects on plankton. A maximum effect-range of horizontal 1.2 km was determined. The findings contradicted the conventional idea of limited and very localised impact of intense sound in general, and seismic airgun signals in particular, on zooplankton, with the results indicating that there may be noise-induced effects on these taxa and that these effects may even be negatively affecting ocean ecosystem function and productivity. The study was compromised by methodological design (small sample sizes, large daily variability in the baseline and experimental data) and the statistical robustness of the data and conclusions (large number of speculative conclusions that appear inconsistent with the data collected over a two-day period). The lead author stressed that even though their conclusions were based on numerous assumptions, the combined likelihood of all measured parameters occurring without being correlated to the airgun survey is extremely low (McCauley, *pers. comm*.).

CSIRO (Richardson *et al*. 2017) simulated the large-scale impact of a seismic survey on zooplankton using the mortality rate and effect range found by McCauley *et al*. (2017). The aim of the CSIRO simulation was to estimate the spatial and temporal impact of seismic activity on zooplankton on the North West Shelf of Western Australian. The major findings of the CSIRO simulation were that there was substantial impact of seismic activity on zooplankton populations on a local scale within or close to the survey area, however, on a regional scale the impacts were minimal and were not discernible over the entire North West Shelf Bioregion. The study found that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey. This relatively quick recovery was due to the fast growth rates of zooplankton, and the dispersal and mixing of zooplankton from both inside and outside of the impacted region (Richardson *et al.* 2017). Though the CSIRO simulation was based on a hypothetical 3D survey of 2,900 km^2 in size and over a 35-day period it is seen as being applicable for this impact assessment based on the following:

- The CSIRO model was designed to model potential impacts to plankton on the North West Shelf where the Keraudren Extension seismic survey will take place;
- Richardson *et al*. (2017) showed that zooplankton communities can begin to recover during the seismic survey, during periods of good oceanic circulation, or “bottom out” at a maximum impact level (presumably where growth rates and/or zooplankton entering the survey area roughly approximate mortality rates) after 23 - 30 days of commencement of survey operations.

Day *et al*. 2016 found that “seismic exposure did not result in a decrease in fecundity, either through a reduction in the average number of hatched larvae or as a result of high larval mortality, compromised larvae or morphological abnormalities”. These results support the suggestion by Pearson *et al*. (1994) that early life stage crustaceans may be more resilient to seismic air gun exposure than other marine organisms. Received levels were ~211 dB re 1 µPa (PK-PK; approximately 205 dB re 1 µPa PK) and similar to those proposed by Popper *et al*. (2014).

Fields *et al*. (2019) exposed captive zooplankton (copepods) to seismic pulses at various distances up to 25 m from a seismic source. The source levels produced were estimated to be 221 dB re 1 µPa^2.s, comparable to the far-field source levels associated with some commercial scale seismic surveys. The study observed an increase in immediate mortality rates of up to 30% of copepods in samples at distances of 5 m or less from the airguns compared to controls. Mortality one week after exposure was significantly higher by 9% relative to controls in the copepods placed 10 m from the airguns. Fields *et al*. (2019) also reported that no sublethal effects occurred at any distance greater than 5 m from the seismic source. The findings of the study indicate that the potential effects of seismic pulses to zooplankton are limited to within approximately 10 m from the seismic source. Fields *et al*. (2019) also note that the findings of the McCauley *et al*. (2017) study are difficult to reconcile with the body of other available research and may, therefore, provide an overly conservative estimate of the potential effects of seismic pulses to zooplankton.

6.2.2.5.3 Thresholds

Popper *et al*. (2014) has published exposure guidelines for fish eggs and larvae (**Appendix H**) which are based on pile driving. The thresholds in **Table 6-2** have been considered in the assessment of noise impacts to plankton.

Also considered are the recent results from McCauley *et al*. (2017) of 178 dB re 1 µPa PK-PK to assess impacts on plankton more conservatively. As a precautionary approach, the 178 dB re 1 µPa PK-PK has also been applied in this impact assessment for zooplankton, which equates to a modelled minimum distance of 6.82 km and a maximum distance of 7.92 km (depending on the site). These are considered highly conservative.

Table 6-2: Sound level threshold criteria and values for mortality, injury, TTS and behavioural impacts to plankton

	Plankton (eggs and larvae)					
	Mortality/Potential Mortal Injury		**Recoverable Injury and TTS**		**Behavioural**	
Threshold Criteria	Few studies to base criteria on, however, Popper *et al.* (2014) provides acoustic criteria extrapolated from simulated pile driving signals which have a more rapid rise time and greater potential for trauma than pulses from a seismic source.		There are currently no acoustic criteria for fish eggs and larvae, however, a scale of relative risk is provided in Popper *et al.* (2014). The scale assumes that larvae have similar sensitivity to noise as juvenile and adult fish, and that recoverable injury and TTS are possible.		There are currently no acoustic criteria for fish eggs and larvae, however, a scale of relative risk is provided in Popper *et al.* (2014). The scale assumes that a behavioural response is possible.	
Relevance of thresholds adopted	Popper *et al.*, 2014 has been used as this cites many of the current references and studies on potential impacts of noise emissions on fish eggs and larvae, and when compared to other studies the threshold levels are similar to those proposed, e.g. Day *et al.* (2016); Fields *et al.* (2019). Popper et al. (2014) suggest that injury to larvae resulting from seismic impulses may occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa2·s (SEL_{24h}). However, Popper et al. (2014) suggest that recoverable injury and TTS is likely within tens of metres of a seismic source, which is generally less than the distance associated with their proposed mortal injury threshold, hence there is some discrepancy. The threshold proposed for mortal injury is derived from pile driving impacts to fish and is likely to be conservative. The body of literature indicates that mortality and sub-lethal injury are limited to within tens of metres of seismic sources.					
Sound Metric	**Per pulse**	**Over 24 hours**	**Proximity to airgun**	**Relative Risk**	**Proximity to airgun**	**Relative Risk**
Threshold Value	207 dB PK[1]	210 dB SEL_{24h}[1]	Near (tens of metres)	Moderate[1]	Near (tens of metres)	Moderate[1]
			Intermediate (hundreds of metres)	Low[1]	Intermediate (hundreds of metres)	Low[1]
Modelled Distance	140 – 230 m MOD 142 – 157 m seafloor	50 – 80 m MOD 0 – 80 m seafloor	N/A	N/A	N/A	N/A

[1] Popper *et al*. (2014)

6.2.2.5.4 Impact assessment

Potential impacts to plankton are considered to be within an acceptable level based on:

- Any mortality or mortal injury effects to fish eggs and larvae resulting from seismic noise emissions are likely to be inconsequential compared to natural mortality rates of fish eggs and larvae, which are very high (exceeding 50% per day in some species and commonly exceeding 10% per day) (Tang *et al*. 2014). For example, in a review of mortality estimates (Houde and Zastrow 1993), the mean mortality rate for marine fish larvae was M = 0.24, a rate equivalent to a loss of 21.3% per day;
- In the experiment undertaken by McCauley *et al*. (2017) zooplankton mortality rate background levels were 19%, thus predicted impacts to zooplankton from the seismic survey are likely to be within natural mortality rates;
- Estimated distances for mortality of fish eggs and larvae (maximum 230 m from the source) and low risk to incur a recoverable injury, TTS or behavioural response (derived from applying the threshold values provided by Popper (2014)), would impact fish eggs and larvae at a local rather than a regional scale with sufficient time for recovery to local populations. For this survey, it is considered that the potential impacts and risks to fish eggs and larvae in the water column will be localised and temporary.
- As described in Richardson *et al*. (2017) zooplankton communities can begin to recover during the seismic survey such that a continuous decline in zooplankton throughout the duration of the seismic survey is not anticipated and parts of the survey area would be replenished as the survey progressed.

Potential impacts to other fauna reliant on plankton as a food or recruitment source are considered to be within acceptable level based on:

Whale shark foraging

- Whale sharks seasonally aggregates in coastal waters off Ningaloo Reef between March and July, at Christmas Island between December and January, and in the Coral Sea between November and December:
  - These seasonal aggregations are thought to be linked to localised seasonal 'pulses' of food productivity (TSSC 2015). If whale sharks are moving between these areas to feed it could be assumed that they are not reliant on feeding while migrating and that feeding is opportunistic;
  - Mortality or mortal injury effects to plankton, fish eggs and larvae do not impact on whale sharks being able to feed on them as the plankton will still be available within the water column; and
  - Though northern migration can occur during July it would be expected that numbers would be low as it is the start of the migration period. There will be no seismic activity within the whale shark migration / foraging BIA from 31 July onwards further reducing potential impacts.

Pearl Oysters

- Spawning of pearl oysters occurs all year round, with an initial peak from October to December and a weaker secondary peak in spawning in February and March (Condie *et al*. 2006). The Keraudren Extension survey is proposed outside of the main peak spawning period.
- Following spawning the pearl oysters then metamorphose, settling into a benthic, filter feeder within 3 to 4 weeks. Pearl oysters are therefore less likely to be impacted by seismic surveys once they have settled on the seabed. Losses in the water column during the planktonic stage are extremely high under natural conditions, and <1% of the fertilised eggs survive the veliger stage (Southgate and Lucas 2008).
- Published information on pearl oyster broodstock by Daume *et al*. (2016) and Condie *et al.* 2006, indicates that:

  - Pearl oyster distribution in the Eighty Mile Beach region is concentrated around the 8 m to 15 m water depths;
  - Broodstock responsible for stock recruitment into the fishery is in water depths less than 20 m, while oysters in deeper water depths do not contribute to recruitment in shallow waters; and
  - Pearl oyster inshore stock appears to be self-sustaining and may even be providing larvae to deeper stock in irregular recruitment events.
- Towed video footage in water depths of 40 – 60 m in the vicinity of the Keraudren Extension 3D MSS survey area indicated that significant numbers of pearl oysters are not likely to occur at these water depths within the operational area (RPS 2019). The findings of this study are consistent with preliminary survey results from the Australian Institute of Marine Science (AIMS)-led North West Shoals to Shore research program, which has surveyed for pearl oysters and pearl oyster habitat in waters of Eighty Mile Beach to the west of the operational area. Preliminary data from the study indicates that pearl oysters are more common in water depths less than 40 m. Only a few individual pearl oysters have been found in water depths between 40 and 70 m (Miller 2019).

Commercial fish eggs and larvae

- There are no specific aggregation areas for spawning within the survey area for key commercial fish species that have spawning windows overlapping the timing of the survey (red emperor, bluespotted emperor, Rankin cod, ruby snapper, goldband snapper and Spanish mackerel). Instead, advice from DPIRD indicates these and other similar species spawn throughout their ranges (refer **Section 3.2.4.3**). Therefore, the assessment of impact on fish eggs of these species assumes that they could be present at any location within the survey area during the time of spawning. If the thresholds for mortality and mortal injury (worse case) for eggs and larvae (**Table 6-2**) are applied then the area exposed over the total duration of the survey for these species of fish could be approximately 8,800 km^2. Note, however, that this refers to the total survey area exposed progressively over the 162-day duration of the survey. At any point in time, the area exposed would be approximately 1.4 km^2 (based on the Popper *et al*. (2014) threshold in **Table 6-2**).
- The multiple, broadcast spawning behaviours of the key demersal and pelagic fishes on the continental shelf, by their very nature, offset potentially high natural embryo and larval mortality as a result of predation or other environmental factors that may occur at a regional scale and thereby spreads the risk or potential opportunity for larval settlement over large areas and long timeframes. The localised effects of a transient seismic source are likely to be negligible in comparison.
- The key demersal and pelagic species belong to extensive biological stocks which are known to have genetic connectivity throughout the Pilbara region, and in some cases across northern Australia (refer **Section 3.2.4.3**). The localised effects of the seismic source on eggs and larvae are not expected to make a discernible difference to the dispersion and settlement of larvae between different areas of habitat within these vast stock areas.
- The timing of the survey within a possible 10-month window (2 months excluded due to timing of peak whale migration) has been further constrained to a 6 month window (February to July) in order to minimise the amount of overlap with key commercial fish species peak spawning. Thus, the spawning period for these species does not occur exclusively within the timing of the seismic survey. Given that only a small proportion of the potential area for spawning would be exposed at any one time, the spawning success of these species of fish is unlikely to be impacted.
- The spawning biomass and breeding stock for indicator species for the PDSF and MMF for assessment and stock status have been assessed as sustainable - adequate (Gaughan *et al*. 2019) for the past 5 years, in which time there has been both ongoing commercial fishing and seismic surveys undertaken.

6.2.2.5.5 Summary

Based on the impact assessment no long-term impacts to plankton or fauna dependent on plankton as a food or recruitment source are predicted, thus, the consequence level is assessed as minor.

6.2.2.6 Invertebrates

6.2.2.6.1 Receptors

The following invertebrates have been considered for this assessment:

- Crustaceans;
- Bivalves, including pearl oyster broodstock up to a maximum 70 m water depth;
- Corals and sponges; and
- Invertebrate communities associated with the ancient coastline at 125 m KEF depth contour.

6.2.2.6.2 Impact pathways and sensitivities

Invertebrates are less sensitive to noise impacts than fish species and marine mammals due to their lack of air-filled internal organs. Exposure to anthropogenic sound sources could have a direct consequence on the functionality and sensitivity of the sensory systems of marine invertebrates. The sensory organs involved in receiving underwater sound in this taxonomic group can be classified into three groups (Budelmann 1992b):

1) Superficial receptor systems on the body surface are receptors sensitive to water displacements, therefore mainly encoding hydrodynamic cues;
2) Internal statocyst receptor systems are found in a wide range of aquatic invertebrates. These are inertial gravity receptor systems that may function as acoustic particle motion detectors and thus play a role in underwater hearing (Budelmann 1992b) or substrate-borne vibrations (Cohen *et al*. 1953, Cohen 1955); and
3) Chordotonal organs are proprioceptive receptors that monitor joint movement, the direction of movement, and static position. These organs are sensitive to oscillation of the water column surrounding it (Budelmann 1992a).

Many marine invertebrates are permanently in contact with sediment on the seabed. The sediment, however, does not follow the movement of the surrounding water. Therefore, exposure to underwater sound will result relative to the movement between the body of these animals and the oscillating water column. Accordingly, it is important to also consider the propagation of vibration through the ground. For benthic organisms, this type of vibration is likely of similar or greater importance than the water-borne vibration or even the compressional component of a sound (Roberts and Elliott 2017). The published scientific information on vibration sensitivity in marine invertebrates is scarce (Roberts *et al*. 2015; Roberts *et al*. 2016; Popper and Hawkins 2018). To date, there is no convincing evidence for any significant effects induced by non-impulsive noise in benthic invertebrates. Given the rapid attenuation of vibrational signals beyond the near-field of a sound source (Morley *et al*. 2014), it is unlikely that these stimuli are causing more than behavioural effects (e.g. flight or retraction) or physiological (e.g. stress) responses in marine invertebrates.

The potential sensitivities are summarised in **Table 6-3**, for each of the key groups of invertebrates likely to be present within the operational area, further detail on relevant scientific studies and research undertaken used to inform this impact assessment is included in **Appendix H**.

Table 6-3: Sensitivities for invertebrates

Crustaceans	There have been several recent reviews of seismic noise impacts to invertebrates — Carroll *et al*. (2017), Edmonds *et al*. (2016), Salgado Kent *et al*. (2016) and Webster *et al*. (2018). Several studies have been undertaken on decapods (crabs, lobsters, prawns) with a range of effects to no effects identified, though none have found any evidence of increased mortality due to acoustic impacts from seismic exposure. A range of physiological responses have been identified in some studies, however, the received sound levels are typically at levels that would be received within a few hundred metres from the sound source or have been from repeated exposure at the same sound levels, which is not realistic in an actual seismic survey. From 2013 to 2015, a long-term study evaluated the acoustic impacts from seismic exposure on southern rock lobsters (*Jasus edwardsii*) (Day *et al.* 2016a). The study found that sub-lethal effects, relating to impairment of reflexes, damage to the statocysts and reduction in numbers of haemocytes (possibly indicative of decreased immune response function), were observed after exposure to measured received sound levels of 209-212 dB re 1 µPa (PK-PK). Payne *et al*. (2007) in a study on seismic impacts to the American lobster (*Homarus americanus*) did not detect any differences in righting time in the 9, 65, or 142 days after exposure to received noise levels of 202 dB re 1 µPa (PK-PK). Payne *et al*. (2007) also found no effects on American lobster haemolymph biochemistry but possible reduction in calcium. The ecological consequences of alterations in physiology and behavioural responses have not been documented.
Bivalves	A number of studies have been undertaken on commercially important scallops (*Pecten fumatus*) with conflicting results. Typically, impacts can be induced in laboratory experiments or have been seen in field studies where there have been repeated exposures that are not necessarily reflective of an actual seismic survey. From studies undertaken on the impacts to scallops exposed to repeated seismic sound, the scallops suffered physiological damage with no signs of recovery over a four-month period; suggesting potentially reduced tolerance to subsequent stressors. In addition, changes in behaviour and reflexes during and following seismic exposure were observed. Day *et al*. (2016a, 2016b), however, cautioned that it was unclear from the study whether the observed physiological and behavioural impairments would result in mortality beyond the timeframes considered in their study. Przeslawski *et al*. (2018) concluded that there was no evidence of increased scallop mortality, or effects on scallop shell size, adductor muscle diameter, gonad size, or gonad stage due to the seismic sound from an actual seismic survey. The authors concluded that the study provided no clear evidence of adverse effects on scallops, fish, or commercial catch rates due to the 2015 seismic survey undertaken in the Gippsland Basin. Przeslawski *et al*. (2018) further concluded that the study provided a robust and evidence-based assessment of the potential effects of a seismic survey on some fish and scallops. However, these results should be interpreted in the context of other studies such as Day *et al*. (2016a, 2016b), and should not be generalised to include other animals due to the vast range of different physiology and sensory systems. No specific studies have focussed on the effects of seismic sources on pearl oysters (*Pinctada maxima)*, however, studies on the impacts of underwater explosions on several species of bivalve, including two pearl oyster species, indicated strong resilience to the shock waves created by the detonation of explosives underwater. LeProvost *et al*. (1986) found that no mortality occurred in the exposed animals over a 13-week period and at a minimum exposure range of 1 m from the blast centre. Extrapolating this finding to seismic sources would suggest even less impact on bivalves than explosives, that is, it is likely that bivalves would have to be within a very close range of a seismic source to experience pathological damage or mortality – available evidence would suggest ~1 to 2 m. These studies do not offer any insights as to the distances at which sub-lethal effects (such as morphological, biochemical and physiological changes being indicators of some level of stress in an animal) could occur.
Corals and sponges	There is limited published literature on the potential impacts of seismic noise on hard and soft corals, and unlike other faunal groups, currently there are no peer-reviewed criteria against which potential noise impacts to coral can be assessed.

	Scleractinian corals, primarily plate corals in families Agaracidae and Acroporidae, and soft corals were monitored *in situ* before, during and after a 3D seismic survey (Heyward *et al.* 2018). There were no detectable impacts on scleractinian coral mortality, skeletal damage or visible signs of stress immediately after and up to four months following the 3D marine seismic survey. Similarly, there was no evidence of a behavioural response, such as polyp withdrawal or flaccidity in soft corals such as *Lobophytum* spp.

6.2.2.6.3 Thresholds

No published exposure criteria currently exist to enable an evaluation of potential mortality/potential mortal injury effects in crustaceans.

The threshold criteria that have been adopted for the assessment of noise impacts to invertebrates and the modelled distances for the criteria are from studies described above and provided in **Table 6-4**.

Table 6-4: Sound level threshold criteria and values for invertebrates

Invertebrates	Potential Impacts		
	Crustaceans - Recoverable Injury	**Bivalves – Mortality/Mortal Injury**	**Corals and Sponges – Mortality/Mortal Injury**
Acoustic Criteria	Crustaceans were the most studied group in terms of the range of metrics investigated, including catch rates and physical, behavioural, and physiological effects (Carroll *et al*. 2017). No threshold criteria currently exist for acoustic impacts from seismic exposure to crustaceans. Though particle motion is likely the mechanism of impacts for invertebrates rather than sound pressure it is not clear what level of particle motion relates to an effect. Thus, for this assessment sound pressure metrics are used to be able to compare to published study results that use the sound pressure metrics of PK-PK. As Payne *et al*. (2007) identified no effects on righting time in lobster at 202 dB re 1 µPa (PK-PK), and Day *et al*. (2016a) found effects at 209 dB re 1 µPa (PK-PK), the level of 202 dB re 1 µPa (PK-PK) has been applied in this assessment as a precautionary threshold to determine potential impacts. To inform the assessment of potential effects on crustaceans the PK-PK sound level at the seafloor was estimated at all modelled sites and compared to assessment criteria of 202 dB re 1 µPa (PK-PK).	No threshold criteria currently exist for acoustic impacts from seismic exposure to bivalves. Particle motion is likely the mechanism of impacts for bivalves rather than sound pressure though it is not clear what level of particle motion relates to an effect. Particle motion is seen as a more relevant criteria for assessment of bivalves as they spend the majority of the time in the seabed sediments rather than the water column. To assess the potential impacts associated with the seismic survey, particle motion has been assessed, specifically particle acceleration and velocity, and the results compared to those presented in Day *et al.* (2016b). The maximum particle acceleration assessed for scallops was 37.57 ms^{-2} [2].	To inform the assessment of potential effects on coral, the PK sound level at the seafloor directly underneath the seismic source was estimated at all modelled sites and compared to the level of 226 dB re 1 µPa PK at which no impacts to coral were identified (Heyward *et al*. 2018).
Sound Metric	**Per pulse**	**Particle Motion Maximum**	**Per pulse**
Threshold Criteria	202 dB PK-PK[1]	37.57 ms^{-2} [2]	226 dB PK[3]
Modelled Distance	351 - 685 m	5 – 55 m Criteria not exceeded at site modelled in water depths > 100 m.	5 m (Site 1, 38 m water depth) Criteria not exceeded at any other sites modelled.

1. Payne *et al.* (2008)
2. Day *et al.* (2016)
3. Heyward *et al.* (2018)

6.2.2.6.4 Impact assessment

Crustaceans

Crustaceans are likely to be present throughout the survey area with patchy distribution based on seabed habitat. Commercial invertebrate species, such as scampi and crabs, are not likely in the survey area as they prefer deeper waters and prawn species are caught closer to the coast. To inform the assessment of potential impacts on crustaceans the PK-PK sound level at the seafloor was estimated at all modelled sites and compared to the assessment criteria of 202 dB re 1 µPa (PK-PK). The assessment criteria of 202 dB re 1 µPa (PK-PK) was reached at ranges between 351 - 685 m.

Potential impacts to crustaceans are considered to be within an acceptable level based on:

- Lethal effects in studies have not been observed (Payne *et al*., 2007, Day *et al.,* 2016a);
- Sub-lethal effects, relating to impairment of reflexes, damage to the statocysts and reduction in numbers of haemocytes are documented at received levels of 209 dB re 1 µPa (PK-PK) (Day *et al*. 2016a). Based on the distances from the seismic source that these levels would be reached, it is possible that some individuals will incur a reduction in fitness. However, it is unlikely that this would occur to the majority of individuals within the survey area, therefore, impacts at a population level due to reduced fitness would be unlikely as there would be sufficient unaffected crustaceans to maintain the population;
- At higher received noise levels of 209 dB re 1 µPa (PK-PK) (Day *et al*. 2016a) impacts to embryonic development were not observed with hatched larvae found to be unaffected in terms of egg development, the number of hatch larvae, larval dry mass and energy content and larval competency (i.e. survival in adverse conditions) thus recruitment should be unaffected (Day *et al*. 2016a). Therefore, impacts at a population level due to reduced recruitment would be unlikely as impacts to larvae and eggs were not observed; and
- The survey area does not overlap significant crustacean habitat or commercial crustacean fishery activity.

Bivalves, including pearl oyster broodstock

Bivalves are likely to be present throughout the survey area with patchy distribution based on seabed habitat. Commercial bivalve species are not harvested within the survey area, though the waters out to 70 m have been anecdotally identified as where pearl oyster broodstock may be present (Aaron Irving, PPA, *pers comm* during consultation for the previous Keraudren 3D MSS). Using the conservative threshold value for impacts to molluscs (**Table 6-4**) of 37.6 m/s^2 for particle motion maximum (presented by Day *et al*. 2016a), a radial distance of 55 m and 5 m is reached at sites in 38 m and 84 m water depth respectively (**Figure 6-7**). The threshold was not exceeded at a modelling site in 137 m water depth, where the maximum level at the seafloor was 26 m/s^2. Shallower water depths, therefore, result in the worst-case particle motion effects, but distances within which impacts may occur are limited.

At sites where the threshold is exceeded, a small proportion of bivalves may experience chronic effects that result in mortality during the weeks and months following exposure, as was observed by Day *et al.* (2016a). Areas of the seabed that are exposed to the seismic source passing overhead for a second time (repeat exposures), such as the < 1 km overlap between survey stages or 5 km overlap between differing line plan options, may experience slightly increased chronic mortality rates, as was also observed by Day *et al.* (2016a). However, mortality rates were found by Day *et al.* (2016a) to be small relative to natural mortality rates.

Potential impacts to bivalves are considered within an acceptable level based on:

- If mortality impacts do occur to bivalves, it would be within natural mortality rates and unlikely to have long term or population effects based on the findings of the study by Day *et al.* (2016a);

- If mortality, injury or behavioural impairments did occur to bivalves during the weeks and months following exposure, it would not occur to all bivalves thus, significant impacts at a population level would be unlikely, as there would be sufficient unaffected bivalves and recruitment from adjacent sediments to maintain the population during the same timeframes;
- The shallowest part of the Keraudren ramp-up zone is approximately 40 m. Harvesting of pearl oysters typically occurs in 10 to 35 m water depths, with the last 10 years of catch data indicating that the closest harvesting area is > 30 km from the operational area. Thus, no direct impacts to commercial pearl oysters in these harvesting grounds are predicted;
- Feedback from the Pearl Producers Association (PPA) is that pearl oyster broodstock may be present out to 70 m water depths. The area of the seismic survey ramp-up and full-power zones that overlaps water depths up to 70 m is approximately 1,100 km^2. This is a small proportion of the seabed within 70 m water depth contour that is adjacent to inshore pearl oyster harvesting areas of the Pilbara region;
- Preliminary findings from RPS (2019) found limited evidence of pearl oysters within water depths of 40 – 60 m in the vicinity of the survey area;
- Preliminary research data from the AIMS North West Shoals to Shore Research Programme indicates that the occurrence of pearl oysters in water depths greater than 40 m is limited; and
- The physical structure, ecosystem functioning and integrity of habitat where pearl oysters may be present are not predicted to be altered.

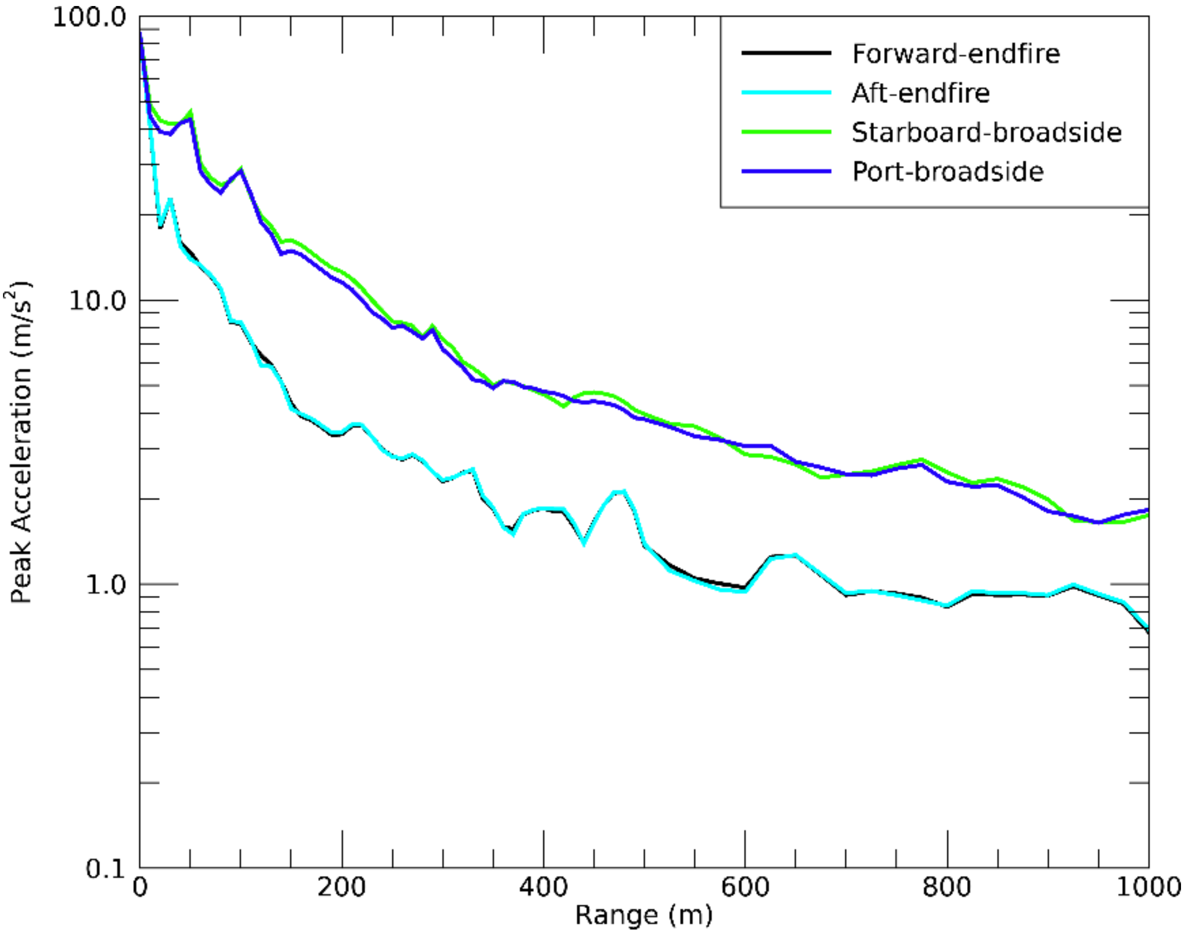


Figure 6-7: Site 1 (38 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3260 in^3 seismic source (Koessler and McPherson 2019)

Corals and sponges

There are no documented areas of corals or exposed hard substrate that could support significant coral habitat in the shallower water depths of the ramp-up/ full-power zone, however, such habitat may occur. Recently, RPS (2019) reported the occasional presence of soft corals in video transects in less than 60 m water depth in the vicinity of the operational area. The threshold value of 226 dB re 1 µPa PK for corals and sponges may be exceeded within approximately 5 m of the seismic source while in the shallow southern portion of the survey area, and is not expected to be exceeded at depths greater than approximately 84 m (**Appendix H**). The 226 dB re 1 µPa PK threshold is also based on the maximum received levels on the seafloor reported by Heyward *et al*. (2018) and no impacts to corals were identified at this level. Therefore, at shallow water sites, where the received levels on the seafloor may exceed this threshold, impacts to corals and sponges may be limited or may not occur at all.

Invertebrate communities associated with the ancient coastline at the 125 m depth contour KEF

Mobile invertebrates (e.g. crustaceans) and sessile invertebrates (e.g. bivalves and coral) may be associated with the high relief habitat thought to be a characteristic of the ancient coastline at the 125 m depth contour KEF. Potential impacts to invertebrates associated with the ancient coastline KEF are considered within an acceptable level based on:

- The maximum modelled particle acceleration levels in water depths equivalent to the water depths of the ancient coastline at the 125 m depth contour KEF are not predicted to exceed the threshold criteria for impacts to bivalves;
- At the water depth of 125 m the assessment criteria of 226 dB re 1 µPa PK for corals is not reached and hence impacts to soft and hard coral, if present at the ancient coastline at 125 m depth contour KEF are not predicted to occur;
- Therefore, impacts to sessile benthic invertebrates within and near the ancient coastline KEF are likely to be negligible.
- RPS (2019) used BRUVS to assess fish assemblages at 125m water depths within and outside of the Keraudren Extension 3D MSS operational area and noted that the seabed was characterised by mobile flat sandy gravel with little conspicuous epibiota, signs of bioturbation, or consistent structurally complex seabed features. Thus, if present, the distribution and abundance of invertebrates on this feature are sparse; and
- The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered.

6.2.2.6.5 Summary

Based on the impact assessment no long term or population impacts to invertebrates (crustaceans, molluscs, corals) are predicted. In the shallower, southern portion of the survey area, received sound pressure and particle motion levels may be sufficient to result in chronic mortality impacts to a proportion of sessile benthic invertebrate communities, but population level effects are not expected. Thus, the consequence level for crustaceans and molluscs is assessed as minor; as no impacts to corals and sponges are predicted the consequence level is assessed as negligible.

6.2.2.7 Fish

6.2.2.7.1 Receptors

The following fish types and receptors have been identified for this assessment:

- Demersal fish species including commercial fish species, such as tropical snappers and emperors;
- Pelagic fish species including commercial fish species, such as mackerel;
- Spawning and recruitment of commercially significant fish species; and
- Fish assemblages associated with the ancient coastline at 125 m depth contour KEF.

6.2.2.7.2 Impact pathways and sensitivities

Although hearing ranges and sensitivities vary substantially between species (e.g., Ladich and Fay 2013), all fish species tested to date can hear sound (Dale *et al*. 2015). Fishes have developed two sensory mechanisms for detecting, localising, and interpreting underwater sounds and vibrations: the inner ear, which is tuned to sound detection, and the lateral line system, which allows a fish to detect vibration and water flow. Inter-specific variations in hearing range and sensitivity result from the different adaptations in these systems for perceiving sound pressure and particle motion information (Popper and Fay 2011).

Based on their morphology, Popper *et al*. (2014) classified fishes into three categories comprising:

- Fishes with swim bladders whose hearing does not directly involve the swim bladder or other gas volumes;
- Fishes whose hearing does directly involve a swim bladder or other gas volume; and
- Fishes without a swim bladder that can sink and settle on the substrate when inactive (Popper *et al.* 2014, Carroll *et al.* 2017).

The Popper *et al*. (2014) classifications can be assigned to the following families or species of fish, common in Australian waters:

- Fishes with swim bladders or other gas volumes, but whose hearing does not directly involve the swim bladder, e.g., snappers, emperors, groupers and rock cods (Lutjanids and Lethrinids such as *Pristipomoides* spp., *Lethrinus* spp., *Lutjanus* spp., and family Serranidae), and some species of tuna (*Thunnus* sp.) (Tavolga and Wodinsky 1963; Higgs *et al.* 2006; Braun and Grande 2008; Engineering-Environmental Management, Inc. 2008; United States Department of the Navy 2008; Caiger *et al*. 2012; Bertrand and Josse 2000; Song *et al*. 2006);
- Fishes whose hearing does directly involve a swim bladder or other gas volume e.g., family Clupeidae (herrings, sardines, pilchards and shads), family Gadidae (true cods such as whiting), and potentially some nearshore / reef species relevant to tropical Australia, including some Pomacentridae (damsel fishes and clown fishes), some Holocentridae (soldierfishes and squirrelfishes) and some Haemulidae (grunters and sweetlips) (Nedwell *et al*. 2004; Braun and Grande 2008; Popper *et al*. 2014); and
- Fishes without a swim bladder (e.g., mackerel, *Scomberomorus* spp., some species of tuna , *Thunnus* sp. and sharks, including whale sharks, *Rhincodon typus*) (Casper *et al*. 2012, Popper *et al*. 2014, Carroll *et al.* 2017).

The most relevant metric for perceiving underwater sound for most fish species is particle motion (Popper and Hawkins 2019; Popper *et al*. 2019) but, with the exception of few species (Popper and Fay 2011; Popper *et al*. 2014), there is an almost complete lack of relevant data on particle motion sensitivity in fishes (Popper and Hawkins 2018).

Most fish species detect sounds from below 50 Hz up to 500-1500 Hz. A smaller number of species can detect sounds to over 3 kHz, while a very few species can detect sounds to well over 100 kHz. The critical issue for understanding whether an anthropogenic sound affects hearing is whether it is within the hearing frequency range of a fish and loud enough to be detectable above threshold. For this impact assessment, it is assumed that all fishes can detect signals below 500 Hz and so can 'hear' the seismic source.

The potential impacts and sensitivities are summarised in **Table 6-5**, further detail on relevant scientific studies and research undertaken used to inform this impact assessment is included in **Appendix H** and **Appendix I**.

Table 6-5: Impact pathways and sensitivities for fish

Impact Pathway	Summary
Mortality and mortal injury	Immediate or delayed death.
Recoverable injury	Injuries, including hair cell damage, minor internal or external hematoma, etc. None of these injuries are likely to result in mortality.
TTS	As per Popper *et al*. (2014): *"Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS has been demonstrated in some fishes, and its extent is of variable duration and magnitude. TTS results from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves innervating the ear (Smith et al. 2006; Liberman 2015). However, sensory hair cells are constantly added in fishes (e.g., Corwin 1981, 1983; Popper and Hoxter 1984; Lombarte and Popper 1994) and also replaced when damaged (Lombarte et al. 1993; Smith et al. 2006; Schuck and Smith 2009), unlike in the auditory receptors of mammals. When sound-induced hair cell death occurs in fishes, its effects may be mitigated over time by the addition of new hair cells (Smith et al. 2006, 2011; Smith 2012, 2015).* *After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure (e.g., Popper and Clarke 1976; Scholik and Yan2001, 2002a, b; Amoser and Ladich 2003; Smith et al. 2004a, b, 2006, 2011; Popper et al. 2005, 2007). While experiencing TTS, fishes may have a decrease in fitness in terms of communication, detecting predators or prey, and/or assessing their environment."*
Masking	Masking is the impairment of hearing sensitivity by greater than 6 dB, including all components of the auditory scene, in the presence of noise. Masking impairs an animal's hearing with respect to the relevant biological sounds normally detected within the environment and can have long lasting effects on survival, reproduction and population dynamics of fishes. Acoustic masking only occurs while the interfering sound is present, and therefore, masking resulting from a single pulse of sound (such as an airgun impulses) or widely separated pulses would be infrequent and not likely affect an individual's overall fitness and survival. In the absence of any qualitative scientific information, acoustic masking of signals caused by the reception of seismic sounds are assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds.
Behavioural effects	Substantial change in behaviour for the marine fauna exposed to a sound. This may include long-term changes in behaviour and distribution, such as moving from preferred sites for feeding and reproduction, or alteration of migration patterns. This behavioural criterion does not include effects on single animals, or where animals become habituated to the stimulus, or small changes in behaviour such as a startle response or small movements. It is currently impossible to determine single value thresholds for the onset of behavioural reactions. Popper *et al*. (2014) propose broad response and effect categories. In the absence of any qualitative scientific information, behavioural effects caused by the reception of seismic sounds are assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. The transient nature of a seismic survey and the soft start ramp-up practices mean that for all fishes that have a relatively large home range and are mobile the possible effects are predicted to commence with a behavioural effect. As the proximity to the sound source increases the effect is anticipated to increase.

Adapted from Popper et al. (2014) and ***Appendix H****.*

The Working Group on the Effects of Sound on Fish and Turtles undertook a review of experimental findings of sound on fishes. In their American National Standards Institute (ANSI) accredited report (Popper *et al*.

2014) sound exposure guidelines for different levels of effects for different groups of species are presented, for three types of immediate effects:

- Mortality, including injury leading to death;
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma; and
- Temporary threshold shift (TTS).

Fish populations may be further impacted if behavioural responses result in deflection from migration paths, feeding grounds or disturbance of spawning, potentially affecting recruitment of fish stocks.

Santos has taken into consideration DPIRD's risk assessment on the impacts of seismic to finfish stocks in the assessment of impacts from the seismic survey (Webster *et al*., 2018), taking into consideration aquatic resource type, water column depth and seismic sound intensity.

6.2.2.7.3 Thresholds

For the assessment of impact to fish from seismic sound it is industry practice to use the exposure guidelines proposed by Popper *et al*. (2014). The presence or absence of a swim bladder and ancillary structures determines the level of susceptibility of fishes to injurious effects from exposure to intense sound. Accordingly, different exposure guidelines were developed for fishes without a swim bladder, fishes with a swim bladder not involved in perception of acoustic signals and fishes that use their swim bladders for hearing. The fish receptors identified for this assessment, such as site-attached species (including syngnathids) and demersal fish species, are included in the category of fish having a swim bladder while mackerel, a pelagic fish species, do not have a swim bladder.

The guidelines set out criteria for injury due to different sources of noise. The criteria include a mixture of indices including SEL, peak sound pressure levels and where insufficient data exists to determine a quantitative guideline value the risk is categorised in relative terms as "high", "moderate" or "low" at three distances from the source.

There are currently no quantitative guidelines or criteria for fish behaviour as Popper *et al.* (2014) found that there was insufficient data available with which to establish sound level thresholds for behaviour. Instead, masking and behavioural effects are qualitatively assessed as relative risk, being the distance of a fish from the seismic source, rather than by a specific threshold. Based on the application of the Popper *et al.* (2014) semi-quantitative exposure criteria, there could be a high risk of behavioural impacts in fish species near (tens of metres) from the seismic source with the level of risk declining to low at thousands of metres from the seismic source.

As described above and in **Appendix H** and **Appendix I**, the threshold criteria in **Table 6-6** have been adopted for the assessment of potential noise impacts to fish. **Table 6-6** provides the modelled distances for the criteria.

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Table 6-6: Sound level threshold criteria and values for mortality and impairment in fish

	Mortality/Potential Mortal Injury	Recoverable Injury	TTS
Threshold Criteria	No studies to date have demonstrated direct mortality of adult fish in response to airgun emissions, even when fired at close proximity (within 1–7 m; DFO 2004; Boeger *et al*. 2006 as cited in NSW DPI 2014; Popper *et al*. 2014). Carroll *et al*. (2017) conclude that "*For fish, there are few data on the physical effects of seismic airguns (e.g. mortality, barotrauma), and of these none have shown mortality*." Though mortality or mortal injury of fish from seismic sources has not been demonstrated it is industry practice to apply the Popper *et al*. (2014) exposure guidelines as part of the impact assessment process.	The effects of change in pressure (barotrauma – resulting in tissue injury) can result in injury. Recoverable injuries include fin hematomas, capillary dilation, and loss of sensory hair cells. Full recovery from these injuries is possible (Popper *et al*. 2014).	*Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure (Popper 2014).* Sound exposure guidelines proposed in Popper *et al*. (2014), which indicated that TTS may occur at SEL_{cum} levels >186 dB re 1 µPa^2·s. Popper *et al*. (2014) summarises that in all TTS studies considered, fish that showed TTS recovered to normal hearing levels within 18–24 hours. Due to this, a period of accumulation of 24 hours has been applied in this study for SEL, which is similar to that applied for marine mammals in Southall *et al*. (2007) and NMFS (2016).
	Popper *et al*. (2014) proposes a dual criteria of PK and SEL_{24hr} for mortality or potential mortal injury and recoverable injury. For the impact assessment the furthest distance to the criteria is be used. For this impact assessment, the time period of 24 hrs is applied to the SEL_{cum} metric.		
Relevance of thresholds adopted	Based on the literature review presented in **Appendix I**, and the indicator commercial species that are present within the operational area (pelagic and demersal fish), Popper *et al*. (2014) has been adopted as relevant to set the threshold criteria. This American National Standards Institute (ANSI) accredited report by the Working Group on the Effects of Sound on Fish and Turtles undertook a review of experimental findings of sound on fishes, presenting thresholds for mortality, recoverable injury and TTS in 2014, and is adopted by industry in Australia for the basis of impact assessment.		

Fish with no swim bladder (including sharks) [Group I in JASCO report][3]						
	Mortality/Potential Mortal Injury		**Recoverable Injury**		**TTS**	
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**
Threshold Values	213 dB PK[1]	219 dB SEL_{24h}[1]	213 dB PK[1]	216 dB SEL_{24h}[1]	Popper *et al*. (2014) does not define a per pulse criteria for TTS for fish.	186 dB SEL_{24h}[1]
Modelled Distance	60 - 70 m MOD 38 – 87 m seafloor	50 m MOD Not exceeded at seafloor	60 – 70 m MOD 38 – 87 m seafloor	50 m MOD Not exceeded at seafloor		4.2 – 6.3 km MOD 4.0 – 6.2 km seafloor

	Fish with swim bladder (not involved in hearing) [Group II in JASCO report] [4]					
	Mortality/Potential Mortal Injury		**Recoverable Injury**		**TTS**	
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**
Threshold Criteria	207 dB PK[1]	210 dB SEL_{24h}[1]	207 dB PK[1]	203 dB SEL_{24h}[1]	Popper *et al.*, 2014 does not define a per pulse criteria for TTS for fish.	186 dB SEL_{24h}[1]
Modelled Distance	140 – 230 m MOD 142 – 157 m seafloor	50 - 80 m MOD 0 – 80 m seafloor	140 – 230 m MOD 142 – 157 m seafloor	140 - 280 m MOD 140 - 280 m seafloor		4.2 – 6.3 km MOD 4.0 – 6.2 km seafloor
	Fish with swim bladder (involved in hearing) [Group III in JASCO report]					
	Mortality/Potential Mortal Injury		**Recoverable Injury**		**TTS**	
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**
Threshold Criteria	207 dB PK[1]	207 dB SEL_{24h}[1]	207 dB PK[1]	203 dB SEL_{24h}[1]	Popper *et al.*, 2014 does not define a per pulse criteria for TTS for fish.	186 dB SEL_{24h}[1]
Modelled Distance	140 – 230 m MOD 142 – 157 m seafloor	60 – 140 m MOD 40 – 130 m seafloor	140 – 230 m MOD 142 – 157 m seafloor	140 - 280 m MOD 140 - 280 m seafloor		4.2 – 6.3 km MOD 4.0 – 6.2 km seafloor
	The distance to sound levels associated with mortality and potential mortal injury on fish based on Popper *et al*. (2014), using the SEL_{24h} metric, are smaller than those estimated using the PK-based metric. Therefore, in line with the conditions of the criteria as per Popper *et al*. (2014)[2], the PK metric should be used to assess these impacts to fish.		The distance to sound levels associated with recoverable injury on fish based on Popper *et al*. (2014), using the SEL_{24h} metric, are bigger than those estimated using the PK-based metric. Therefore, in line with the conditions of the criteria as per Popper *et al*. (2014)[2], the SEL_{24h} metric should be used to assess these impacts to fish.		There is no per pulse criteria for TTS, as such the SEL_{24h} metric is used to assess these impacts to fish. Modelled ranges to TTS are based on unweighted sound energy accumulated over 24 hours. However, fish lack the ability to detect many of the distant impulses that occur during this 24-hour period and so the ranges are likely to be conservative. The majority of sound energy contributing to potential TTS effects will be received when the seismic survey vessel is at very close range to the fish (Popper 2018).	
	Behaviour					
	It is currently impossible to determine single value thresholds for the onset of behavioural reactions. Popper *et al*. (2014) propose broad response and effect categories. For all three groups of fish (Group I,II and III) the behavioural criteria are described as a relative risk qualitatively. • For Group I (no swim bladder) fish the risk is High within tens of metres, Moderate within hundreds of metres, and Low within thousands of metres. • For Group II fish (swim bladder not directly involved in hearing) the risk is High within tens of metres, Moderate within hundreds of metres, and Low within thousands of metres.					

	• For Group III fish (swim bladder directly involved in hearing) the risk is High within tens of metres, High within hundreds of metres, and moderate within thousands of metres. Based on these categories, significant behavioural responses in fish are predominantly limited to within tens or hundreds of metres from the seismic source. At greater distances (i.e. kilometres), fishes with a swim bladder or gas-filled volume are able to detect sound pressure to varying degrees, but behavioural responses at these ranges are unlikely to be significant, except potentially for fishes with swim bladders directly involved in hearing.

1: Popper *et al*. (2014)

2: Given that dual criteria are defined the largest distance resulting from either SEL or PK are applied for the impact assessment, Popper *et al*., 2014.

3: Pelagic fish (mackerel): For PK thresholds, the modelling results for maximum-over-depth have been used for pelagic fish as they reside within the water column.

4: Demersal fish (snapper, emperor and cod): For PK thresholds, the modelling results with the maximum distance has been used as demersal fish reside in both the water column and close to the seafloor.

5: Site-attached fish: The ancient coastline at the 125 m depth contour KEF is the only recognised significant feature within the ramp-up/ full-power zone where site-attached fish may occur due to the association with epibenthic communities that may develop on exposed hard substrate. For PK thresholds, the modelling results for the seafloor have been used as site-attached fish species reside close to the seafloor.

For this impact assessment the Popper *et al*. (2014) sound exposure guideline for TTS of 186 dB SEL_{cum} is applied with a period of time applied to the SEL metric of 24 hrs. There have recently been some concerns raised by stakeholders on other seismic programs (Bethany 3D MSS) in regard to the appropriateness of using a 24-hour period to assess SEL_{cum} and the potential for TTS and other effects associated with SEL_{cum}. An independent, expert peer review in relation to this issue was conducted by Professor Arthur Popper (Popper 2018). The review considered the potential impacts of cumulative seismic noise from the proposed Santos Bethany 3D seismic survey on fish, including TTS effects, and length of time for recovery and the applicability of an SEL_{24h} metric. Though this information was based on another survey it is applicable to the Keraudren Extension 3D MSS as pelagic and demersal fish species within the areas are similar and the premise for the modelling was a racetrack that bought the vessel back to a similar starting point within 24 hrs, thus receiving the closest shots within a 24-hour period. The review noted:

- It is highly unlikely that there would be physical damage to fishes as a result of the survey unless the animals are very close to the source (perhaps within a few meters).
- Most fishes in the Bethany region (and given the similarity in fish species, therefore can be applied for the Bedout Sub-basin), being species that do not have hearing specialisations, are not likely to have much (if any) TTS as a result of the survey.
- If TTS does take place, the duration of exposure to the most intense sounds that could result in TTS will be over just a few hours. Thus, accumulation of energy over longer periods than a few hours is probably not appropriate.
- If TTS takes place, its level is likely to be sufficiently low that it will not be possible to easily differentiate it from normal variations in hearing sensitivity. Even if fishes do show some TTS, recovery will start as soon as the most intense sounds end, and recovery is likely to even occur, to a limited degree, between seismic pulses. Based on very limited data, recovery within 24 hours (or less) is very likely.
- Nothing is known about the behavioural implications of TTS in fishes in the wild. However, since the TTS is likely very transitory, the likelihood of it having a significant impact on fish fitness is very low.

Considering that most (if not all) demersal and pelagic fish species in the operational area have relatively poor hearing (compared to fishes with hearing specialisations and swim bladders directly involved in hearing), each individual fish is exposed to relatively “loud” sounds for only a short period of time and the exposure is only at levels that might lead to potential effects if the fish is relatively close to the sound source for an extended period of time. Instead, the modelled SEL_{24hr} scenarios are not weighted to the auditory thresholds of fishes and so account for a great many seismic pulses over the 24-hour period that are likely too low and distant for fishes to be able to hear.

As part of the acoustic modelling undertaken for the Keraudren Extension 3D MSS (**Appendix H**), the accumulated sound exposure levels were modelled at static receivers at perpendicular offsets from the closest survey line in each of the 24-hour scenarios. Based on the advice in an independent, expert peer review (Popper 2018) that the duration of exposure to the most intense sounds that could result in TTS will be over just a few hours, the accumulated SEL results were also presented for several different time windows (1, 2, 3 and 4 hours) that are representative of the “few hours” of the most intense sounds that may be received by fish as the seismic source passes their location at the closet point of approach. The results of this analysis are presented in **Table 6-7** and **Figure 6-8**. These results demonstrate that concepts described by Popper (2018), whereby the majority of sound energy contributing to potential TTS effects will be received when the seismic survey vessel is at very close range and over a short period of time. Sound energy included in the 24-hour accumulation scenario from greater distances and over greater timeframes contributes very little to the overall accumulated SEL experienced by fishes. What the analysis does not show is the recovery that may take place between periods of exposure, which Popper (2018) indicates will start as soon as the most intense sounds end. Therefore, some recovery may occur in fishes in between the main periods of exposure and the ranges to TTS in fishes based on the 24-hour scenario is likely to be conservative.

Table 6-7: Distances to maximum-over-depth SEL_{24hr} based on fish TTS criteria for different time windows for the considered static receiver locations

Threshold for SEL_{24hr} (dB re 1 µPa²·s)		Scenario 1					Scenario 2				
		1 h	2 h	3 h	4 h	24 h	1 h	2 h	3 h	4 h	24 h
		Range (km)					Range (km)				
Fish TTS	186	3.0	3.1	3.1	3.1	3.3	3.5	4.0	4.2	4.3	4.7

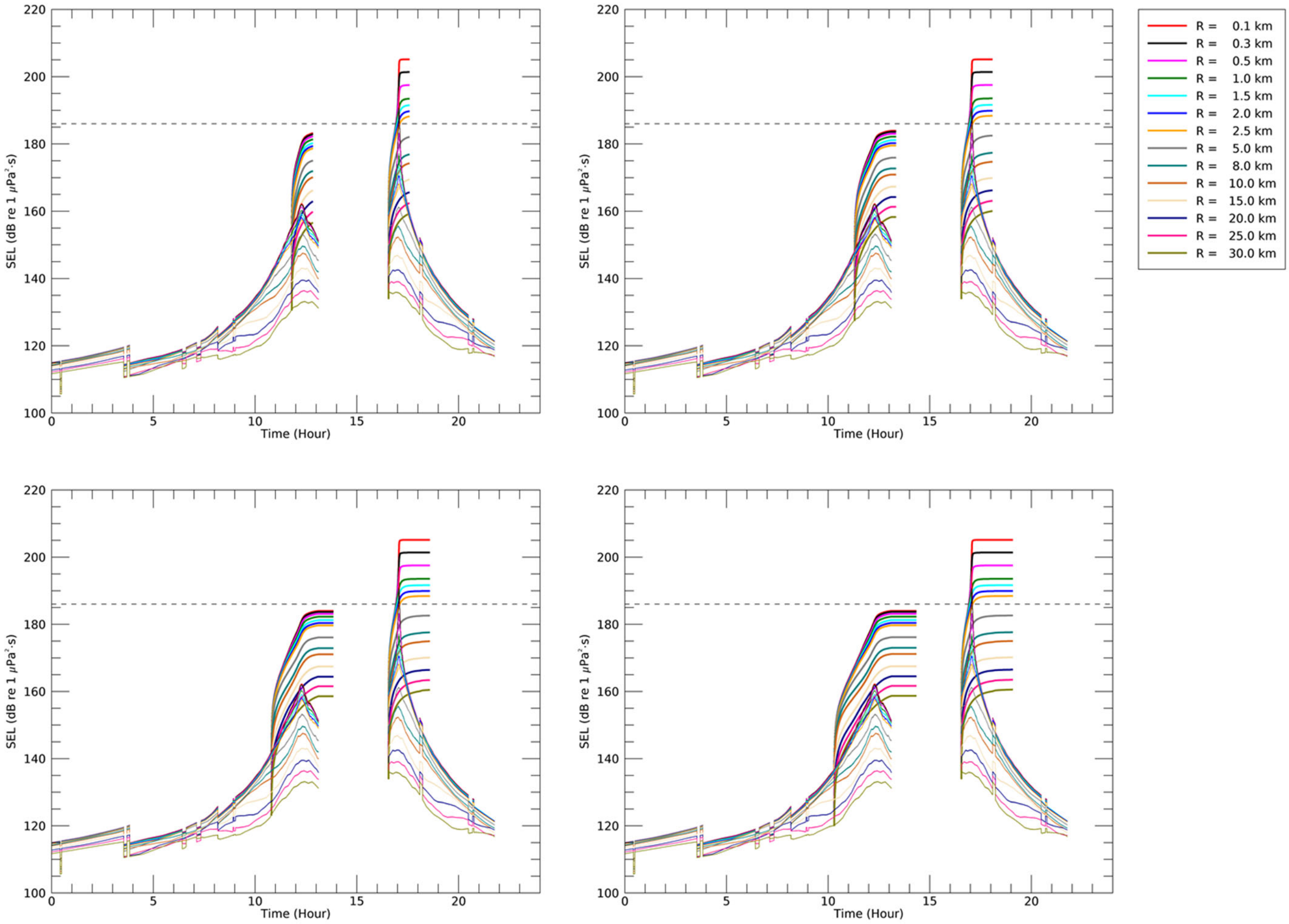

Figure 6-8: Example of maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receiver locations at increasing distance from the survey lines for Scenario 1. Clockwise from top-left the plots show accumulation over a 1, 2, 3 and 4 hour window. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 µPa²·s

6.2.2.7.4 Impact assessment

Potential impacts to fish in general are within an acceptable level based on:

- The assessment criteria applied are conservative (based on the review of the research and scientific papers (**Appendix I**);
- In relation to the Fisheries Research Report No. 288, *Risk Assessment of potential impacts of seismic air gun surveys on marine finfish and invertebrates in Western Australia* (Webster *et al*. 2018), the risk assessment outcomes for individuals of finfish, based on water depth and volume of air guns categories, returned the maximum risk scores ranging from high for demersal finfish to negligible for pelagic finfish. This applies to mortality of individual fish only and does not relate to populations.
- Mortality of fish (both immediate and delayed) is considered highly unlikely based on no documented cases of mortality in free-swimming fish upon exposure to seismic airgun sound under experimental or field operating conditions (ERM 2017). Given that the type of demersal and pelagic fishes characteristic of the habitats in the operational area are free swimming species, the potential for exposure to sound at levels that can result in mortality, mortal injury or recoverable injury is unlikely given that fish are able to detect the direction of the sound and may move. Adult fish not in the immediate vicinity of the noise generating activity are generally able to vacate the area and avoid physical injury.
- Popper *et al*. (2005) reports that fish that showed TTS recovered to normal hearing levels within 18-24 hours, the potential area of impact for fish TTS is assessed as being acceptable based on hearing loss (and subsequent decrease in fitness) being temporary and recovery taking place in a relatively short timeframe after the source array has moved away from the exposed fish, and the sound levels are reduced;
- Any behavioural impacts are likely to be short-lived and fish would return to normal behaviours once the vessel has moved away based on research by Woodside (2011a, 2011b), Miller and Cripps (2013) and Wardle *et al*. (2001). Based on Popper *et al*. (2014) behavioural effects are assessed as high within tens of metres of the seismic source. Behavioural impacts to demersal and pelagic fish species are possible but would be temporary, localised and unlikely to impact at a population level;
- Pelagic fish such as mackerel are strong swimmers swimming up to 100 km along the coast (DPIRD 2018). Thus, potential mortality injury, recoverable injury and TTS are unlikely as they can swim away from a seismic source. Impacts are more likely to be behavioural including avoiding or moving away from the area for the period of the survey;
- Demersal fish species such as snapper, emperor and cod though not as strong swimmers as pelagic fish species are able to move away from an approaching seismic source. Thus, potential mortality, potential mortality injury, recoverable injury and TTS are unlikely with behavioural impacts more likely;
- Available evidence suggests that behavioural changes for some fish species may be no more than a nuisance factor, and that within a few seconds they continue their previous activity. The temporary, short range displacement of pelagic or migratory fish populations may have insignificant repercussions at a population level (McCauley, 1994).

Demersal fish species

The various species of demersal snappers (Lutjanidae), emperors (Lethrinidae), rock cods and groupers (Serranidae) that are characteristic of the operational area do not possess a mechanical connection between the swim bladder and the ears, and can be said to have mid to poor hearing ability (Tavolga and Wodinsky 1963; Higgs *et al*. 2006; Braun and Grande 2008; Engineering-Environmental Management, Inc. 2008; United States Department of the Navy 2008; Popper 2012; Caiger *et al*. 2012). Therefore, these species of fish are considered to belong to the group of fishes that are primarily sensitive to particle motion with limited sensitivity to sound pressure. For example, **Figure 6-7** in **Section 6.2.2.6** demonstrates how particle acceleration at the seafloor is predicted to increase significantly within tens-to-hundreds of metres of the seismic source.

Despite exhibiting particular habitat preferences and some fidelity to an area, these demersal fish species can be found across a variety of habitats and are typically more mobile and have relatively large home ranges (several kilometres) (Ovenden *et al*. 2004; Moran *et al*. 2004; Newman *et al*. 2008; Parsons *et al*. 2011; Harasti *et al*. 2015). Therefore, demersal fishes can reasonably be expected to exhibit an avoidance response and swim away from the approaching seismic source before sound levels approach levels that may result in mortality, injury or significant TTS effects.

Popper *et al*. (2014) indicate that the potential for behavioural impacts in this category of fishes is high in the near-field (tens of metres), moderate at intermediate distances (hundreds of metres) and low in the far field (thousands of metres). Therefore, behavioural responses are considered likely to occur within tens or hundreds of metres from the seismic source. The fishes' awareness of the sound and any resultant behavioural responses may be limited to a few hours as the seismic source approaches from several kilometres away and passes, while significant behavioural responses (startle or avoidance) are more likely to be limited to a short period (less than an hour) when the seismic source passes close by. As the seismic source will be transient (i.e. continuously moving) during seismic data acquisition, demersal fishes will only be exposed to significant sound levels for a relatively short period of time as the seismic survey vessel passes nearby before sailing away again.

Fish behaviours may return to normal within less than an hour (sometimes just minutes) of the seismic survey vessel passing (Wardle *et al*. 2001; Woodside 2011a, 2011b; Miller and Cripps 2013). Limited data on biochemical stress indicators in fishes exposed to seismic sound indicates there may not be any discernible change (e.g. McCauley *et al*. 2000, 2003). However, if fishes were to experience stress as a result of sound exposure, levels may return to normal within 72 hours (Santulli *et al*. 1999).

Pelagic fish species

Key pelagic fish species that may occur in the operational area include Spanish mackerel and various other mackerels (e.g. grey mackerel), as well as various species of tuna and billfish. These species either do not possess a swim bladder or it is poorly developed and not directly connected to hearing (Popper *et al*. 2014), indicating that they are sensitive only to the particle motion component of sound at close range to a sound source.

Pelagic fishes such as mackerel travel distances up to 100 – 300 km or more, while tunas and billfish may travel in the order of thousands of kilometres. Therefore, pelagic fishes can reasonably be expected to exhibit an avoidance response and swim away from the approaching seismic source before sound levels approach levels that may result in mortality, injury or TTS.

Popper *et al*. (2014) indicate that the potential for behavioural impacts in fishes that do not possess a swim bladder or where the swim bladder is not directly linked to hearing is high in the near-field (tens of metres), moderate at intermediate distances (hundreds of metres) and low in the far field (thousands of metres). Therefore, behavioural responses in species such as mackerel are considered likely to occur within tens or hundreds of metres from the seismic source. Therefore, the extent and duration of behavioural impacts to large pelagic fishes in the operational area is likely to be similar or less than those predicted for demersal fishes. In addition, the transient nature of the seismic source and the highly mobile nature of pelagic fish species means that behavioural avoidance responses and effects on distribution will be incidental, localised and of short duration.

It is acknowledged that the large predatory pelagic fishes target smaller pelagic fishes as prey such as herrings or sardines which have a swim bladder connection in their hearing and may therefore be more sensitive to sound from the seismic source than mackerels, tunas and billfish. These more sensitive baitfish may exhibit a behavioural response and some level of avoidance over several kilometres from the seismic source. Again, given the highly transient nature of the survey and pelagic fishes, the impacts will be short-term and relatively insignificant, but may result in predatory pelagic species such as mackerel following the food source, which may result in changes in distribution over several kilometres. While changes in fish behaviours may be limited to a few minutes or hours, the duration of changes in fish distribution may vary. For example, Wardle *et al*. (2001) observed that the distribution of mackerels showed no sign of moving away from the reef where they were being studied, whereas studies into more sound sensitive herring and cod species reported that their distribution may potentially remain altered for days following exposure (e.g. Slotte *et al*. 2004; Engås *et al*. 1996 and Engås and Løkkeborg 2002).

Spawning and recruitment of commercially significant fish species

During the relatively short periods of behavioural disturbance, fishes may be temporarily diverted away from activities such as egg production and spawning (Hawkins and Popper 2016; Carroll *et al*. 2017).

Consultation with commercial fishing stakeholders (**Section 4**) has identified concerns that seismic surveys have long term impacts to the fish stocks, and their concern is that the risk to the fish stocks and responsibility for managing the stocks is placed entirely on the fishing industry. Therefore, Santos has considered the potential impact of the Keraudren Extension 3D MSS on the spawning of key indicator fish stocks in more detail.

To assess the potential impacts of the Keraudren Extension 3D MSS on the spawning fish populations, Santos has considered the potential spatial and temporal overlap of the survey with the key indicator fish stocks for the Pilbara region. As outlined in **Section 3.2.4.3**, many of the demersal and pelagic fish species spawn throughout their ranges at locations where water depths, habitat and a range of other environmental conditions are suitable (Domeier and Colin 1997; Claro and Lindeman 2003; Claydon 2004). These types of demersal fishes are highly fecund, multiple broadcast spawners, releasing large numbers of eggs on multiple occasions over an extended spawning season (typically millions of eggs per year) (Claydon 2004; Newman *et al*. 2008). Some of these species show genetic connectivity across northern Australia (e.g. Spanish mackerel, red emperor) indicating that spawning throughout this range contributes to the recruitment of stock. This could contribute to the resilience of the fish stocks to localised disturbances.

As described for individual fish species in the Australian Fisheries Research and Development Corporation (FRDC) Status of Australian Fish Stocks (SAFS) reports (https://www.fish.gov.au/), stock structures may be considered in terms of the genetic stock, whereby genetic homogeneity is maintained by the dispersal of pelagic eggs and larvae among regions (Newman et al. 2000; Department of Fisheries 2004). The eggs and larvae released by spawning adult fish in the region may disperse for several days or weeks and may travel for hundreds of kilometres or more before settling on the seabed (Newman et al. 2000; Mackie et al. 2009, 2010; Marriott et al. 2012; Berry et al. 2012).

The fish stocks are also considered in terms of smaller more discrete management units, which are adopted by fisheries management authorities for the purposes of fisheries management. The management units consider the genetic stock, but also take into account the smaller ranges and localised movements of adult and juvenile fish, and the extent of the fisheries that target the stocks. Consequently, the fisheries management units are typically smaller than the extent of the genetic stocks, which is appropriate for the purposes of fisheries management given the potential for fishing mortalities and the number of adult fishes in an area to be reduced.

However, as demonstrated above, seismic surveys are not expected to kill adult fishes or reduce the spawning adult biomass. Therefore, the potential for impacts to the wider genetic stock as a result of localised disturbances to spawning fishes, potentially leading to a reduction in the spawning success of those fishes and the number of eggs and larvae released within the stocks, is the key consideration for this impact assessment. Therefore, Santos has assessed the potential effect of a seismic survey on the genetic stocks of key indicator fish species.

Fish stock area boundaries and spawning depths (**Table 6-8**) and durations (refer to **Section 3.2.4.3**) have been used based on the available information, noting that fish will not be equally distributed within these areas, however, these fish species are present across large areas and a wide range of water depths, and spawn over extended periods. Therefore, the assessment provides a simplistic method of assessing the potential spatial and temporal overlap of the Keraudren Extension 3D MSS with the identified fish stocks.

The spatial and temporal overlap of the Keraudren Extension 3D MSS with key indicator fish stocks is presented in **Table 6-8**. This includes the spatial overlap of the entire survey area with principal fish depth ranges and resultant percentage of overlap with the fish stock range; and the temporal overlap with fish species spawning period both in days and as a percentage of the spawning period.

Table 6-8: Spatial and temporal overlap of the Keraudren Extension 3D MSS with the spawning range and spawning periods of key indicator fish stocks

Key Indicator Fish Stock	Survey area spatial overlap with principal depth range	Maximum survey temporal overlap with fish spawning period
Red emperor:		
Principal depth range: 10 – 180 m **Stock range (area within depth range):** 494,173 km^2 A single genetic stock between Queensland and Shark Bay in WA, but for the purposes of the assessment, a smaller stock range has been assumed to extend from the WA-NT border. **Spawning period:** 303 days (Sept-Jun)	8,620 km^2 2%	150 days 50%
Bluespotted emperor		
Principal depth range: 5 – 110 m **Stock range (area within depth range):** 177,449 km^2 A single biological stock from the Lacepede Islands to Abrolhos Islands. **Spawning period:** 275 days (Jul-Mar)	4,986 km^2 3%	90 days 33%
Rankin cod		
Principal depth range: 10 – 150 m **Stock range (area within depth range):** 195,877 km^2 A single biological stock from the Lacepede Islands to Shark Bay. **Spawning period:** 245 days (June-Dec, Mar)	7,872 km^2 4%	120 days 49%
Goldband snapper		
Principal depth range: 50 – 200 m **Stock range (area within depth range):** 124,441 km^2 A single genetic stock is considered from Lynher Bank north of Broome to Shark Bay, but the stock	8,620 km^2 6.9%	120 days 49%

range has been conservatively assumed to extend only to the North West Cape, which is the westerly limit of the Pilbara fisheries.		
Spawning period: 244 days (Oct-May)		
Ruby snapper		
Principal depth range: 150 – 480 m	707 km^2 2%	89 days 59%
Stock range (area within depth range): 43,572 km^2 The genetic stock is uncertain, and the Pilbara management unit has been used for the purposes of the assessment instead.		
Spawning period: 152 days (Dec-Apr)		
Spanish mackerel		
Principal depth range: 0 – 50 m	10 km^2 0.01%	0 days 0%
Stock range (area within depth range): 186,753 km^2 The north and west coasts of Australia (Northern Territory and WA), but a smaller stock from the NT border to Shark Bay has been used for the purposes of the assessment.		
Spawning period: 91 days (Sept-Dec)		

In considering the spatial overlaps in **Table 6-8**, it is important to recognise that not all fish within the survey area will be exposed to seismic sound impulses at the same time. Behavioural fish disturbances, and potential spawning affects, at any one time are predicted to be limited to areas in close proximity to the operating seismic source (tens to hundreds of metres; Popper et al. 2014). Disturbance over kilometres is possible for some fish species, but the potential for this is considered low by Popper et al. (2014) specifically in the context of the commercially targeted demersal and pelagic species and their hearing mechanisms. The same fish may be exposed again to the seismic source within the next day or two when the seismic vessel returns to acquire the adjacent lines in the 'racetrack', which are spaced approximately 450 m apart. The seismic vessel will gradually move across the survey area, and the sound levels will reduce. Hence, there will be large areas within the survey area unaffected by sound or with sound below levels that might disturb fish.

After the seismic source has passed and sound levels fall below levels that may result in behavioural changes in fish at a specific location, fish behaviour and physiological responses (e.g. stress) may return to normal within minutes or hours, or within a few days as a worst case, based on the literature referenced in **Appendix I**.

Therefore, despite the potential for some temporary and localised disturbances, there is unlikely to be a significant population level affect, particularly considering natural levels of variability in spawning and recruitment. For example, an assessment undertaken by the former WA Department of Fisheries (2015b) of the status of red emperor and goldband snapper in the region indicated that the red emperor spawning population decreased to approximately 35% of unfished levels between 1980 and 2013 while annual recruitment success fluctuated between approximately 150 million fish and 400 million fish per year over the same period with no apparent trend or reduction in recruitment associated with the reduced spawning biomass. Similarly, goldband snapper spawning biomass also declined steadily to less than 40% of unfished levels while annual recruitment success fluctuated between a minimum of approximately 250,000 and 900,000 fish. This provides an indication of the normal inter-annual variability in spawning and recruitment of demersal fishes.

It is acknowledged that the Keraudren Extension 3D MSS may affect spawning fish and the fish stocks, which is in addition to other natural influences and commercial fishing pressures placed on the stocks. However, the proportion of the stocks exposed to the seismic source is relatively small. The Australian Government's Fisheries Research & Development Corporation has previously noted that long-lived species such as goldband snapper are unlikely to be affected by 'short-duration' environmental/climatic changes (of one or a few years), because adult stocks comprise fish that are recruited over many years (Martin *et al*. 2014). Therefore, in comparison, the occasional, short-term, transient and localised disturbances to groups of fish as a result of the seismic survey would have impacts many orders of magnitude smaller than regional scale environmental/climatic events that would affect entire stocks.

Potential impacts to spawning and recruitment within commercially significant demersal and pelagic fish stocks are therefore within an acceptable level based on:

- The high fecundity and broadcast spawning characteristics of key demersal and pelagic fish species in the region, which provide for genetic connectivity of the stocks over extensive areas;
- The proposed timing of the Keraudren Extension 3D MSS (February to July) avoids significant proportions of the spawning periods by many of the key indicator fish species, for example, five of the nine spawning months of red emperor, six of the eight spawning months of bluespotted emperor, and all of the Spanish mackerel spawning period;
- A small spatial-temporal overlap of the Keraudren Extension 3D MSS with the genetic stocks and spawning periods of key indicator fish species;
- The approach to assessing the spatial-temporal overlap of the survey includes a level of conservatism as it assumes that fish within the area of disturbance fail to spawn completely, whereas they may actually delay spawning until the seismic source has passed their location or move elsewhere and spawn normally;
- The level of disturbance and spatial-temporal overlap with the key fish stocks is expected to be negligible in the context of natural variability in spawning success and recruitment; and
- Commercial fish catches within the Pilbara Demersal Scalefish Fisheries and Mackerel Managed Fishery have been within or exceeded the acceptable catch ranges, with significant increases in catch within the trawl fishery since 2016, despite a history of seismic surveys across the fisheries.

Fish assemblages associated with the ancient coastline at 125 m depth contour KEF

The SPRAT profile for the ancient coastline at 125 m depth contour KEF states "*Little is known about fauna associated with the hard substrate of the escarpment, but it is likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates"*. There is little published information on the fish communities associated with the ancient coastline at 125 m depth contour KEF but due to the presence of epibenthic communities associated with hard substrate, it was considered that demersal fish species may be present in abundance. As described in **Section 3.2.3.2**, a recent study of the ancient coastline KEF within part of the Keraudren Extension 3D MSS operational area has indicated that a consistent structurally complex seabed feature that may provide unique habitat for demersal and site-attached fish was not evident (RPS, 2019).

The Keraudren Extension 3D MSS overlaps with approximately 20% of the ancient coastline at the 125 m depth contour KEF. During the survey, demersal fish populations associated with the KEF will be exposed to short term increases in sound levels form the transient seismic source as it passes across the KEF. Given that the demersal fishes in this region are generally free-swimming species that are able to avoid the approaching sound source and significant behavioural disturbances are likely to be limited to ranges of tens or hundreds of metres form the seismic source and behaviours may return to normal within minutes or hours, these disturbances are not expected to result in significant population level impacts. No significant or long-term changes to the spatial distribution or numbers of demersal fishes are expected and so the potential long-term implications to populations are expected to be negligible.

6.2.2.7.5 Summary

Based on the impact assessment no long term or population impacts to individual fishes or fish stocks, or fish assemblages associated with the ancient coastline at the 125 m depth contour KEF are predicted, thus the consequence level is assessed as minor.

6.2.2.8 Sharks

6.2.2.8.1 Receptors

The operational area overlaps a whale shark foraging and migration BIA. Other shark species (e.g. sandbar shark, *Carcharhinus plumbeus*) are likely to transit the operational area, but potential impacts to whale sharks within a known migratory path has been used as a worst-case scenario for this environmental assessment.

Foraging habitat for whale sharks and other shark species is a conservation value of the Argo-Rowley Terrace AMP located 23 km north of the operational area and 46 km north of the survey area (full power zone and ramp-up zone).

Eighty Mile Beach AMP is adjacent to State coastal waters that are important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish and river sharks. However, these areas are located over 50 km from the operational area and no disturbance will occur in these waters.

6.2.2.8.2 Impact pathways and sensitivities

Limited research has been conducted on shark responses to marine seismic surveys. Myrberg (2001) stated that sharks differ from bony fish in that they have no accessory organs of hearing such as a swim bladder and therefore are unlikely to respond to acoustical pressure. The study also suggested that the lateral line system does not respond to normal acoustical stimuli and is unable to detect sound-induced water displacements beyond a few body lengths, even with large sound intensities (Myrberg 2001). Other reports indicate that sharks are highly sensitive to sound between approximately 40 and 800 Hz, which overlaps with seismic sound frequencies. Klimley and Myrberg (1979) established that an individual shark will suddenly turn and withdraw from a sound source of high intensity (more than 20 dB re 1 µPa above broadband ambient SPL) when approaching within 10 m of the sound source.

6.2.2.8.3 Thresholds

No threshold criteria currently exist for acoustic impacts from seismic exposure to sharks.

As a conservative and precautionary approach, the Popper *et al*. (2014) exposure guideline for fish with no swim bladder for potential mortality, mortal injury and recoverable injury peak pressure level threshold of >213 dB re 1 µPa (PK) has been applied for this assessment.

6.2.2.8.4 Impact assessment

The threshold criteria of >213 dB re 1 µPa (PK) for injury was reached at a maximum distance of 70 m for maximum-over-depth, which is relevant for sharks that reside within the water column, and between 38 and 87 m on the seabed (refer **Table 6-6**).

It is expected that the potential effects to whale sharks foraging within the BIA associated with acoustic noise will be the same as for other pelagic fish species, resulting in minor and temporary behavioural change such as avoidance. This aligns with Popper *et al*. (2014) guidelines, which detail that there is the potential for high risk of behavioural impacts in fish species near (tens of metres) the seismic source with the level of risk declining to low at thousands of metres from the seismic source.

Shark species are highly vagrant and naturally cover large distances. As such, short-term exposures from the transient seismic source is expected to result in only localised behavioural responses and movements of sharks. The research by Bruce *et al*. (2018), which tagged two commercially targeted shark species (broadnose shark and school shark) and monitored their movements in response to a seismic survey in Australian waters noted that both control sharks and exposed sharks moved freely in and out of the study area which did not indicate any changes in behaviour or distribution as a result of seismic sound exposure.

Potential impacts to whale sharks are considered to be within an acceptable level based on the following:

- Acoustic modelling indicating sound levels with potential harmful effects limited to within less than 100 m of the seismic sources. Mortality, potential mortal injury and recoverable injury to sharks are unlikely with impacts more likely to be behavioural including avoiding or moving away from the area for the period of the survey.
- The ramp-up/ full-power zone overlaps approximately 5% of the total whale shark foraging and migration BIA (220,505 km^2).
- Whale sharks spend majority of their lives in the open ocean; however, they also form predictable seasonal aggregations of mostly juvenile males on the coastal shelves of tropical regions e.g. Ningaloo from March to July (Andrzejaczek, 2016). These whale sharks then migrate north along the 200 m isobath mainly between July and November (TSSC 2015). Thus, transiting whale sharks from Ningaloo Reef may occur within the Keraudren Extension 3D MSS operational area. The operational area overlaps the whale shark foraging BIA. However, the BIA is not restricted by the location of the seismic activity, with sufficiently deep open water around the entire operational area for whale sharks to traverse.
- Whale sharks may be momentarily disturbed during foraging but will not be displaced from their foraging habitat.
- As the seismic survey will be acquired before 31 July, there is only a small period in time where potentially a low number of northern migrating whale sharks may be encountered within the operational area.
- Seismic noise has not been identified as a threat to whale sharks (or other shark species identified that may be in the area) in either the Approved Conservation Advice (TSCC 2015) or previous in force Whale Shark Recovery Plan 2005 – 2010 (DEH 2005a). Noise pollution is not identified as a pressure to whale sharks in the Marine Bioregional Plan for the North-west Marine Region (DSEWPaC 2012b).

6.2.2.8.5 Summary

Based on the impact assessment no long term or population impacts to whale sharks, or other shark species, are predicted thus the consequence level is assessed as minor.

6.2.2.9 Cetaceans

6.2.2.9.1 Receptors

As described in **Section 3.2.3**, eleven cetacean species may occur in the operational area; eight whale species and three dolphin species. The operational area does not overlap any known resting, nursing, breeding or foraging habitats for any cetacean species, however, key sensitivities include the following:

- Humpback whale migration pathway and BIA, which occurs in nearshore waters and overlaps the southern part of the operational area;
- Pygmy blue whale migration BIA, which passes approximately 30 km north-west of the operational area and over 100 km from the survey area;

A number of other cetacean species may also occur in the operational area from time to time, such as sei, fin, Bryde's and sperm whales, orcas, and spotted bottlenose dolphin, but the operational area and surrounding waters are not identified as significant habitat for these species.

Based on the available information on potential habitat use of these species, individuals in the operational area are expected to be transitory. Based on presence of BIAs, the following environmental assessment focuses on humpback and pygmy blue whales.

The humpback whale migration pathway is a value of the Eighty Mile Beach AMP located approximately 6 km south of the operational area. The pygmy blue whale migration pathway is a value of the Argo-Rowley Terrace AMP, located 23 km north of the operational area.

6.2.2.9.2 Impact pathway and sensitivities

The potential impacts of anthropogenic noise on marine mammals, specifically cetaceans, have been the subject of considerable research. Current data and predictions show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity, as well as frequency band of hearing (Richardson *et al.* 1995; Wartzok and Ketten 1999; Southall *et al*. 2007). To better reflect the auditory similarities between phylogenetically closely related species, but also significant differences between species groups among the marine mammals, Southall *et al.* (2007) assigned the extant marine mammal species to functional hearing groups based on their hearing capabilities and sound production. More recently, U.S. Navy technical reports by Finneran (2015, 2016) proposed new auditory weighting functions and the U.S. NMFS (2016, 2018) undertook a comprehensive review of PTS and TTS dual metric criteria for marine mammals and revised the threshold criteria for each frequency-weighted functional hearing category of cetacean. **Table 6-9** summarises the generalised hearing ranges for each of the defined functional hearing groups of marine mammals, adapted from NMFS (2018). The potential impact pathways and sensitivities are summarised in **Table 6-10**, further detail on relevant scientific studies and research undertaken used to inform this impact assessment is included in **Appendix I**.

Table 6-9: Marine mammal functional hearing groups (NMFS 2018)

Low-frequency (LF) cetaceans (mysticetes or baleen whales)	This functional hearing group comprises all baleen whale species (mysticetes). There has been no direct measurement of hearing sensitivity in any of these species. The audible frequency range of mysticetes – collectively treated as a single functional hearing group – is approximately between 10 Hz to 35 kHz (based on anatomical data and functional models of the hearing system). Baleen whales (humpback and pygmy blue whales) are predominantly LF species. Generalized hearing range: 7 Hz to 35 kHz
Mid-frequency (MF) cetaceans (odontocetes: dolphins, toothed whales, beaked whales, bottlenose whales)	Based on the frequency range of their vocal emissions as well as the known hearing ranges, most dolphin species, all beaked and killer whale species and the sperm whale belong to this functional hearing group. The frequency range of their sounds excluding echolocation clicks are mostly <20 kHz with most of the energy typically around 10 kHz, although some calls may be as low as 100 to 900 Hz, ranging from 100 to 180 dB re 1 µPa (Richardson *et al*. 1995). Generalized hearing range: 150 Hz to 160 kHz
High frequency (HF) cetaceans (other odontocetes: true porpoises, *Kogia*, river dolphins, cephalorhynchid, hourglass dolphin, Peale's dolphin)	Porpoises, dwarf and pygmy sperm whales (*Kogia spp*.), river dolphins, as well as hourglass dolphins and Peale's dolphin produce narrow-band high-frequency echolocation signals. This group of species have been collectively classified as high-frequency cetaceans. Generalized hearing range: 275 Hz to 160 kHz

Table 6-10: Impact pathways and sensitivities for cetaceans

Impact Pathway	Summary
Mortality and mortal injury	There is no conclusive evidence of a link between noise produced from seismic surveys and mortality of cetaceans (Gotz *et al*., 2009).
PTS (physical injury to an animal's hearing organs)	PTS is hearing loss form which marine fauna do not recover (permanent hair cell or receptor damage). PTS is considered injurious in marine mammals, but there are no published data on the sound levels that cause PTS in marine mammals. The NMFS (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy (SEL_{24h}), or very loud, instantaneous peak sound pressure levels.
TTS (temporary reduction in an animal's hearing sensitivity)	Hearing loss from which marine fauna recover, usually within a day at most. Exposure to sufficiently intense sound may lead to an increased hearing threshold in any living animal capable of perceiving acoustic stimuli. If this shift is reversed and the hearing threshold returns to normal, the effect is called a temporary threshold shift (TTS). The onset of TTS is often defined as threshold shift of 6 dB above the normal hearing threshold (Southall *et al*. 2007). If the threshold shift does not return to normal, the residual shift is called a permanent threshold shift (PTS). Threshold shifts can be caused by acoustic trauma from a very intense sound of short duration, as well as from exposure to lower level sounds over longer time periods (Houser *et al*. 2017). Injury to the hearing apparatus of a marine animal may result from a fatiguing stimulus measured in terms of sound exposure level (SEL), which considers the sound level and duration of the exposure signal. Intense sounds may also damage the hearing apparatus independent of duration, so an additional metric of peak pressure (PK) is needed to assess acoustic exposure injury risk. In marine mammals, the onset level and growth of TTS is frequency specific, and depends on the temporal pattern, duty cycle and the hearing test frequency of the fatiguing stimuli. Sounds generated by seismic airguns, pile-driving and mid-frequency sonars have been tested directly and proven to cause noise-induced threshold shifts in marine mammals at high received levels. There is, however, considerable individual difference in all TTS-related parameters between subjects and species tested so far.
Masking	Masking is the process by which the threshold of hearing for one sound is raised by the presence of another (masking) sound (Erbe & Farmer 1998; Erbe 2008; Erbe *et al*. 2016). This describes the reduction in audibility for one sound (termed 'signal') caused by the simultaneous presence of another sound (termed 'noise'). Auditory masking can lead to disruption of a behaviour, lack of appropriate behavioural reactions, increased vulnerability to predators, reduced access to prey, reduced communication, changes in vocal behaviour, disruption of spawning activities and stress. While masking can be detrimental to the fitness, reproduction, and survival of individuals, it ends immediately after the masking sound ceases. Both anthropogenic and natural marine sound can affect hearing and partially or completely reduce an individual's ability to effectively communicate; detect important predator, prey, and/or conspecific signals; and detect important environmental features associated with spatial orientation (Clark *et al*. 2009). This is true for all marine fauna; however, masking is most frequently associated with marine mammals. Masking reduces the communication space of marine mammals (Clark *et al*. 2009; Hatch *et al*. 2012).
Behavioural effects	Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate sound exposure metric for assessing behavioural reactions. It is considered that avoidance behaviour represents a temporary and minor effect, unless avoidance results in displacement of whales from breeding, resting or feeding areas. There are no such known areas within the operational area. The intensity of behavioural responses of marine mammals to sound exposure ranges from subtle responses, which may be difficult to observe and have little implications for the affected animal, to obvious responses, such as avoidance or panic reactions. The context in which the sound is received by an animal affects the nature and extent of responses to a stimulus. The threshold for elicitation of behavioural responses depends on received sound level, as well as multiple contextual factors such as the Activity state of animals exposed to different sounds, the

	nature and novelty of a sound, spatial relations between a sound source and receiving animals, and the gender, age and reproductive status of the receiving animal.

6.2.2.9.3 Thresholds

The threshold criteria in **Table 6-11** have been adopted for the assessment of potential noise impacts to cetaceans. Threshold criteria are presented as dual metric thresholds using weighted cumulative sound exposure level (SEL_{cum},) and peak sound pressure (PK) metrics for impulsive sounds. NMFS 2018 considers onset of PTS to have occurred when either one of the two is exceeded. For non-impulsive sounds, threshold criteria are provided using the weighted SEL_{cum} metric. **Table 6-11** also provides the modelled distances for the criteria.

There are no defined noise exposure criteria for mortality and potential mortal injury impacts for cetaceans. These effects are extremely unlikely to occur as received sound levels of sufficient magnitude to cause mortality/ potential mortal injury are only likely to occur at extremely close range (i.e. <10 m) to an operating seismic source. This scenario is extremely unlikely to occur given the control and mitigation measures that are implemented for marine seismic surveys in Australian waters, in compliance with EPBC Policy Statement 2.1 (i.e. use of MFOs; observation, low-power and shutdown zones; soft starts etc.).

Table 6-11: Sound level threshold criteria and values for mortality and impairment in cetaceans

	Potential Impacts					
	Impairment - PTS		Impairment - TTS		Behavioural	
Threshold Criteria	PTS is considered injurious in marine mammals, but there are no published data on the sound levels that cause PTS in marine mammals. Impact assessment evaluates dual metric criterion requiring consideration of both PK and accumulated SEL. PTS onset thresholds for marine mammals have not been directly measured, the NMFS (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy (SEL_{24h}), or very loud, instantaneous peak sound pressure levels (PK) through extrapolation from available TTS onset measurements.		The onset of TTS is often defined as threshold shift of 6 dB above the normal hearing threshold (Southall *et al*. 2007). In marine mammals, the onset level and growth of TTS is frequency specific, and depends on the temporal pattern, duty cycle, and the hearing test frequency of the fatiguing stimuli. There is considerable individual difference in all TTS-related parameters between subjects and species tested so far.		NMFS currently uses a step function with a 50% probability of inducing behavioural responses at an SPL of 160 dB re 1 µPa to assess behavioural impact. This threshold value was derived from the HESS (1999) report, which, in turn, was based on the responses of migrating mysticete whales to an airgun sounds (Malme *et al*. 1983, 1984). An extensive review of behavioural responses to sound was undertaken by Southall *et al*. (2007, their Appendix B). They found varying responses for most marine mammals between an SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report. There is no SEL_{24h} metric for behavioural responses in HF cetaceans, so per pulse SPL of 160 dB re 1 µPa criterion is used to assess these impacts. *Note – the same unweighted behavioural response criteria are used for all cetaceans.*	
Relevance of thresholds adopted	The PTS and TTS thresholds are from NMFS (2018) which is the most current, globally recognised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing has been adopted for this Activity. Given that it is difficult to determine thresholds for behavioural response in individual cetaceans as often the way they respond varies (Nowacek *et al.* 2004, Gomez *et al.* 2016, and Southall *et al.* 2016) and is influenced by both biological and environmental factors such as age, sex, and activity at the time etc. The behavioural disturbance threshold criteria applied is the current NMFS criterion for marine mammals and which summates the most recent scientific literature on the impacts of sound on marine mammal hearing so considered the most relevant to this Activity.					
	Potential Impacts: High-Frequency (HF) cetaceans					
	Impairment - PTS		**Impairment - TTS**		**Behavioural**	
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**
Threshold Values	202 dB PK[1]	155 dB SEL_{24h}[1]	196 dB PK[2]	140 dB SEL_{24h}[2]	160 dB SPL[3]	

Modelled Distance	230 - 430 m	50 m (scenario 1 - south) 40 m (scenario 2 - north)	690 - 780 m	530 m (scenario 1 - south) 860 m (scenario 2 - north)	5.7 - 8.8 km	NMFS 2013 does not define an SEL exposure criteria for behaviour for cetaceans.
	Potential Impacts: Mid-Frequency (MF) cetaceans					
	Impairment - PTS		**Impairment - TTS**		**Behavioural**	
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**
Threshold Criteria	230 dB PK[1]	185 dB SEL_{24h}[1]	224 dB PK[2]	170 dB SEL_{24h}[2]	160 dB SPL[3]	NMFS (2013) does not define an SEL exposure criteria for behaviour for cetaceans.
Modelled Distance	< 20 m	Not exceeded (scenario 1 - south) 20 m (scenario 2 - north)	20 m	40 m (scenario 1 - south) 20 m (scenario 2 - north)	5.7 - 8.8 km	
	Potential Impacts: Low-Frequency (LF) cetaceans					
	Impairment - PTS		**Impairment - TTS**		**Behavioural**	
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**
Threshold Criteria	219 dB PK[1]	183 dB SEL_{24h}[1]	213 dB PK[2]	168 dB SEL_{24h}[2]	160 dB SPL[3]	NMFS (2013) does not define an SEL exposure criteria for behaviour for cetaceans.
Modelled Distance	40 m	2.2 km (scenario 1 - south) 3.1 km (scenario 2 - north)	60 – 70 m	25.7 km (scenario 1 - south) 31.1 km (scenario 2 - north)	5.7 - 8.8 km	

1: NMFS (2018) – Table 4

2: NMFS (2018) – Table AE-1

3: NMFS (2014)

6.2.2.9.4 Impact assessment

The type and scale of the effect of seismic sound on cetaceans will depend on a number of factors including the level of exposure, the physical environment, the location of the animal in relation to the sound source, how long the animal is exposed to the sound, the exposure history, how often the sound repeats (repetition period) and the ambient sound level. The context of the exposure plays a critical and complex role in the way an animal might respond (Gomez *et al*. 2016; NMFS 2016). Without appropriate control measures in place, noise emissions from the seismic source have the potential to impact cetaceans by causing changes to hearing (PTS and TTS) as a result of high sound levels at close range to the seismic source, or behavioural disturbance impacts.

No high-frequency (HF) cetaceans are likely to be present in the operational area and surrounding waters, and accordingly the impact assessment is focused on low-frequency (LF) cetaceans (baleen whales) and mid-frequency (MF) cetaceans (toothed whales and dolphins).

The humpback whale migration BIA passes through the southern part of the operational area and survey area (**Section** 3.2.3). The area of overlap of the seismic survey with the humpback whale migration BIA is presented in **Section 3.2.3.5**. The proposed timing for acquisition of the Keraudren Extension 3D MSS (February to July) means that there may be overlap with the beginning of the northbound migration, which may begin in June and peak in July, continuing into August. The survey will not coincide with the southbound migration of humpback whales through the region (September to October).

Table 6-12: Potential area of impact for humpback whales

	Total area of overlap	% of BIA	Comments
Humpback whale migration BIA overlap with operational area	2,476 km^2	1.3%	Area of operational area as % overlap of the NWMR component of the humpback whale migration BIA.
Humpback whale migration BIA overlap with ramp-up/ full power zone	1,175 km^2	0.6%	Area of operational area as % overlap of the NWMR component of the humpback whale migration BIA.

The operational area overlaps with the distribution BIA for pygmy blue whales, which is a very large area ranging from nearshore coast waters to water depth in excess of 1,000 m (**Figure 3-6**). The migration BIA is located over 100 km north-west of the survey area and over 30 km from the operational area. Acquisition of the survey may overlap the northbound migration (April to August), but avoids the southbound migration period for pygmy blue whales in the region (September to December).

Considering the NMFS (2018) SEL_{24h} threshold criterion, LF-cetaceans (such as humpback and pygmy blue whales) are predicted to experience PTS and TTS at a maximum predicted distance of 2.2 km and 25.7 km respectively in the southern part of the survey area (scenario 1) where there is overlap with the humpback whale migration BIA. In the northern part of the survey area (scenario 2), LF-cetaceans are predicted to experience PTS and TTS at a maximum predicted distance of 3.1 km and 31.1 km respectively. For MF-cetaceans (such as sperm whales, orcas and dolphins) the maximum predicted distance to PTS and TTS effects reduces to 20 m and 40 m respectively, considering both single impulse and SEL_{24hr} metrics.

Based on these modelled distances, PTS and TTS effects may occur to LF cetaceans. Given the pygmy blue whale migration BIA is located over 100 km form the survey area, there is no potential for PTS or TTS to occur to pygmy blue whales as they migrate through these waters along the continental slope. Pygmy blue whales may still traverse the operational area infrequently, however, large numbers of migrating individuals are not expected.

There is, however, potential for PTS and TTS effects to occur within the humpback whale migration BIA during the migration period. As discussed above, the 24-hour SEL is a cumulative metric that reflects the dosimetric (measured dose) impact of noise levels over a period of 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. Therefore, a reported radius for SEL_{24h} criteria does not mean that a whale travelling within this radius of the source will experience PTS or TTS, but rather that an animal could be exposed to the sound levels associated with these effects if it remained in that range for 24 hours. The modelling results show that the corresponding SEL_{24hr} radii for LF-cetaceans were larger than those for peak pressure criteria, but they represent a worst-case scenario that is overly conservative and unlikely to occur.

More realistically, whales would not stay in the same location or at the same range from the seismic source for 24 hours. This would particularly be the case for an animal migrating through the operational area. Data on tagged migrating humpback whales through the waters of the operational area (Jenner *et al*. 2001; Thums *et al*. 2018) shows that whales may move through the area in less than half a day. Therefore, animals are not expected to remain within ranges where PTS may occur. The range at which TTS effects may occur is likely to be highly conservative. A whale passing the survey in less than a day is unlikely to remain within a fixed range of the seismic source, particularly given that the seismic source will be continuously moving along survey lines, in and out of the migration BIA. In the event that any whales do experience TTS, it is expected that there will be full recovery after sound exposure ceases (NMFS 2018).

Behavioural impacts, such as behavioural avoidance, are more likely to occur if whales pass near the active seismic source. The predicted maximum distance to the NMFS (2014) marine mammal behavioural threshold (single-pulse 160 dB re 1 µPa SPL), for both LF and MF-cetacean, is approximately 5.7 - 8.8 km, across all water depths modelled. Therefore, migrating humpback whales may deviate from their normal course by several kilometres to avoid the seismic sound source, but this distance is relatively small in the context of the distance travelled in a day. Importantly, this distance does not constrain the migration path of humpback whales to the south of the operational area, with approximately 40 km of distance between the behavioural effects footprint and coastal waters if the source is operational at the most southerly point in the operational area at the time. This would only occur for a matter of minutes or hours, and for the majority of the survey, the seismic survey vessel and the seismic source will be sailing at greater distances from the coast.

Humpback whales have not been observed to be significantly displaced from their migratory pathways as a result of seismic sound, with the most consistent response to seismic activity being an alteration of course and swimming speed (McCauley *et al*. 2000). A comprehensive study carried out by McCauley *et al.* (2003) monitored the effects of seismic survey noise on humpback whales in the Exmouth Gulf region of Western Australia and concluded the following:

- only localised avoidance was seen by migrating whales during the seismic operation, indicating that the 'risk factor' associated with the seismic survey was confined to a comparatively short period and small range displacement; and
- coupled with the fact that humpback whales were seen to be actively utilising the 'sound shadow' near the surface, then it was unlikely that animals were at any physiological risk unless at very short range from a large acoustic array, perhaps of the order of a few hundred metres;

Therefore, impacts to humpback whales are predicted to comprise localised behavioural avoidance impacts with no long-term ecological implications for migration or the population. Whales will not be displaced from the BIA. Even so, it is noted that once significant numbers of humpback whales migrate through these waters, disturbance to individuals or small groups of animals may become a frequent occurrence.

In terms of potential masking, the intermittent nature and relatively short duration of individual seismic pulses is unlikely to result in any significant masking of whale calls, although may cause whales to cease or alter their vocalisations at times, as outlined in Wood *et al*. (2012) and Erbe at al. (2016).

6.2.2.9.5 Summary

Based on the impact assessment no long-term or population impacts to cetaceans are predicted thus the consequence level is assessed as minor.

6.2.2.10 Dugongs

Although the PMST report stated that dugong, or dugong habitat, may occur in the operational area, the water depth range (~40 to 250 m) and lack of seagrass habitat within the operational area suggests that presence is highly unlikely. The closest dugong habitat is expected to occur in inshore areas close to the mainland coast (note, no seagrass habitat has been reported around Bedout Island 45 km south of the operational area). At the closest point, the operational area is located over 50 km from Eighty Mile Beach and over 170 km from the nearest dugong BIA.

Based on the limited data regarding noise levels that elicit a behavioural response in sirenians, the lower threshold level of SPL 160 dB re 1 µPa level from NMFS (2013) is typically applied, both in Australia and by NMFS. Noise modelling at the closest point to land (Scenario 1, Site 1; **Appendix H**) suggest noise levels equalling this threshold could occur up to 8.8 km from the seismic source. Dugong habitat (i.e. seagrasses) is not known to occur within this area. Received levels in coastal waters over 50 km away, where dugongs may occur, will be < 140 dB re 1 µPa SPL at the closest point and is not expected to result in any discernible effects to dugongs.

6.2.2.11 Marine Turtles

6.2.2.11.1 Receptors

The PMST report identified five species of marine turtle that may occur within the operational area: flatback, hawksbill, green, loggerhead and leatherback. In addition, the marine turtle BIAs and critical habitats, as shown in **Figure 3-7** and described in **Section 3.2.3.7**, indicate a 28 km overlap with the flatback turtle internesting BIA, while the Habitat Critical designated for internesting flatback turtles overlaps the southern edge of the operational area and survey area by approximately 3 km.

Studies of the internesting behaviour of flatback turtles using satellite telemetry also provide evidence that flatback turtle internesting movements do not overlap the Keraudren seismic survey area either in space or time, based on the following:

- Whittock *et al*. (2014) describes the internesting movements from 4 flatback rookeries (Barrow Island, Thevenard Island, Mundabullangana and Port Hedland (Cemetery Beach)). The distance travelled between nesting events ranged from 3.4 to 62.1 km for 56 monitored flatback turtles representing 112 internesting events in December and January over a 6-year period. For Cemetery Beach, the closest rookery in the study to the Keraudren operational area, the greatest internesting distance travelled was to the south of North Turtle Island which is at least 60 km from the ramp-up zone of the Keraudren survey at its closest point.
- Further analysis, modelling and interpretation of satellite tracks by flatback turtles by Whittock *et al*. (2016) led to defining suitable internesting habitat as water depths of 0 to 16 m located within 5 to 10 km of the nesting coastline with sea surface temperatures between 27° and 29.9°. No areas of high suitable habitat occurred in water depths of > 25 m water deep and >27 km from the coastline.
- A study of internesting distances travelled by flatbacks from the Lacepede Islands (approximately 400 km to the north of the Keraudren survey) reported a median distance from the deployment location of 12.51 km with all transmissions within 48.28 km of the deployment location. Tracked flatback turtles commenced their post-nesting migration by mid-January.
- Waayers and Stubbs (2016) summarise a decade of monitoring flatback turtles in Port Hedland and indicate that nesting begins in mid-October and ends in late January with the peak in late November.

- Thums *et al*. (2017) reported that internesting movements of 11 flatback turtles tagged on the Lacepede Islands remained at an average distance of 15.75 +/-12.25 km from West Lacepede Island, in water depths of 16 +/- 3 m.
- Pendoley *et al*. (2014) reported that post-nesting migration for flatbacks from 4 rookeries on the North West Shelf commenced between end of November and end of January.

With regards to post-internesting movements of flatback turtles, less is known and been studied. Thums *et al*. (2017) used satellite telemetry to follow the movements of 11 flatback turtles after nesting on islands in the waters off the coast of the Kimberley region of northern Australia. The turtles migrated along the coast in water depths of 63 +/- 5m to foraging grounds on the mid-Sahul Shelf in the Timor Sea in average water depths of 74 +/- 12m and 135 +/- 35 km from shore. Pendoley *et al*. (2014) report a range of depths for post-nesting migration of flatbacks from 4 rookeries on the North West Shelf from 50 to 127 m water depth and a maximum track distance from shore of 125 km (+/-35 km, range of 36 to 125 km). On the basis of these studies, it can be concluded that it is possible for post-nesting flatback turtles to migrate through the Keraudren operational area.

In terms of protected marine turtle habitats defined in the Recovery Plan for Marine Turtles in Australia (DotEE, 2017), the BIA and the Habitat Critical for flatback turtles are considered of most relevance to the assessment of impacts from noise emissions from the Keraudren Extension 3D MSS due to the spatial overlap. For conservatism, the BIAs and the Habitat Critical for greens, loggerheads and hawksbill turtles have also been considered noting that there is no spatial overlap of these areas with the seismic survey area. All species of transiting or migratory turtles are also considered.

6.2.2.11.2 Impact pathways and sensitivities

Marine turtles are considered to be less sensitive to noise than marine mammals as they do not have an external hearing organ but can detect sound through bone-conducted vibration in the skull with their shell providing a receiving surface (Lenhardt *et al*. 1985). Morphological studies of green and loggerhead turtles (Ridgway *et al*. 1969; Wever 1978; Lenhardt *et al*. 1985) found that the turtle ear is similar to other reptile ears but has adaptations for underwater listening.

Most studies researching the effect of seismic noise on sea turtles focused on behavioural responses, as physiological impacts are more difficult to observe in living animals. Turtles avoid low-frequency sounds (Lenhardt 1994) and sounds from an airgun (O'Hara and Wilcox 1990), but these reports did not note received sound levels. Moein *et al*. (1995) found that penned loggerhead turtles initially reacted to an airgun but then showed little or no response to the sound (i.e. they habituated to it). Caged green and loggerhead turtles increased their swimming activity in response to an approaching airgun when the received SPL was above 166 dB re 1 µPa, and they behaved erratically when the received SPL was approximately 175 dB re 1 µPa (McCauley *et al*. 2000).

6.2.2.11.3 Thresholds

As described above and in **Appendix H** and **Appendix I**, the threshold criteria in **Table 6-11** have been adopted for the assessment of noise impacts to turtles. **Table 6-11** also provides the modelled distances for the criteria.

Popper *et al*. (2014) provides exposure guidelines to set threshold criteria for marine turtles exposed to seismic noise as detailed in **Table 6-13**. Though mortality or potential mortal injury to turtles from seismic noise exposure has not be reported, Popper *et al*. (2014) provides exposure guidelines of >207 dB re 1 µPa PK or >210 dB re 1 $\mu Pa^2.s$ SEL_{cum}. Popper *et al*. (2014) also defined semi-quantitative exposure criteria for potential hearing impairment (recoverable injury and TTS). Finneran *et al*. (2017) recently proposed thresholds of 232 dB re 1 µPa (PK) and of 226 dB re 1 µPa (PK) for PTS and TTS effects in turtles respectively. Therefore, the Popper *et al*. (2014) criteria for mortality/mortal injury may be conservative.

McCauley *et al*. (2000) found that turtles showed behavioural responses (i.e. increased swimming behaviour) to an approaching seismic source at received sound levels of approximately 166 dB re 1 µPa SPL, and a stronger avoidance response at around 175 dB re 1 µPa SPL. Similarly, Moein *et al*. (1995) monitored the behaviour of penned loggerhead turtles to seismic sources operating at 175–179 dB re 1 µPa SPL at 1 m. Avoidance of the seismic source was observed at first exposure, but the turtles habituated to the sound over time. The 166 dB re 1 µPa SPL has been used by the U.S. NMFS as the threshold level for a behavioural disturbance response (NSF 2011). Finneran *et al*. (2017) identified 175 dB re 1 µPa SPL as the level at which marine turtles are expected to actively avoid seismic exposures. However, the Recovery Plan for Marine Turtles in Australia (DoEE 2017a) acknowledges the 166 dB re1 µPa SPL reported by McCauley *et al*. (2000) as the level that may result in a behavioural response to marine turtles.

Table 6-13: Sound level threshold criteria and values for mortality, impairment and behaviour in turtles

	Turtles				
	Mortality/Potential Mortal Injury		Recoverable Injury and TTS		Behavioural
Threshold Criteria	Few studies to base criteria on, however, Popper *et al*. (2014) provides acoustic criteria for mortality and potential mortal injury. The criteria are based on pile driving and other impulsive sounds and do not represent the levels at which impacts will occur, but levels at which no impacts have been observed. They are therefore likely to be conservative.		A scale of relative risk is provided in Popper *et al.* (2014) for recoverable injury and TTS. The scale assumes that recoverable injury and TTS are possible. The relative risk is defined as High in the near field (tens of metres), and Low in the intermediate and far fields (hundreds to thousands of metres). Recent thresholds defined by Finneran *et al*. (2017) for PTS and TTS in marine turtles have been adopted.		There are currently no acoustic criteria for sea turtles, however, a scale of relative risk is provided below from Popper *et al.* (2014). The scale assumes that a behavioural response is possible. McCauley *et al*. (2000), observed behavioural response in caged sea turtles at 166 dB SPL, as referenced by NSF 2011 and in the Recovery Plan for Marine Turtles in Australia (DoEE 2017a)
Relevance of thresholds adopted	There is limited information on sea turtle hearing. Most studies looking at the effect of seismic noise on marine turtles have focussed on behavioural responses given that physiological impacts are more difficult to observe in living animals. Exposure criteria developed by Popper at al (2014) based on results from the Working Group on the Effects of Sound on Fish and Turtles as well as Finneran *et al*. (2017) has been adopted. These thresholds are typically applied by NMFS, and within Australia as relevant threshold levels.				
Sound Metric	**Per pulse**	**Over 24 hours**	**Per pulse**	**Over 24 hours**	**Per pulse**
Threshold Value	207 dB re 1 µPa (PK)[1]	210 dB SEL_{24hr}[1]	PTS: 232 dB re 1 µPa (PK)[2] TTS: 226 dB re 1 µPa (PK)[2]	PTS: 204 dB SEL_{24hr}[2] TTS: 189 dB SEL_{24hr}[2]	166 dB SPL
Modelled Distance	140 – 230 m	50 – 80 m	PTS: Not exceeded TTS: Not exceeded	PTS: 60 - 120 m TTS: 1.2 - 1.3 km	2.9 – 4.2 km MOD

1: Popper *et al.* (2014), noting that the criteria for potential mortality/mortal injury may be conservative given the criteria proposed by Finneran *et al*. (2017) for PTS and TTS.

2: Finneran *et al*. (2017)

6.2.2.11.4 Impact assessment

From the noise modelling study (**Appendix H**) the further distance to the mortality or potential mortality threshold criteria using the dual criteria of >207 dB re 1 µPa (PK) or >210 dB SEL_{24hr} was the PK guideline at 230 m. However, as indicated above, this threshold is conservative. The thresholds recommended by Finneran *et al*. (2017) for PTS and TTS are not exceeded.

The SEL_{24hr} threshold criteria were also examined in relation to the potential for mortal injury, PTS and TTS. Injury and PTS as a result of these accumulated sound exposures are predicted to be limited to 120 m of the source, while TTS was predicted to a maximum range of 1.3 km. However, this range also does not represent a realistic range, as a turtle would be unlikely to remain within range of the moving seismic source for an extended period of time. The potential for injury and hearing impairment in turtles may be limited to waters in immediate proximity to the seismic source. The potential for injury or significant hearing impairment is further limited as turtles would likely attempt to swim away and avoid the approaching seismic source before being in such close range.

The behavioural threshold was exceeded at distances of 2.9 – 4.2 km, varying depending on differences in water depth, bathymetry and seabed sediments. Based on these results, it is reasonable to expect that some turtles will begin to show some increased swimming behaviour as the seismic source approaches a location from a few kilometres away. As the seismic source gets closer, more obvious fast swimming and stronger avoidance reactions, as observed by McCauley *et al*. (2000) at levels of approximately 175 dB re 1 µPa SPL, may occur when the seismic source is approximately one kilometre from a turtle's location. At the proposed seismic survey vessel speed of 4.5 knots, such an exposure scenario that would occur over a period of approximately 30 minutes with sufficient time for turtles to avoid the approaching seismic source. Therefore, behavioural disturbances to marine turtles would be short-term and temporary.

The majority of the operational area and survey area are not designated as important foraging or internesting habitat for marine turtles. However, should the seismic source be operated within the flatback turtle internesting BIA and Habitat Critical during the internesting period, there is the potential to disturb turtles during an important life stage.

A priority action in relation to flatback turtles, stated in the Recovery Plan for Marine Turtles in Australia (DoEE 2017a), is to manage anthropogenic activities to ensure marine turtles are not displaced from identified Habitat Critical. In addition, the Recovery Plan also states that a precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. Based on available data that suggests flatback turtle nesting period in this region is largely complete by the end-January and because the survey ramp-up zone is over 58 km from the mainland, a survey commencement date of no earlier than 1 February is considered acceptable. Further, Santos commits to not discharging a seismic source within the boundary of the Habitat Critical for internesting turtles. In addition, consistent with the Recovery Plan for Marine Turtles in Australia (DoEE 2017), soft starts will be implemented to provide time for turtles to move away from the approaching seismic source.

6.2.2.11.5 Summary

Based on the impact assessment no long term or population impacts to turtles are predicted. The Keraudren 3D MSS will be timed to occur outside of the peak internesting period for flatback turtles. Thus, the consequence level is assessed as minor.

6.2.2.12 Seabirds

6.2.2.12.1 Receptors

A number of seabirds may occur in the operational area. The BIAs for some of these species also overlap the operational, including:

- Lesser frigatebird (surface feeder) – overlap with foraging BIA;
- White-tailed tropicbird (plunge-diver) – overlap with breeding BIA surrounding Rowley Shoals;
- Brown booby (plunge-diver) – overlap with foraging BIA.

A number of migratory shorebirds may also occur in the operational area, however, given the lack of emergent features, individuals are likely to be flying over the area rather than foraging or spending significant periods of time on or beneath the water's surface.

6.2.2.12.2 Impact pathways and sensitivities

Acoustic noise from seismic surveys is not anticipated to have a direct effect on seabird or shorebird species, due to the method of the Activity, and that birds and vessels are transient. Only bird species that plunge dive (such as tropicbirds, boobies, shearwaters and tern species) could potentially be exposed to underwater noise, although little or no impact is expected. Stemp (1985; as cited in LGL 2012) conducted observations on the effects of seismic exploration on seabirds and did not observe any negative effects. Lacroix *et al.* (2003; as cited in LGL 2012) investigated the effect of near shore seismic surveys on moulting long-tailed ducks in the Beaufort Sea, Alaska, and also failed to detect any negative effects. Furthermore, they noted that seismic activity did not appear to change the diving intensity of the ducks significantly. However, some species may be affected indirectly as identified below.

6.2.2.12.3 Thresholds

There are no thresholds or assessment criteria for noise impacts to seabirds from seismic surveys.

6.2.2.12.4 Impact assessment

The EPBC Act Policy Statement 3.21 – *Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (Commonwealth of Australia 2017b) does not identify any impacts and risks to shorebirds from offshore seismic activities.

Impacts to foraging seabirds have not been observed previously during seismic surveys. Only birds diving and foraging within the operational area have the potential to be exposed to increased sound levels generated by the operating seismic source while diving for prey near the sea surface. Such behaviours may result in a startle response during diving. Birds resting on the surface of the water in proximity to the seismic survey vessel have limited potential to be affected by sound emissions underwater due to the limited transmission of sound energy between the water-air interface but may also be startled by seismic pulses in close proximity to the seismic source. However, given the likely avoidance response from fish and other prey species in waters immediately surrounding the seismic source, birds are unlikely to ever forage or be present near the operating seismic source. In the unlikely event that birds dive and forage near the seismic source, this is likely to only affect individual birds, resulting in a startle response with the affected birds expected to move away from the area as a result. The consequence of this is expected to be negligible and impacts at a population level are extremely unlikely to occur. Avifauna will not be displaced from the wider area of the breeding and foraging BIAs.

It is noted that the behaviour and distribution of some fishes may be affected for short periods during and after exposure to the seismic source. This may result in short-term and localised changes in the distribution of target prey species. Prey abundance could either increase or decrease because of the seismic Activity. However, these effects are unlikely to be discernible to foraging birds in the context of the normal movements and variation in the distribution of fishes. The behaviours and distribution of prey at any one time will remain largely unaffected throughout the wider BIAs and the operational area.

6.2.2.12.5 Summary

Based on the impact assessment no impacts to seabirds are predicted thus the consequence level is assessed as negligible.

6.2.2.13 Commercial Fisheries

Effects on fishing from seismic surveys may occur in two ways. The physical presence and interaction of the seismic survey vessel and towed equipment (as assessed in **Section 6.1**) has the potential to directly impact the physical activities of commercial fishing operators, potentially limiting access to specific fishing grounds. Underwater sound from the seismic source has the potential to affect target fish species and may result in temporary effects to fisheries catch rates.

Consultation with commercial fishing stakeholders (**Section 4**) has identified concerns that seismic surveys may impact catch rates in the vicinity of the survey, as well as result in long term impacts to the fish stocks due to effects on fish spawning and recruitment. The potential effects of the survey on fish, including fish behaviours and spawning success are assessed in **Section 6.2.2.7**. The potential impacts to commercial fisheries are assessed in this section.

6.2.2.13.1 Receptors

The following key fisheries that have historic fishing effort within the operational area have been identified for this assessment, based on 2009-2018 FishCube data (**Appendix E**):

- Pilbara Fish Trawl Interim Managed Fishery;
- Pilbara Line Fishery;
- Pilbara Trap Managed Fishery; and
- Mackerel Managed Fishery (Area 2).

In addition to finfish commercial fisheries, the seismic survey overlaps with the Pearl Oyster Fishery Area 2 and pearl diving activities have historically taken place approximately 30 km to the south of the operational area. Potential impacts to pearl oysters are discussed in **Section 6.2.2.14**.

6.2.2.13.2 Impact pathways and sensitivities

Scientific evidence of acoustic impacts on fish catches are somewhat equivocal because of the lack of determination between natural movements and changes in fish abundance. Based on studies presented in Engås *et al.* 1996 and Slotte *et al.* (2004) where fish were observed to return to the survey areas within 3-5 days following completion of the seismic surveys, any disruptions would likely be short-term and during the survey, with conditions returning to 'normal' levels soon after.

However, not all studies have resulted in behavioural alteration. Feeding Atlantic herring (*Clupea harengus*) schools off northern Norway showed no changes in swimming speed, direction or school size in response to a transmitting seismic survey vessel as it approached from a distance of 27 km to 2 km, over a 6-hour period (Peña *et al.* 2013). As fishing areas are large and commercial fish species are free-swimming, if fish are 'scared' temporarily from an area, based on evidence presented, it is likely they will be displaced temporarily to another area still within the fishing zone and so able to be caught.

There is little research undertaken on what effect seismic surveys have on fish catchability. Salgado Kent *et al*. (2016) "*The issue of changes in commercial fisheries catch rates due to seismic surveys is almost always contentious in Australia*". They acknowledge that there has been some effort to relate fisheries catch data to seismic survey effort, but to date none of the Australian efforts to relate finfish catch rates with seismic surveys have yielded results of any meaning. The GMEM project provided no clear evidence of adverse effects on scallops, fish, or commercial catch rates due to the 2015 seismic survey (Przeslawski *et al*. 2016b): *"Catch rates in the six months following the seismic survey were different than predicted in nine out of the 15 species examined across both Danish Seine and Demersal Gillnet sectors. Across both fishing gear types, six species (tiger flathead, goatfish, elephantfish, boarfish, broadnose shark and school shark) indicated increases in catch subsequent to the seismic survey, and three species (gummy shark, red gurnard, sawshark) indicated decreases in catch. These results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types."* Research to date has identified effects and no effects from seismic surveys on catch rates and abundance. This is likely due to the importance of the context of exposure. In many instances, fish may move away from an area when a seismic survey is being undertaken. This could impact on the catchability and catch rates for the target species of any commercial fisheries occurring in the same area at the same time.

A critical review of the potential impacts of marine seismic surveys on fish and invertebrates (Carroll *et al.* 2017) found that other studies on fish have positive, inconsistent, or no effects from seismic surveys on catch rates or abundance. A desktop study of four species (gummy shark, tiger flathead, silver warehou, school whiting) in Bass Strait, Australia, found no consistent relationships between catch rates and seismic survey activity in the area, although the large historical window of the seismic data may have masked immediate or short-term effects which cannot therefore be excluded (Przeslaki *et al*. 2016). Przeslawki *et al*. (2016) concluded that "*These results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types*". The body of peer-reviewed literature does not indicate any long-term abandonment of fishing grounds by commercial species, with several studies indicating that catch levels were similar to pre-survey levels after seismic activity had ceased (Carroll *et al.* 2017). As noted by Przeslawski *et al.* (2016), it is possible that fish may be displaced from a survey footprint to adjacent areas, however, the total number of fish within the fishery stock remains unchanged.

6.2.2.13.3 Impact assessment

As assessed in **Section 6.2.2.7**, the effects of sound produced by the seismic source during the Keraudren Extension 3D MSS are not expected to result in the mortality or injury of fishes targeted by the key commercial fisheries that operate in the same waters. This is because the demersal and pelagic species targeted by the fisheries are relatively free-moving species with the capability of avoiding the approaching sound source. In addition, no significant impacts to fish spawning and recruitment are predicted (**Section 6.2.2.7**). Therefore, a direct reduction in the targeted stocks is not predicted.

The principal mechanism for impacts to fisheries catch rates is likely the result of behavioural effects or changes in distribution. While significant behavioural effects are likely to be limited to within tens or hundreds of metres from the seismic source, changes in distribution may also occur over larger areas if the distribution of target prey species is also affected (**Section 6.2.2.7**). Changes in behaviour may last for minutes or hours, while the distribution of fishes may take hours or days to return to normal.

Historical fishing catch and effort data (FishCube data) indicates that catch rates in the Pilbara fisheries have remained consistent, broadly relative to catch effort over the last 5 - 10 years and at the same time that seismic surveys have been carried out in the region. In the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF), annual catch levels have increased steadily from 2015. According to Newman *et al*. (2019a), landings in the PFTIMF have increased despite no apparent material increases in the level of effort (number of vessels or number of days fished) since 2015.

It is acknowledged that seismic surveys may influence fish behaviour and catchability during the survey, but such effects are expected to be limited to the vicinity of the survey area and only when the survey is active. Overall annual catch levels throughout the fishery are not expected to be significantly impacted.

The previous Keraudren 3D MSS was partially acquired between May and July 2019. As at end of November 2019, commercial fishers have not claimed a loss of catch within the Pilbara demersal scalefish fishery for the period of the survey; granted commercial fishers have 12 months to make such a claim. Santos is working with one commercial mackerel fisher to review a loss of catch claim, and no conclusions can be made at this point in time. Should a loss of catch be demonstrated as a result of the Keraudren 3D MSS then commensurate make good payments will be made.

To provide further context on the proportion of the fisheries that may be affected by the Keraudren Extension 3D MSS, **Table 6-14** presents the areas of overlap with the Pilbara Fish Trawl Interim Managed Fishery and the Mackerel Managed Fishery (Area 2) based upon i) the total overlap of the survey area (full power and ramp-up zones), and ii) for the area of overlap from approximately one week of survey lines (a racetrack) with a conservative 5-km buffer applied to account for the ranges where fish behaviour and distribution may be affected. This is considered to be representative of the area that may be ensonified by the operating seismic source during normal survey activities and is broadly indicative of where the behaviours of target fish may be affected. The 5-km distance is considered conservative given that target demersal and pelagic fish species are primarily sensitive to particle motion effects rather than sound pressure over long distances, and any significant behavioural change is likely to be limited to within tens or hundreds of metres from the seismic source. An equivalent area will apply throughout the duration of the survey as the seismic survey vessel progresses acquisition over the survey area.

Table 6-14 shows that relatively large areas of the actively fished PFTIMF (and MMF) will be available for fishing, with the conclusion based on previously presented evidence (**Appendix I**) that any fish behavioural affects within these areas should be localised and temporary.

Table 6-14: Survey area overlap with commercially important Pilbara fisheries based on 2009 – 2018 FishCube data supplied by DPIRD

Fishery	Fished Area (2009 – 2018)	Survey Area Overlap	Racetrack (1-week) Overlap
Mackerel Managed Fishery (Area 2) - MMF	51,848 km^2	1,417 km^2 3%	1,295 km^2 2.5%
Pilbara Fish Trawl Interim Managed Fishery (PFTIMF)	23,058 km^2	4,655 km^2 20%	1,438 km^2 6%

FishCube data for the Pilbara Line Fishery and Pilbara Trap Managed Fishery were only available in 60 nm CAES block resolution. As such it is not possible to reliably predict the fished area for these fisheries. However, the trap and line fisheries occur over larger areas than the trawl fishery which is subject to more area closures and restrictions. The trap and line fisheries also account for a significantly smaller proportion of the demersal scalefish catch. As such, these fisheries are not assessed further, noting that the Pilbara Fish Trawl Interim Managed Fishery accounts for approximately 75% of the demersal scalefish fishing in the Pilbara region, the potential impacts to this fishery have been assessed as a worst case for the Pilbara demersal scalefish fisheries.

Santos has assumed that past fishing activity (based on 2009 – 2018 fishing effort data) is representative of future target areas, fish presence and fishery catch. The % impacts calculation in **Table 6-14** is based on the fishing effort area of the fishery and excludes any closure areas where fishing is not permitted to take place.

It is important to note that the FishCube fishing effort data represents the annual catch for the fishery per CAES block for a ten-year period, and that this is considered to be representative of where the fishery may be active. During consultation for the original Keraudren 3D MSS, it was communicated to Santos (by fishers and DPIRD) that the fishers may target specific areas of higher fish density, however based on CPUE data from 2004 – 2008 presented in Newman *et al*. (2018) the fishing effort within the operational area for all key indicator species appears to be evenly distributed. CPUE data and FishCube fishing effort data also indicate that a potentially greater level of trawl fishing activity seems to occur in Area 1 and Area 2 of the Pilbara Trawl Interim Managed Fishery, located over 400 km to the south west of the operational area.

The proportion of the Mackerel Managed Fishery that may be exposed to increased sound levels and potential disturbance to catch is limited to a small area in the south-east corner of the survey which constitutes a relatively small proportion of the fished area in this fishery (**Table 6-14**). This area is noted as being relatively significant for the fishery (refer to **Section 6.1**), however, the seismic survey vessel will acquire data in the southern parts of the survey area for only a small proportion of the total survey duration (likely in the order of one to two weeks).

Potential impacts to catch rates are within an acceptable level based on:

- Mortality, injury or impairment to target demersal and pelagic fish (both immediate and delayed) is considered highly unlikely based on no documented cases of fish mortality upon exposure to seismic airgun sound under experimental or field operating conditions (ERM 2017) and the free-swimming nature of the key indicator fish species;
- Santos has applied all the relevant mitigation strategies listed in Table 1 of the Fisheries Occasional Publication No. 112, *Guidance Statement on undertaking seismic surveys in Western Australian waters* (Department of Fisheries, 2013);
- Large areas of the fisheries (95% or more) are out of range of predicted sound levels that could disturb fish and affect catchability at any one time (**Table 6-14**);
- Given the presence of fish in previously surveyed areas following cessation of the acoustic disturbance, if there was an impact to catchability because of the Activity, catch rates post-survey return to typical catch levels relative to fishing effort;
- Santos will have a commercial fishers payment claim protocol in place. Should a loss of catch be demonstrated as a result of the Keraudren Extension 3D MSS then commensurate make good payments will be made.

6.2.2.13.4 Summary

Based on the impact assessment no long-term impacts to the overall catch rates in the commercial fisheries are predicted. Santos will make good on evidenced-based temporary loss of catch claim to mitigate risks to commercial fishers. The consequence level is assessed as minor.

6.2.2.14 Other socio-economic

6.2.2.14.1 Receptors

In addition to commercial fisheries, other potential socioeconomic receptors are present in the operational area including:

- Shipping;
- Tourism and recreational fishing and diving; and
- Submarine cable networks.

Discharge of acoustic emissions will not have any impacts to commercial shipping. Given the anticipated level of recreational fishing is likely to be low within the operational area (**Section 3.2.4.4**) the impacts discussed in the commercial fisheries and fish sections are likely to represent a greater level of potential impact of the seismic survey on recreational fishing activity. Therefore, the following impact assessment relates to diving activities and the subsea cable network.

Subsea Cables

Two subsea communications cables cross the ramp-up zone, the North West Cable System and the JASURAUS telecommunication cable (which was decommissioned in 2012 and no longer used).

Divers

Recreational and commercial divers may operate within the EMBA. The following areas have been identified as locations where diving may occur in waters adjacent to the ramp-up zone:

- Bedout Island - 45 km from the operational area;
- Pearl holding site (North Turtle Island) – 84 km from the operational area; and
- Pearl fishing areas – > 30 km from the operational area.

Interaction with divers includes a variety of different types of diving activities, for example (but not limited to) commercial, recreational, scientific, and fisheries (e.g., pearl oyster divers).

6.2.2.14.2 Impact pathways and sensitivities

Subsea Cables

As per ICPC Recommendation No. 8 Procedure to be Followed whilst Offshore Seismic Survey Work is undertaken in the Vicinity of Active Submarine Cable Systems (ICPC 2014) if the internal components of these electro-optic devices (OED) are subjected to acceleration greater than specification there is a risk of serious damage. The procedure details that where a planned survey would result in pressure waves of 2.0 bar and above arriving at the seabed in the location of an OED, the seismic survey is required to be adjusted in order to reduce the pressure to the OED.

Divers

Divers exposed to high levels of underwater sound can suffer from dizziness, hearing damage or other injuries to other sensitive (mainly air-filled) organs, depending on the frequency and intensity of the sound. The human auditory system is significantly less sensitive underwater than in air and is further degraded if diving equipment obstructs the ears or face (e.g. diving with a hood or full facemask).

6.2.2.14.3 Assessment Criteria

Subsea Cables

Based on the ICPC (2014) a +2-bar overpressure is not to be exceeded. Overpressure is the positive peak pressure, or what is modelled as peak pressure (PK). Based on the conversion of PK to Bar (10^((PK -220)/20)) a + 2 bar overpressure is equivalent to ~ 226 dB re 1 µPa PK.

Divers

Under water, the human ear is about 20 dB less sensitive than it is in air at low frequencies (20 Hz), increasing to 40 dB at mid-frequencies (less than 1 kHz), and increasing to 70–80 dB less sensitive at higher frequencies (Parvin 1998). Divers who wear neoprene hoods have even higher hearing thresholds (lower sensitivity) above 500 Hz because the hood material absorbs high-frequency sounds (Sims *et al*. 1999). Exposure studies related to divers have typically focused on military sonar exposure, with little information on seismic survey operations, and as such care is required when considering thresholds for non-military divers, particularly for impulsive sounds such as seismic source impulses (Ainslie 2008).

Underwater auditory threshold curves indicate that the human auditory system is most sensitive to waterborne sound at frequencies between 400 Hz to 1 kHz (Parvin *et al*. 1994); cited in Anthony *et al*. 2009), and these frequencies have the greatest potential for damage. Within the literature (all as cited in Ainslie, 2008), there is some variation in acceptable SPLs for divers.

The auditory threshold of hearing under-water was lowest at 1 kHz (70 dB re 1 µPa SPL) and increased for lower and higher frequencies to around 120 dB re 1 µPa at 20 Hz and at 20 kHz (Parvin 1998). Fothergill *et al*. (2000) and Fothergill *et al*. (2001) conducted controlled acoustic exposure experiments on military divers under fully controlled conditions at a US Ocean Simulation Facility and an US Open water test facility. The following exposure limit for both military and recreational divers was suggested as a conservative measure: For frequencies between 100 and 500 Hz, the maximum SPL should be 145 dB re 1 µPa over a maximum continuous exposure of 100 seconds or with a maximum duty cycle of 20 per cent and a maximum daily cumulative total of three hours. The trading relation between the maximum SPL and duration was 4 dB per doubling of duration (e.g., 141 dB SPL for a 200 second exposure) (Pestorius *et al*. 2009).

In alignment with these studies, and considering only frequencies between 100 and 500 Hz, Parvin (2005) suggested 145 dB re 1 µPa as a safety criterion for recreational divers and swimmers. Seismic airgun sources are broadband sources, and therefore, for this assessment the most precautionary and conservative diver acoustic impact threshold is the 145 dB re 1 µPa SPL suggested by Parvin (2005). This does not imply that this level is associated with the onset of injury.

6.2.2.14.4 Impact assessment

Subsea Cables

The area where the subsea cables overlap the ramp-up zone (**Section 3.2.4.4**) aligns closely with the acoustic modelling Site 5 (101 m depth) (**Figure 6-1**). At this location 226 dB re 1 µPa PK was not reached at the seafloor (**Appendix H**). Thus, no impacts to the subsea cables are predicted. The only modelling location with potential to exceed 226 dB re 1 µPa PK at the seabed was Site 1 in shallower water (38 m) to a maximum distance of 5 m from the source.

Divers

From the acoustic modelling the maximum distance where received levels exceed 145 dB re 1 µPa SPL is approximately 26 km. Guidance note DMAC 12 issued by the UK Diving Medical Advisory Committee (DMAC) “Safe Diving Distance from Seismic Surveying Operations” (DMAC 2011) recommends that where diving and seismic activity occur within 30 km of each other, a joint risk assessment should be conducted. Where diving and seismic activities occur within 45 km of each other, all parties should be made aware of the planned activity. The 30 and 45 km diver safety contours are illustrated in **Figure 6-9** in relation to the location of the operational area.

A workgroup comprising of IMCA, the International Association of Oil & Gas Producers, DMAC and seismic survey representatives was formed to consider the matter and the draft updated guidance will recommend:

- Where diving and seismic activity are scheduled to occur within 45 km, all parties should be made aware of the planned Activity. As a minimum, this should include clients/operators, diving and seismic contractors;
- Where seismic survey/diving SIMOPS are proposed within 30 km, a joint risk assessment should be undertaken. The risk assessment should consider ramp-up trials as well as other risk control measures;
- If the risk assessment generates a requirement for a ramp-up trial, the starting point for the trial will also need to be determined by the risk assessment; and
- Should any member of the diving team in the water suddenly experience discomfort, the seismic source should be turned off immediately if a request is made to do so.

Recreational diving is common along the mainland coast and inshore islands of WA and is generally restricted to water depths less than 40 m, which is the prescribed depth limit for recreational divers (World Recreational Scuba Training Council). Charter boat operators do not offer bluewater diving tours (i.e. depths >40 m) and the maximum dive depths of >40 m is limited to exceptionally experienced divers. Recreational diving is therefore usually conducted in shallow waters of 40 m or less, as this is the depth limit that standard recreational dive certification allows.

Based on the recommendations of DMAC (2019), there are no known dive sites within 30 km of the operational area. Pearl fishing grounds and water depths to 40 m surrounding Bedout Island where people may dive occur within 45 km (**Figure 6-9**).

Consultation has been undertaken with the PPA (**Section 4**) and they have been informed of the distances between the survey area and pearling lease and harvesting area.

There are no known tour operators that go to Bedout Island, which is 96 km from the nearest town of Port Hedland thus it is not a likely destination for diving. If diving does occur there it is by private boat thus stakeholders are not able to be identified.

Consultation with the only recreational dive shop in Port Hedland during the preparation of the original Keraudren 3D MSS identified that free diving is mostly undertaken around Bedout Island's offshore reef and coral bombies. Blue water diving does occur deeper chasing pelagic fish but no more than 1 – 5 nm (1.8 – 9.3 km) from the island.

6.2.2.14.5 Summary

With controls in place, potential impacts to commercial or recreational divers will be negligible. As no impacts to the subsea telecommunication cables are predicted the consequence level will be negligible.

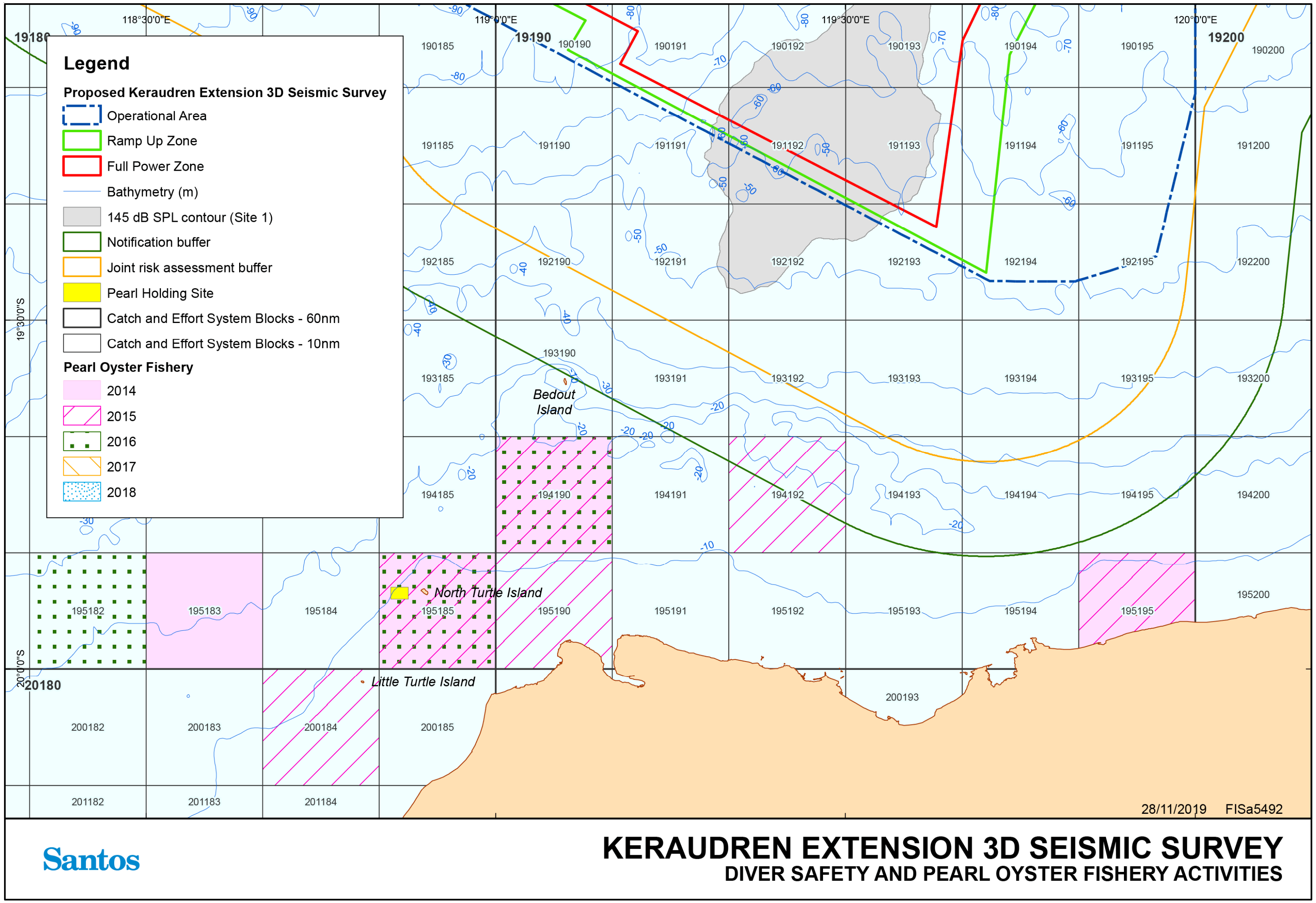

Figure 6-9: Diver safety threshold acoustic contour

6.2.3 Nature and Scale of Environmental Impacts – Helicopter and Vessel Noise

The potential receptors of sound produced by vessels and helicopters are cetaceans, marine turtles and fish. Reactions of cetaceans to circling aircraft (fixed wing or helicopter) are sometimes conspicuous if the aircraft is below an altitude of 300 m, uncommon at 460 m and generally undetectable at 600m (NMFS, 2001). Baleen whales sometimes dive or turn away during over-flights, but sensitivity seems to vary depending on the activity of the animals. The effects on cetaceans seem transient, and occasional over-flights probably have no long-term consequences on cetaceans. Observations by Richardson and Malme (1993) indicate that, for bowhead whales, most individuals are unlikely to react significantly to occasional single-pass low-flying helicopters transporting personnel and equipment at altitudes above 150 m. Leatherwood *et al*. (1982) observed that minke whales responded to helicopters at an altitude of 230 m by changing course or slowly diving.

Marine fauna including cetaceans, marine turtles and fish are expected to show minor behavioural responses to the in response to vessels. Any potential marine fauna behavioural impacts due to vessel or helicopter noise are expected to be localised and short term.

6.2.4 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- EPO-16: Undertake seismic acquisition in a manner that prevents serious or irreversible impacts to plankton or fauna dependent on plankton as a food source within the operational area.
- EPO-14: No serious or irreversible impacts to listed marine fish (including sharks) due to noise associated with the operation of seismic sources, consistent with the MNES Significant Impact Guideline 1.1.
- EPO-15: Undertake seismic acquisition in a manner that prevents serious or irreversible impacts to marine invertebrate populations within the operational area due to noise associated with the operation of seismic sources.
- EPO-9: No serious or irreversible impacts to the values of the KEF (ancient coastline at 125 m depth contour KEF).
- EPO-10: No mortality or permanent injury to cetaceans due to noise associated with the operation of seismic sources.
- EPO-11: No disturbance to humpback whales during the peak migration period.
- EPO-12: No mortality or permanent injury to turtles due to noise associated with the operation of seismic sources.
- EPO-13: Undertake seismic acquisition in a manner consistent with the Recovery Plan for Marine Turtles in Australia 2017-2027.
- EPO-17: No serious or irreversible impact on the following fisheries due to noise associated with the operation of seismic sources:
  - Pilbara Trap Managed Fishery;
  - Pilbara Fish Trawl Interim Managed Fishery (Area 4 or 5);
  - Pilbara Line Fishery;
  - Mackerel Managed Fishery (Area 2); and
  - Pearl Oyster Managed Fisher (Zone 2)
- EPO-19: Commercial fishing licence holders are no worse off as a result of the seismic survey.
- EPO-20: Seismic acquisition is undertaken in a manner that prevents impacts to divers.

- EPO 21: Far-field source levels for the selected seismic source for the Keraudren Extension 3D MSS are consistent with levels assessed in this EP.
- EPO-22: Seismic acquisition is undertaken in a manner that prevents impact to subsea cables.

Control Measures considered for this Activity are given below.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-10	EPBC Regulations (Part 8) for interacting with cetaceans	Reduces risk of physical and behavioural impacts to cetaceans from support vessels, helicopters and seismic survey vessel (when not operating)	Potential additional costs in not being able to recommence activity (if not acquiring the seismic survey) increasing survey duration and costs to Santos. Personnel costs involved in reporting sightings to authorities.	**Adopted** – benefits in reducing impacts to cetaceans and other marine fauna outweigh the costs incurred by Santos implementing EPBC Regulations (Part 8).
CM-11	Implementation of EPBC Policy Statement 2.1 (Part A): • Pre start-up visual observation • Soft start procedures • Start-up delay procedure • Operations procedure • Stop work procedure • Nighttime and low visibility procedures Apply these requirements to cetaceans, marine turtles and whale sharks.	Minimise acoustic impacts to cetaceans, marine turtles and whale sharks transiting through the survey area.	Use of MFOs and shutdowns can result in downtime of activity increasing survey duration and costs to Santos. Costs of employing MFOs and personnel costs involved in reporting sightings to authorities.	**Adopted** – benefits in reducing impacts to cetaceans, marine turtles and whale sharks outweigh the costs incurred by Santos. Implementing EPBC Policy Statement 2.1 Part A for marine turtles and whale sharks (rather than just whales) ensures compliance with the EPBC Regulations. MFOs will be on the seismic survey vessel.
CM-12	Marine fauna observations undertaken to minimise the disturbance to fauna caused by the Activity.	Reduces risk of physical and behavioural impacts to cetaceans, whale sharks and turtles from vessels, and close proximity to seismic source	Use of MFOs and shutdowns can result in downtime of activity increasing survey duration and costs to Santos. Costs of employing MFOs and personnel costs involved in reporting sightings to authorities.	**Adopted** – benefits in reducing impacts to marine fauna outweigh the costs incurred by Santos. Implementing EPBC Policy Statement 2.1 Part A and partial Part B for other fauna including turtles and whale sharks (rather than just whales) ensures compliance with the EPBC Regulations.
CM-13	Implementation of some control options consistent with EPBC Policy Statement 2.1 Part B:	Reduces risk of physical and behavioural impacts to cetaceans, whale sharks, dugongs and turtles from	Use of MFOs and shutdowns can result in downtime of activity increasing survey duration and costs to	**Adopted** – benefits in reducing impacts to marine fauna outweigh the costs incurred by Santos. Implementing EPBC Policy Statement 2.1 Part A and partial Part B for

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
	Use of 2 MFOs (MMOs) on board the seismic survey vessel. At least one MFO will have >12 months experience in Australian waters (Part B.1)	vessels, and close proximity to seismic source	Santos. Costs of employing MFOs and personnel costs involved in reporting sightings to authorities. Employment of experienced MFOs is not considered a significant additional cost.	other fauna (rather than just whales) ensures compliance with the EPBC Regulations.
CM-14	Implementation of EPBC Policy Statement 2.1 (partial part B.6 – adaptive management): • Ceasing seismic acquisition for 24 hours if there are 3 or more humpback whale induced shutdowns/ power downs within the previous 24-hour period. • Seismic acquisition may re-commence after 24 hours if there have been no further sightings of humpback whales and in accordance with CM-11, CM-12, CM-13. • The survey will be terminated if there are 3 consecutive days of no seismic acquisition due to the presence of migrating humpback whales.	Survey acquisition will not occur during the peak humpback whale migration period. Adaptive management of shutdowns based on sightings of humpback whales rather than a fixed date optimises the time for seismic acquisition without increasing the risk to migrating humpback whales. Based on industry experience, it is highly unlikely for more than three power-downs/ shut-downs to occur within 24 hours. The key indicator of an increase in the density of whales in the survey area is an increase in the number of sightings within the power-down or shut-down zone. Ceasing survey operations after a 24-hour duration of higher than 3 or more sightings within the power-down/ shut-down zone is a conservative approach to	To set a specific date for peak migration of humpback whales, which varies from season to season, may result in stopping the survey prior to completion, even though peak migration of humpback whales may not have commenced. Whilst inefficient and costly, this may also have flow on impacts to commercial fishers if the survey needs to be completed at a future time.	**Adopted** – The implementation of adaptive management provides opportunity for the survey to continue based on actual timing of peak humpback whale migration (rather than a date range when humpback whale migration may occur), without increased risk to humpback whales and without significant time delays and costs.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		ensure no impacts to humpback whales.		
Additional control measures				
All receptors				
N/A	Reduction of source volume or source level to reduce area of potential impact	Lower source size could result in lower sound levels received by marine fauna at a given distance. Although it is noted that sound levels that propagate from the seismic source depend not only on volume, but the configuration and geometric layout of individual guns in the array.	Minimum source volume is required to meet the technical objectives of the MSS and is dictated by the depth and nature of the geological target.	**Not Adopted** – The seismic source volume specification for the survey has been selected based upon the technical requirements and objectives of the survey. A seismic source with a volume of between 3,000 and 3,500 in^3 has been identified for this purpose. Reducing the source volume may mean the objectives of the survey cannot be met.
CM-15	Seismic source validation	If the seismic source selected for the Activity is different to those modelled, then additional source modelling will be undertaken to confirm whether the sound levels are consistent with levels assessed as acceptable under this EP. Provides confidence in the impact assessment which was based on modelling results.	Source modelling can be undertaken at minimal cost and relatively quickly.	**Adopted** – Given that the seismic source to be used is not yet confirmed, this control measure ensure that the impact assessment is accurate at limited cost.
Megafauna (cetaceans, dugong, turtles, whale sharks)				
N/A	Pre-survey research would involve sending a dedicated research vessel to the planned	Would increase knowledge of marine fauna activity in the area.	Long lead time as a research vessel sent out to the field would need to go one year	**Not Adopted** – Through avoiding the peak migration periods for humpback whales, and given the lack of spatial overlap of the operational area with blue whale

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
	survey area ahead of time. Allows for MSS planning around areas of peak migration and aggregation, therefore reducing risks to marine fauna (EPBC Policy Statement 2.1 – Part B.2)		ahead of the MSS at the planned time to collect relevant data, survey areas often not defined >1 yr. in advance, further risks from vessel collision and emissions; Cost of research vessel.	migration pathways, Santos considers the likelihood for migrating blue and humpback whales to be present in the survey area during the Activity to be unlikely. Santos has captured all relevant information in this EP of the likely behaviour and migration routes of marine fauna in the vicinity and through observations made on their own vessels and platforms (which are reported to DoEE), and therefore have a sound baseline knowledge to enable MSS planning. Additional baseline surveys are not considered necessary as they would introduce further environmental risks to the marine environment through vessel emissions and discharges (e.g. sewage, cooling water, noise) in areas of known marine fauna activity. To benefit from the pre-survey the finalised survey area and timing would need to be known at least 1 year in advance to allow for it to be undertaken at the same time as the planned MSS which is not practicable. The environmental benefit is therefore outweighed by the cost and scheduling issues and Santos' existing environmental review and working knowledge of the area is considered to reduce the seismic survey timing impacts to ALARP.
N/A	Spotter planes/ vessels sent ahead to survey planned night-time survey area (EPBC Policy Statement 2.1 – Part B.2 & B.3)	Could increase detection of individuals or groups of marine fauna which may be displaced or disturbed during night-time operations when visibility is low.	Marine fauna may have moved away from the area by the time the operating seismic survey vessel arrives, or other marine fauna entered the area rendering the pre survey check invalid. Diving cetaceans may not be observed during pre-survey check. Cost of specialist aircraft with good downward visibility, or	**Not Adopted** – Costs outweigh benefits as other controls will be implemented where the likelihood of encountering whales is high, such as no seismic activity during peak humpback whale migration periods. The Activity will therefore be limited during periods where the likelihood of encountering whales is high, and adaptive management procedures will be implemented if observed numbers of fauna are higher than expected. Support vessels also note any marine fauna observations. The uncertainty of the viability of spotter planes/ vessels and the added environmental impacts from increased noise and air emissions and increase in safety risks (e.g. vessel collision) are grossly

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			cost of an additional spotter vessel additional MFOs required on board aircraft (approximately S10 - $20k per day). Additional risks to environment through use of vessels/airplanes, increased safety risks to personnel on board additional vessels/airplanes.	disproportionate to the minimal environmental benefit of identifying marine fauna ahead of the seismic activity at night.
N/A	Marine fauna sightings - vessels/aircraft utilised to spot fauna ahead of the seismic survey vessel over whole survey area (EPBC Policy Statement 2.1 – Part B2 & B.3)	Could increase detection of individuals or groups of marine fauna which may be displaced or disturbed	As above for spotter planes used prior to nightfall.	**Not Adopted** – Only benefit would be marine fauna aggregations could be spotted and MSS acquisition route amended for the day, but the aggregations of large fauna would be spotted by MFOs on board the seismic survey vessels and the same precaution zones observed. Similarly, through avoiding the peak migration periods for humpback whales and the lack of spatial overlap with blue whale migration pathways, Santos considers the likelihood for encountering migrating humpback in the survey area during the Activity to be unlikely. The additional control of sightings from support vessels is considered effective, as the support vessels patrol a larger area around the seismic survey vessel and can radio marine fauna sightings to the seismic survey vessel. As before, the cost and safety considerations would outweigh the environmental benefit considering the MSSs is not being completed in a key breeding or resting area for cetaceans and other fauna, they will only be passing through the area on the migratory route.
N/A	Thermal Imaging camera can be used to detect cetaceans and blows during daylight and low	Could increase probability of detection of cetaceans which may not be detected by MFOs.	Requires good weather conditions, stabilised platform required to mount camera, and	**Not Adopted** – the observer must be focusing the thermal imaging camera on the cetacean when it surfaces to enable a positive verification to be

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
	visibility/night-time by detecting heat signatures. Can detect cetaceans at night which reduces the risk of impacts if undertaking seismic acquisition due to no MFO observations		camera must still be focused towards the cetacean when it surfaces: limited field of vision. Expensive (~ $250K plus trained personnel), should be used in conjunction with PAM.	made. Given the costs involved in the use of the equipment, requirement for calm weather conditions so the whales can be spotted between peaks and troughs on the water, as well as the recommendation that it should be used in conjunction with PAM (which is not considered ALARP), the cost outweighs the environmental benefit and therefore is not considered an appropriate mitigation control.
N/A	Increased duration of pre-start visual observations	Could increase detectability of marine fauna in the observation zone	Potential to increase the survey duration in event of increased fauna sightings.	**Not Adopted** – Area does not represent foraging areas for cetaceans. Individuals are likely to be transiting through the area. Soft starts will prevent PTS from occurring.
Cetaceans specific controls				
N/A	Noise management plan	None – an impact assessment has been conducted and control measures have been developed for this EP. The operational area and survey timing do not overlap with humpback whale calving, resting, foraging areas, or confined migratory pathways.	No additional cost to Santos other than negligible personnel costs of preparing and reviewing the management plan	**Not Adopted** – this EP, including control measures constitutes a management plan, no additional benefits identified.
CM-16	No acquisition during peak humpback whale migration.	Avoidance of peak humpback whale migration periods would eliminate any potential impact to humpback whales during these times.	Reduces the timeframe available for seismic acquisition. This may result in the survey objectives not being met should start date be delayed. This may result in multiple years of survey.	**Adopted** – control measures to reduce impacts to humpback whales will be implemented, these include the survey ceasing after 31 July 2019, or if there are three consecutive days of no seismic acquisition due to the presence of migrating humpback whales.
N/A	No acquisition during peak pygmy blue whale migration	Minimal benefits to blue whales given there is no spatial overlap between the operational area	Further reduces the timeframe available for seismic acquisition meaning a smaller area is	**Not Adopted** – given the distance between the ramp-up zone and the blue whale migration BIA, noise levels are not expected to exceed PTS, TTS or behavioural response thresholds for this species in the migration

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		and migration pathways (including BIA)	covered. Survey objectives are unlikely to be met.	BIA. As such, impacts to migrating individuals are not expected and the high costs associated with incomplete survey acquisition is grossly disproportionate.
N/A	Passive Acoustic Monitoring (PAM) involves the use of hydrophones subsea to detect and monitor the presence of vocalising marine mammals and can assist in the confirmation of the presence of vocalizing cetaceans therefore supporting MFO observations on board the seismic survey vessel. Additional detection methods reduce the risks to marine fauna in the vicinity by influencing the seismic survey operations (EPBC Policy Statement 2.1 – Part B.5)	Potential to identify toothed cetaceans which do not breach the sea surface (e.g. on long dives)	Difficult to detect the distance and direction of cetaceans to enable implementation of precaution zones unless confirmed by visual observations, only applicable for cetaceans not whale sharks or other marine fauna (as they do not vocalise), only applicable to vocalizing cetaceans, PAM very dependent on environmental conditions. Minimal costs for basic PAM, however, to enable PAM to be utilized efficiently, more complex PAM systems would be required, with a dedicated vessel thus increasing cost.	**Not Adopted** – Three types of PAM can be utilized, fixed PAM, towed PAM and active acoustic monitoring (AAM). AAM is less mature but could be an effective method for detecting animals that are not producing sounds (Bingham, 2011) but should be used in conjunction with PAM and MFOs. Given the more available access to PAM, AAM is not considered feasible for this MSS. While PAM can potentially be a valuable tool in identifying the presence of cetaceans, the following observations have been made with respect to the technology, which may limit its effectiveness. Further investigation into the use of PAM to detect the distance of cetaceans from the seismic survey vessel area has resulted in confirmation from PAM providers (e.g. Blue Planet Marine) that there is no guarantee that the distance and direction of cetaceans can be detected therefore precaution zones could not be implemented based on PAM alone. It therefore could not be used as an adaptive management measure in times of low visibility and night-time operations. The MSS can also mask the whale calls and prevent detection. Cetaceans detected by PAM must be confirmed with visual observations by MFOs and this could be considered in areas with high numbers of cetaceans expected to help confirm sightings of cetaceans. In addition, PAM is not as effective at detecting humpback and blue whales which are the mostly likely species to be detected as PAM will only detect animals that are vocalising at a level detectable by the system, therefore if there is no sound it does not indicate absence of marine mammals. Only humpback whale males' vocalise - it is estimated that

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				around 22% of whales vocalise at one time. Assuming that the male to female sex ratio is 50%, you could assume that only 12% of the population is vocalising and available for detection through PAM- so, at best there would be a non-detection rate of 88% of the population and 100% of female and calves. Also, the current set-up that Blue Planet Marine have is not suitable for the frequency range of humpback whales- it is more suited to sperm whales. BPM would have to develop another system suitable for humpbacks, for which there may be level of accuracy limitations
N/A	No start up or operations at night-time / low visibility (EPBC Policy Statement 2.1 – Part B.2)	Would reduce probability of a cetacean occurring within the low power/shutdown zone and not being detected.	Increases time of MSS as operations only continue for ~10 hours/day. Increase cost due to increased MSS time (more than double the cost). Survey objectives would not be met in available timeframe.	**Not Adopted** – Cost outweighs the environmental benefit given the low numbers of marine fauna that reside in the area as opposed to transiting through. Through avoiding the peak migration periods for humpback whales, and lack of spatial overlap with blue whales, Santos considers the likelihood for migrating blue and humpback whales to be present in the survey area during the Activity to be unlikely. Therefore, no additional controls such as "no start up or operations at night-time or in low visibility (EPBC Policy Statement 2.1 Part B.2)" are further considered. However, to minimise impacts to marine fauna which may be in the area, a control will be adopted that will prevent night-time and low visibility operations if > 3 whale instigated shutdowns per day for 3 consecutive days occur. Low visibility/night-time seismic operations will not resume until there has been a 24-hour period with no whale shut downs.
Marine turtles				

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-17	No acquisition in Habitat Critical for flatback turtles between October and March.	Minimise impacts to flatback turtles	There is a minor overlap between Habitat Critical and the operational area, with minimal potential costs/issues by not operating the seismic source in this area between October and March.	**Adopted** – Consistent with the requirements of the Recovery Plan for Marine Turtles in Australia (DEE 2017a), a precautionary approach will be applied, such that no operation of the seismic source will take place inside Habitat Critical for flatback turtles during the nesting season (Oct – Mar).
Whale sharks				
N/A	No acquisition in whale shark BIA (July - Nov)	Minimise potential for acoustic impacts to whale sharks	Further reduces the timeframe available for seismic acquisition meaning a smaller area is covered. Survey objectives are unlikely to be met.	**Not Adopted** – the current survey timing only overlaps with a small proportion of this timeframe, therefore the number of whale sharks occurring in the operational area is low. The operating vessels are not expected to act as a barrier to migration. Given the limited potential for impacts to occur and the low number of individuals potentially impacted, the minimal potential benefits are outweighed by the high costs of survey objectives not being met.
Fish				
N/A	Timing survey to avoid spawning periods for key indicative species for commercial fisheries (as identified in consultation with DPIRD).	Minimise potential impacts to spawning fish of commercial importance and their fish larvae and eggs.	Survey would not be able to occur due to combined spawning of these species occurring year-round. Further reduction in the proposed operating window may mean multiple years of surveys at a cost to the business.	**Partially Adopted** – Survey cannot be timed to avoid all spawning periods due to the species present. However, Santos has committed to no seismic acquisition between August to January to minimise the survey overlap with key commercial indicator fish species spawning months, as well as whale migration periods (late July through to October). There have been no requests from DPIRD nor commercial fishers to further reduce the proposed operating window, acknowledging that a further reduction would increase the likelihood of surveys occurring over multiple years given the time required to acquire the data.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	No acquisition in the ancient coastline at 125 m water depth KEF.	Reduce potential impacts on any site-attached species associated with the ancient coastline at 125 m KEF.	Would not achieve objectives of the survey given that the 125m ancient coastline KEF intersects the survey area.	**Not Adopted** – The KEF is not expected to support large numbers of site-attached species, and therefore any impacts to individuals are not expected to lead to population or ecosystem level impacts. The costs incurred with avoiding the KEF are grossly disproportionate to the minimal benefit gained.
Invertebrates				
N/A	Avoid <70 m water depth area to reduce the area of overlap with pearl oyster fishery	Minimises potential pearl oyster habitat that may be impacted based on stakeholder consultation.	Reducing the survey acquisition area would result in the survey not achieving its objectives. Santos has identified hydrocarbon target prospects in water depths of <70 m.	**Not Adopted** – A smaller survey area would prevent acquisition over all geological targets of the required data. This will likely result in additional future surveys being required. The additional surveys would result in additional costs to Santos, as well as additional impacts and risks associated with vessel presence. Based on weight of evidence it is unlikely that significant numbers of pearl oysters or pearl oyster habitat exists within the survey area.
Socio-economic				
N/A	Restrict the survey area to reduce the area of overlap with commercial fisheries	Minimise the potential impacts to the commercial fishers.	Would not achieve objectives of the survey.	**Not Adopted** – this will prevent acquisition over all geological targets of the required data, which will likely result in additional future surveys being required. The additional surveys would result in additional costs to Santos, as well as additional impacts and risks associated with vessel presence. While a reduction in survey area would reduce the potential overlap with commercial fisheries, the impact assessment presented above does not predict significant impacts to commercial fishing or fish resources. Furthermore a short-term loss of catch or displacement will be managed via a make good payment framework to ensure commercial fishers are no worse off (further detail is provided in **Section 8.6.2**).

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-18	Adopt *UK Diving Medical Advisory Committee* Guidance Note DMAC 12.	Reduce potential health and safety risks to commercial and recreational divers	No additional cost to Santos other than negligible personnel costs of preparing and reviewing a joint risk assessment.	**Adopted** – potential risks to diver health and safety are a priority.
CM-19	No firing of the seismic source within 100 m the subsea cables that intersect the ramp-up zone	Eliminates the risk of impact to subsea cables intersecting the ramp-up zone	There is a minimal overlap of the ramp-up zone with a subsea cable route and avoiding firing over the cable would be of no additional cost to Santos.	**Adopted** – not firing the seismic source within 100 m of the subsea cables eliminates the risk of any impact.
N/A	No helicopter operations	Minimise acoustic disturbance to marine fauna from helicopter operations	Vessel would be required to return to port (approximately every two weeks) for crew change. This would increase the duration of the survey incurring additional costs. Survey may not be completed in available timeframe.	**Not Adopted** – considering the low potential for impacts to marine fauna to occur, the potential costs associated with vessel downtime, extended duration and the risk of not meeting survey objectives are grossly disproportionate.
CM-9	Commercial fishery payment claims (further detail is provided in **Section 8.6.2**).	Should relevant commercial fishers experience interruption to their fishing activities or a temporary loss of catch because of the seismic survey then Santos is prepared to consider financial payments so that commercial fishers are not materially worse off as a result of the seismic survey. Payments to commercial fishing licence holders will be assessed for loss of catch and/or relocation expenses should concurrent fishing and seismic	For Santos to accept a payment claim, fishers will need to provide sufficient evidence to demonstrate the loss of catch as a result of the seismic survey. This will require fisher's time and effort. Santos is prepared to invest the time to assess the merits of all claims. Fishing licence holders new to fishing areas overlapping the operational area may have difficulty proving displacement.	**Adopted** – All evidence-based payment claims made by commercial fishing licence holders relating to temporary loss of fish catch or displacement costs related to the survey will be assessed for merit, and as appropriate, paid by Santos. Santos is also prepared to enter into agreements with commercial fishing holders in relation to the potential impact of the survey on them.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		survey vessel operations not be practicable. Evidenced-based compensation models are not new to seismic surveys in Australia.		

6.2.5 Impacts and Consequence Ranking

Receptor	Consequence Level
Noise from operation of seismic source	
Threatened / Migratory / Protected Fauna	Acoustic emissions generated by the seismic source may result in impacts to receptors including; behavioural response, TTS, PTS or injury and mortality. Noise levels at which these effects have been recorded differs between species, as such receptor-specific thresholds have been applied, as support by the scientific literature. *Plankton* By applying conservative thresholds from McCauley *et al.* (2017) and using these as the basis to model impacts to plankton populations (Richardson *et al.* 2017), 14% of the plankton biomass may be potentially removed up to 7.92 km from the seismic source. Given the length of sail lines and the currents in the area aiding natural replenishment, this level of plankton depletion is not expected to have ecosystem-wide impacts, including on the seasonal migration of whale sharks through the area, or have population level effects to species with planktonic life stages, including commercial fish and invertebrate species. Based on the impact assessment no long-term impacts to plankton or fauna dependent on plankton as a food or recruitment source are predicted, thus, the consequence level is assessed as **minor**. *Invertebrates* Crustaceans are likely to be present throughout the operational area with patchy distribution based on seabed habitat. Thresholds for lethal effects were not exceeded, although sublethal effects could occur to a proportion of the population. At received noise levels comparable to those predicted in the noise modelling, studies found no evidence of impacts to embryonic development or the factors effecting recruitment. Changes in behaviour and risk of mortality to bivalves from multiple exposures to seismic sources have been reported. Bivalves are likely to be present throughout the operational area with patchy distribution based on seabed habitat, with presence more likely in the ancient coastline at 125 m depth contour KEF. Pearl oysters are not harvested within the operational area though the waters out to 70 m have been identified anecdotally as where pearl oyster broodstock may be present. It is expected that if mortality impacts did occur, it would be within natural mortality rates and a very small proportion of the local population. If physiological and behavioural impairments did occur effects would be seen at the individual rather than population level. There are no documented areas of corals or exposed hard substrate that could support significant coral habitat in the shallower water depths of the operational area, however, such habitat may occur. At shallow water sites, where the received levels on the seafloor may exceed this threshold, impacts to corals and sponges may be limited or may not occur at all. Based on the impact assessment no long term or population impacts to invertebrates (crustaceans, bivalves, corals) are predicted. In the shallower, southern portion of the survey area, received sound pressure and particle motion levels may be sufficient to result in chronic mortality impacts to a proportion of sessile benthic invertebrate communities, but population level effects are not expected. Thus, the consequence level for crustaceans and molluscs is assessed as **minor**; as no impacts to corals and sponges are predicted the consequence level is assessed as **negligible**. *Fishes* Hearing ranges and sensitivities vary substantially between species depending on anatomy (e.g. presence of swim bladder) and behaviour (e.g. mobile or site attached). Fish species may be exposed to noise levels exceeding thresholds for mortality/ mortal injury, recoverable injury, TTS and behavioural responses. Mortality/ mortal injury is not expected to occur to fishes that have the ability to move away from the source array, and to date such have impacts have not been documented. TTS and recoverable injury may occur to a small proportion of the overall population and recovery is expected. Behavioural effects are assessed as high within tens of metres of the seismic source, which pelagic and demersal fish can avoid. Behavioural impacts to site attached species that may be associated

	with the ancient coastline at 125 m depth contour KEF, and demersal and pelagic fish including commercial species are possible but would be temporary, localised and unlikely to impact at a population level. Based on the impact assessment no long term or population impacts to individual fishes or fish stocks, or fish assemblages associated with the ancient coastline at the 125 m depth contour KEF are predicted, thus the consequence level is assessed as **minor**. *Sharks* There is limited research on the effects of seismic on sharks, however, due to the lack of swim bladders it is expected that the potential effects will be the same as for other pelagic fish species without swim bladders, resulting in minor and temporary behavioural change such as avoidance. The operational area overlaps a migration and foraging BIA for whale sharks. As the seismic survey will be acquired before 31 July, there is only a small period in time where potentially a low number of migrating whale sharks may be encountered within the operational area. Other shark species (e.g. sandbar shark, *Carcharhinus plumbeus*) are likely to also transit the operational area. Shark species are highly vagrant and naturally cover large distances. As such, short-term exposures from the transient seismic source is expected to result in only localised behavioural responses and movements of sharks. Based on the impact assessment no long term or population impacts to whale sharks, or other shark species, are predicted thus the consequence level is assessed as **minor**. *Cetaceans* PTS through cumulative sound exposure is considered unlikely because of the behavioural response of the individual whales (e.g. moving away from the source) and the application of the EPBC Act Policy Statement 2.1 (pre-start visual observations, soft start, lower-power zone and shut down zone). Due to control measures in place (soft starts and application of the EPBC Policy Statement 2.1 – Part A), physical injury or PTS is unlikely to occur. Impacts will be restricted to temporary impacts to hearing (TTS) or behavioural responses, such as avoidance. No foraging, calving or resting areas are within an area where noise levels could be elevated above impact threshold levels. Although the ramp-up/ full-power zone overlaps with the humpback whale migration BIA, there will only be a short period of potential overlap with the peak migration period nominally being from mid-July. During this period of overlap it is expected that migrating humpback whale numbers would be low and an adaptive management procedure will be in place to mitigate impacts if humpback whales numbers are greater than expected. Additionally, the timing of the survey overlaps with the pygmy blue whale migration period, but noise levels in the migration BIA do not exceed impact thresholds. Impacts are expected to be temporary behavioural response (lasting days) or TSS (lasting 24 hrs) to transient individuals only. As such, the consequence has been assessed as **minor**. *Dugongs* Although the PMST report stated that dugong, or dugong habitat, may occur in the operational area, the water depth range (~40 to 250 m) and lack of seagrass habitat within the operational area suggests that presence is highly unlikely. The closest dugong habitat is expected to occur in inshore areas close to the mainland coast (note, no seagrass habitat has been reported around Bedout Island 45 km south of the operational area). Received levels in coastal waters over 50 km away, where dugongs may occur, will be < 140 dB re 1 µPa SPL at the closest point and is not expected to result in any discernible effects to dugongs. *Marine turtles* Impacts to marine turtle may include mortality/potential mortal injury or behavioural response. The majority of the operational area and survey area are not designated as important foraging or internesting habitat for marine turtles. Santos will not acquire seismic data or operate the seismic source within Habitat Critical for flatback turtles during the October to March nesting period. The potential for injury and hearing impairment in turtles may be limited to waters in immediate proximity to the seismic source. The potential for injury or significant hearing impairment is further limited as turtles would likely attempt to swim away and avoid the approaching seismic source before being in such close range. The implementation of soft starts will prevent discharge of the seismic source at full capacity in close proximity to marine turtles, and therefore impacts will be limited to behavioural disturbance to transient individuals. Based on the impact assessment, no

Receptor	Consequence Level
	long term or population impacts to turtles are predicted. The Keraudren 3D MSS will be timed to occur outside of the peak internesting period for flatback turtles. Thus, the consequence level is assessed as **minor.** *Seabirds* Diving seabirds may be exposed to underwater noise during foraging, particularly plunge-divers, although incidence of injury is absent. Due to the scale of scale of impacts to prey species (fish and invertebrates) indirect effects due to displacement of prey species is unlikely. Temporary displacement may occur around the vessels, however, given the areas over which pelagic seabirds forage, this is unlikely to be of significant impact to individuals or populations. The consequence level is assessed as **negligible.**
Physical Environment/ Habitat	Impacts to the physical attributes of the ancient coastline at 125 m depth contour KEF are not expected. The consequence of potential impacts to the values and sensitivities are discussed above.
Threatened ecological communities	Not applicable – no threatened ecological communities identified in the area over which noise emissions are expected.
Protected Areas	Noise levels may exceed impact thresholds within the Eighty Mile Beach AMP for humpback whales and turtles which are included as values and sensitivities for the AMP. The consequence of potential impacts to these receptors is discussed above.
Socio-economic receptors	Potential impacts to fish from noise levels exceeding exposure thresholds may have direct effects on commercial fisheries. Population level impacts to fish are not expected, with potential impacts being restricted to behavioural responses at the individual level. Behavioural responses may displace fish from known fishing grounds; however, such responses are expected to be temporary. No long-term changes to benthic habitats, including invertebrate populations or plankton populations are expected and therefore there is no compelling reason to suggest that temporary behavioural responses will result in long term avoidance of key fishing grounds. Behavioural responses may temporarily disrupt spawning of some commercial fish species, however, given the size of the survey area in context of the broader region, and the length of fish spawning periods, is unlikely to lead to complete recruitment failure of future cohorts. Santos is committed to ensure that commercial fishing licence holders are no worse off as a result of the seismic survey. The consequence to commercial fisheries has been assessed as **minor**. The pearl oyster fishery uses diving as a method of harvesting. Additionally, recreational divers, while not as common compared to elsewhere in WA (e.g. Ningaloo Reef) may be present around Bedout Island or along the mainland coast. Control measures, implemented based on locations where noise levels are expected to exceed the safety criterion, will prevent physiological impacts to divers. However, this may result in temporary displacement if it is agreed that diving will not be undertaken. As such, the consequence has been assessed as **minor**.
Overall worst-case consequence	B – Minor Consequence rankings were provided for receptor groups due to the variation in receptor sensitivity. Impact assessments were based on worst case scenarios for received noise levels and receptor sensitivity (e.g. behaviour in BIAs). Where evidence is lacking or contradictory, a conservative approach was taken.
Noise from operation of vessels and helicopters	
Threatened / Migratory / Protected Fauna	Noise generated from vessels and helicopters may result in physiological or behavioural impacts to marine fauna. However, acoustic emissions from vessels and helicopters will be less than that of the seismic sources.

Receptor	Consequence Level
Physical Environment/ Habitat	Likely habitats to be impacted from noise in the area are benthic habitats, which have non-coral invertebrates (such as sea fans and gorgonians) which are not known to be significantly impacted by noise emissions. No decrease in local population size / area of occupancy of species / loss or disruption of critical habitat / disruption to the breeding cycle / introduction of disease is expected.
Threatened ecological communities	Not applicable – no threatened ecological communities identified in the area over which noise emissions are expected.
Protected Areas	Not applicable – noise emissions form vessels and helicopters in the operational area will not result in noise levels exceeding impact thresholds in protected areas.
Socio-economic receptors	Due to the lower noise emissions form vessels and helicopters compared to the seismic source, the consequence of impacts to fish, and therefore fisheries, will be less than that of the seismic sources.
Overall worst-case consequence	A – Negligible Considering the levels of received noise from operating vessels and helicopters, impact thresholds described in **Section 6.2.2** are unlikely to exceeded more than a few metres around the vessel. Potential impacts will be restricted to temporary behavioural responses such as avoidance and are expected to have negligible consequence on populations or ecosystem function.

6.2.6 ALARP Evaluation

No alternative options to the use of a seismic source are possible in order to undertake the Activity. Alternative options to the survey design have been assessed by Santos. In regard to survey design options, Santos has attempted to optimise the survey to minimise the operational area size and seismic survey duration, and defined a set window during which the seismic survey will be completed (1 February to 31 July). A further reduction in survey area and duration would mean that the survey objectives would not be met, or the survey would need to be conducted over multiple years.

To ensure the Activity is conducted in a manner consistent with the Approved Conservation Advice for Humpback Whale and the Blue Whale Conservation Management Plan, elements of the EPBC Policy Statement 2.1 have been adopted to minimise acoustic impacts to cetaceans, specifically humpback whales that are known to migrate through the operational area when heading northwards to the calving grounds. All control measures outlined in the EPBC Policy Statement 2.1 were considered, but only those expected to provide an environmental benefit that was not disproportionate to the additional costs will be adopted. Details of the evaluation assessment are provided in **Section 6.2.4.**

Since the peak humpback migration times show large inter-annual variation in timing, and that implementation of shutdown/ power down procedures reduces potential acoustic impacts to individuals to an acceptable level, basing the start of peak migration period on the number and frequency of humpback whale-instigated shutdowns/ power downs, instead of dates, is considered ALARP.

In avoiding peak humpback whale migration period, the available time window is reduced. This means that periods of peak activity for other receptors (foraging/migrating whale sharks and fish spawning) cannot be practicably avoided without compromising the objectives of the survey. Additional control measures were identified in **Section 6.2.4,** including the avoidance of sensitive areas (e.g. BIAs) or time periods (e.g. migration) for these receptors. The survey timing overlaps with the start of the expected peak whale shark activity in the area suggesting that the number of individuals encountered during the Activity will be low. Furthermore, shutdown procedures as per EPBC Policy Statement 2.1 are adopted for turtles and whale sharks.

The majority of the operational area and survey area are not designated as important foraging or internesting habitat for marine turtles. A priority action in relation to flatback turtles, stated in the Recovery Plan for

Marine Turtles in Australia (DoEE 2017a), is to manage anthropogenic activities to ensure marine turtles are not displaced from identified Habitat Critical. In addition, the Recovery Plan also states that a precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. Therefore, Santos will avoid peak nesting season and will not acquire seismic data or operate the seismic source within Habitat Critical for flatback turtle during the October to March internesting period. In addition, consistent with the Recovery Plan for Marine Turtles in Australia (DoEE 2017), soft starts will be implemented to provide time for turtles to move away from the approaching seismic source.

No additional control measures to those provided in **Section 6.2.4** were identified to further minimise impacts to fish spawning, fish, commercial fishers, invertebrates and plankton. The survey is unable be timed to avoid all spawning periods due to the species present. However, Santos has committed to no seismic acquisition between August to January to minimise the survey overlap with key commercial indicator fish species spawning months, as well as whale migration periods (late July through to October). A further reduction in the window of acquisition would increase the likelihood of surveys occurring over multiple years given the time required to acquire the data.

To reduce the survey area would prevent acquisition over all geological targets of the required data. This will likely result in additional future surveys and defer potential impacts and risks to a future time, including future additional interference with commercial fishing licence holders. The survey has been optimised to acquire data over specific geological trends, changing the survey direction or shape to potentially reduce impacts to commercial fishing effort will cause the survey to become less efficient and more time consuming, leading to greater cost and more noise emissions. Santos will consult with the fishers to develop concurrent operations plans to minimise the disruption to their fishing effort during the survey. Therefore, the proposed control measures are considered appropriate to manage the consequence of acoustic impacts due to operation of the seismic sources to ALARP.

Given that the seismic survey may potentially impact commercial fisheries whose fishing operations overlap with the seismic survey, Santos has made an overarching commitment that commercial fishing licence holders will be no worse off as a result of the seismic survey, and will implement the commercial fishers payment claim protocol (refer to **Section 8.6.2**). Payments to commercial fishing licence holders will be assessed for loss of catch and/ or displacement costs should concurrent fishing and seismic vessel operations not be practicable. Santos has based the commercial fishery payment model on what it understands to be an acceptable industry standard for an evidence-based compensation model, leveraging the CSIRO peer reviewed model that Santos implemented for the NOPSEMA–accepted Santos Bethany 3D Seismic Survey. CSIRO (2017) confirmed the approach proposed by Santos for compensating fishers was consistent with international best practice. For the Keraudren Extension 3D MSS, Santos has expanded its protocol to assist commercial fishers collate historical fish catch data and reimburse commercial fishers for reasonable and agreed expenses incurred during the claims process. These are further examples of Santos' willingness to work with commercial fishers to ensure they are no worse off as a result of the survey.

The available time window (i.e. 6 months from the survey completion) for commercial fishers to claim a loss of catch or displacement costs is considered appropriate as long terms impacts to the fishery and commercial fishers are not predicted. Further, Santos does not consider it reasonable to have a long-term evidenced-based payment claim protocol, as factors such as fishery management, climate, and other marine uses (e.g. other seismic surveys) affect long term fish catch. Santos has made the commitment that commercial fishers will be no worse off as a result of the seismic survey and commits to working with commercial fishers to ensure this performance outcome is achieved.

Additional controls were also considered to minimise the potential disturbance to marine fauna (specifically cetaceans) from helicopter operations. Due to the length of the survey, returning to port for crew changes would increase the duration of the survey, increasing costs and prolonging the period for planned impacts or unplanned events to the marine environment to occur. Through the implementation of EPBC Regulations (Part 8) impacts are considered to be managed to ALARP.

6.2.7 Acceptability Evaluation

Is the consequence ranked as A (Negligible) or B (Minor)?	Yes – Maximum consequence from noise emissions is B (Minor).
Is further information required to support or validate the consequence assessment?	No – Sufficient information is available to understand the nature and scale of potential impacts, and to assess impact consequence. It is recognised that the levels of acoustic exposure that may result in injury or behavioural changes in marine fauna is an area of ongoing research. Due to differences in experimental design, methodology and units of measure, comparison of studies to determine likely thresholds can be difficult. There are numerous studies on the effects of seismic sound on receptors with a range of effects to no effects identified. Seismic surveys in Australia are well regulated and guidance is available for managing potential impacts to sound sensitive marine fauna. On assessment of the available science, the thresholds used for informing the impact assessment, and interpreting the numerical noise modelling are considered conservative, and in line with industry practice.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with Part 8 of the EPBC Regulations and EPBC Policy Statement 2.1 -Part A. Controls implemented will minimise the potential impacts from the Activity to species identified in Recovery Plans and Approved Conservation Advice, Management Plans and Recovery Plans (blue whale, fin whale, humpback whale, sei whale and marine turtles) as having the potential to be impacted by noise emissions.
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – Where concerns have been raised by stakeholders Santos have included relevant controls to reduce the potential risks to ALARP. Santos understands that commercial fishers have concerns regarding the impacts of seismic surveys on access to fishing grounds, catchability and fish stock. To further reduce potential commercial impacts to a level that is as low as reasonably practicable (ALARP), Santos commits to assess evidence-based payment claims from commercial fishing licence holders who claim to be affected by the seismic survey (CM-10). If additional control measures are identified through ongoing engagement with commercial fishers, then Santos will assess the merits of these and communicate these assessments to stakeholders accordingly. This will ensure that impacts to commercial fishers remain acceptable and ALARP for the duration of the seismic survey.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above)

6.3 Cumulative and Additive Seismic Impacts

6.3.1 Description of Event

Cumulative and Additive Seismic Impacts	
Aspect	Cumulative and additive impacts refer to situations where successive seismic surveys are undertaken over the same area, or where concurrent seismic survey activities occur throughout the region, affecting the same environmental or socio-economic receptors. It is recognised that the effects resulting from multiple seismic surveys, when considered collectively, may result in a greater level of impact or risk than the effects arising solely from the Keraudren Extension 3D MSS. The two types of impact are defined as follows: • **Cumulative impacts** – Cumulative impacts are considered where the spatial footprint of impacts from previous seismic surveys have occurred over the same area as impacts from the Keraudren Extension 3D MSS. Cumulative impacts will only occur where the effects of previous surveys overlap the same area and when recovery of the impacts from these seismic surveys has not occurred prior to the Keraudren Extension 3D MSS commencing. • **Additive impacts** – Additive impacts are different from cumulative impacts and are assessed separately. Additive impacts may result from other seismic surveys, where the effects may or not overlap spatially, but when taken together have an additive or incremental effect on the same receptors. Additive impacts may occur if other seismic surveys are undertaken concurrent with the Keraudren Extension 3D MSS and within the range and extent of the same receptors, for example, where both surveys overlap with the distribution of the same population of a marine species or with the same commercial fishery. Cumulative and additive impacts are assessed in relation to the aspects of underwater noise emissions and the physical interaction of the seismic survey activities with other marine users. This section does not assess cumulative impacts from seismic surveys that may occur after the Keraudren Extension 3D MSS. It is not possible to anticipate what surveys will be planned after the Keraudren Extension 3D MSS and it is the responsibility of future seismic survey proponents to assess the potential cumulative impacts in their EPs.
Extent	Operational area (cumulative impacts) North West Marine Region (additive impacts)
Duration	For the duration of the Activity as described in **Section 2**.

6.3.2 Nature and Scale of Cumulative Impacts

A review of data available on the National Offshore Petroleum Information Management System (NOPIMS) and Seisintel websites identified two 3D seismic surveys and two 2D seismic survey that have been undertaken in the waters overlapping or adjacent to the Keraudren Extension 3D MSS operational area in the past five years. These surveys are presented in **Figure 6-10** and summarised in **Table 6-15.**

The 3D Oil Sauropod 3D MSS overlaps with the northeast corner of the Keraudren Extension 3D MSS survey area. The EP for this survey had been submitted, but not accepted by NOPSEMA, and the survey acquisition dates, and full-fold survey area were unknown at the time of writing this impact assessment. According to publicly available information, 3D Oil is planning on acquiring their survey in 2020 or 2021. Therefore, their survey could be acquired prior to the Keraudren Extension 3D MSS and could cause cumulative impacts within the overlapping portion of the Keraudren Extension 3D MSS survey area. As such, the worst-case scenario where the maximum Sauropod 3D MSS is acquired has been considered in this assessment.

Completion of the Keraudren Extension 3D MSS will provide complete coverage of modern 3D seismic data over the prospective portion of the operational area. Future seismic acquisition within Santos' acreage would only likely be required in the event of future potentially commercial hydrocarbon discoveries and would likely comprise relatively small surveys that could be acquired in weeks rather than months, and which would be very unlikely to occur any earlier than 2023.

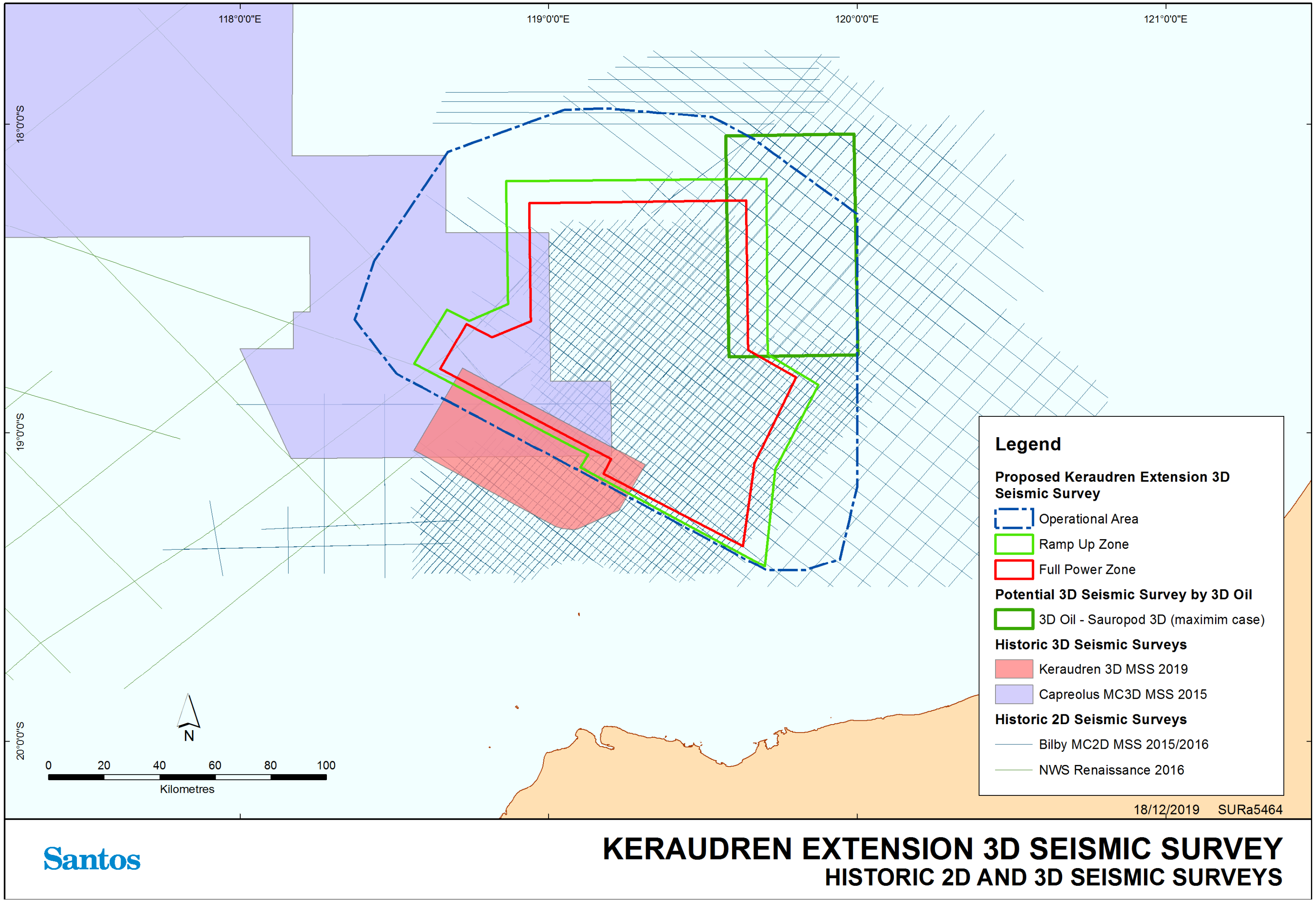

Figure 6-10: Other seismic surveys that have been acquired (or maybe) within or adjacent to the Keraudren Extension 3D MSS since 2015

Table 6-15: Other seismic surveys that have been acquired (or maybe) within or adjacent to the Keraudren Extension 3D MSS since 2015

Survey Name	Acquisition Period(s)	Seismic Source	Acquisition Lines	Spatial Overlap	Period between the Completed Survey and Feb 2020	Potential Cumulative Impacts to Ecological Receptors
Polarcus Capreolus 3D MSS	15/01/2015 - 30/04/2015	3,480 in^3	3D racetrack acquisition line formation, orientated E-W. Two seismic survey vessels operating simultaneously.	Approximately 2,200 km^2 of the survey overlaps with the western portion of the Keraudren Extension 3D MSS.	> 4 years	The Capreolus 3D MSS covered a proportion of the Keraudren survey area, and although the Bilby 2D MSS covered most of the survey area it was of lower spatial 'intensity'. All three surveys were completed approximately 3 – 4 years prior to the earliest potential commencement date of the Keraudren Extension 3D MSS. In 2017 and 2018, no surveys occurred across or near the operational area. Due to the spatial overlap and time between surveys, cumulative ecological impacts are not expected as a result of the Keraudren Extension 3D MSS.
Searcher Seismic Bilby 2D MSS	10/03/2015 - 27/04/2015 08/06/2015 - 01/07/2015 19/05/2016 - 27/06/2016	3,480 in^3	2D orthogonal lines over 2x4, 4x8 and 8x8 km grids. Lines orientated NW-SE and NE-SW.	The 2D survey lines overlap with the Keraudren Extension 3D MSS.	> 3.5 years	
TGS North West Shelf Renaissance 2D MSS	30/06/2016 - 27/09/2016	3,620 in^3	2D orthogonal grid. Lines spaced >10 km apart and orientated NW-SE and NE-SW.	The 2D survey lines overlap with the western edge of the Keraudren Extension 3D MSS.	> 3 years	
Santos Keraudren 3D MSS	19/05/2019 - 16/07/2019	3,260 in^3	3D racetrack acquisition line formation, orientated 30˚/120˚.	The Keraudren Extension 3D MSS will need to overlap with the previous Keraudren 3D MSS in order to tie-in the acquired seismic data. The overlap may comprise several sail lines,	> 6 months	The Keraudren 3D MSS will have been completed at least 6 months prior to the earliest potential commencement date of the Keraudren Extension 3D MSS (i.e. Feb 2020). Impacts to most ecological receptors within the survey area will have recovered, with the recovery of any impact benthic communities significantly advanced. Some residual chronic and sub-lethal effects to some benthic invertebrates may persist, but differences in overall community composition and structure are unlikely to be discernible from natural levels.

				equivalent to approximately 450 km^2.		Due to the relatively small overlap between the two Keraudren surveys (limited to a small number of survey tie-in sail lines), material cumulative impacts are not expected to result as a result of the Keraudren Extension 3D MSS.
3D Oil Sauropod 3D MSS	Survey has not yet commenced. The survey may take place January – April 2020 or January – April 2021.	3,090 in^3	3D racetrack acquisition line formation, orientated N-S.	Approximately 480 km^2 of the maximum case survey overlaps with the north-eastern part of the Keraudren Extension 3D MSS.	-	In the unlikely event that acquisition of the maximum case Sauropod 3D MSS goes ahead and the Keraudren Extension 3D MSS is acquired soon afterwards, some cumulative impacts may occur and disturbance to marine receptors in this location may continue from one survey to the next. Benthic invertebrate communities in the area of survey overlap may be subject to repeat sound exposures which may result in an increase in chronic lethal and sub-lethal effects in a small proportion of these soft-sediment invertebrates (**Section 6.2.2.6**). However, full recovery of these communities is expected following the surveys and any cumulative impacts are expected to be minor.

6.3.2.1 Cumulative effects on ecological receptors

The potential for cumulative impacts to occur depends on whether recovery of impacts from previous surveys will have occurred prior to the Keraudren Extension 3D MSS commencing or not. As described in **Section 6.2**, the duration of recovery following exposure to underwater noise emissions from a seismic survey is in the order of minutes to hours for some receptors, or weeks to months for other receptors, for example:

- Localised changes in zooplankton abundance are likely to be replenished and indistinguishable from natural levels within hours of a seismic survey vessel passing or, based on the most conservative studies and a precautionary approach, within a few days of a seismic survey being completed.
- Sub-lethal effects and chronic lethal effects to some benthic invertebrates may occur for weeks or several months after exposure, although changes in overall benthic community composition and structure are expected to be negligible in the context of natural mortality and recruitment.
- Changes in fishes' behaviour, abundance and distribution have been observed to last for minutes, hours or days, depending on the species, hearing sensitivity and situational context.
- Behavioural changes in migrating or foraging marine fauna (e.g. cetaceans, turtles, whale sharks) returning to normal within hours or days after exposure.

Ecological receptors are therefore expected to have recovered from the effects of a seismic survey within days to months of completion, with potential lethal effects to some immobile benthic invertebrate communities considered to have the longest population recovery period (>12 months). Longer term, only sublethal impacts to some benthic invertebrate organisms may persist but would not inhibit reproductive potential or community structure (refer to **Section 6.2.2.6** and **Appendix I**).

Based on these recovery periods, an assessment of the potential cumulative impacts to ecological receptors is included in **Table 6-15**. Given the time that has elapsed since previous surveys were undertaken in this area, most receptors will have recovered from the effects of previous surveys prior to commencement of the Keraudren Extension 3D MSS. **Section 6.2.2.6** principally identifies residual impacts to the benthic communities within the survey area. There is the possibility of some cumulative impacts to occur to benthic invertebrate communities in areas where the Keraudren Extension 3D MSS overlaps with the previous Keraudren 3D MSS or Sauropod 3D MSS, however, this will affect a relatively small proportion of benthic invertebrate organisms and full recovery of these communities is expected following survey completion. As described in **Section 6.3.2**, it would seem highly unlikely that these areas would be subject to further 3D seismic survey and impact; at least not in the short to medium term.

6.3.2.1 Cumulative effects on commercial fisheries

Consultation with commercial fishery stakeholders has identified concerns that multiple seismic surveys undertaken in successive years will impact fish stocks through disturbances to fish spawning and recruitment, as well as repeated disruptions to fishing activities. Further, that cumulative impacts to fisheries are often overlooked in environmental impact assessments.

To address these concerns, Santos has reviewed historical seismic surveys across the Pilbara Demersal Scalefish Fishers and Mackerel Managed Fishery, and analysed available FishCube data over the same period. For the purposes of this EP, the assessment focuses on the PMTIMF as this fishery is the most relevant to the Keraudren Extension 3D MSS in terms of the potential for marine user interaction and area of overlap with the fishery.

Figure 6-11 to **Figure 6-16** show the history of seismic surveys across the PMTIMF between 2014 and 2018 in relation to trawl fishing vessel presence within 10 nm CAES fishing blocks. Vessel presence per fishing block per month was the only complete data set available within the FishCube data. Total fish catch and fishing days per month per block is confidential information for fisheries with less than 3 operating vessels. Hence, vessel presence was used as an indicator of the general level of fishing activity in the fishery.

Overall, the figures show that fishing vessels continue to fish in similar areas each year with no obvious variations in fishing vessel distribution attributable to the presence of seismic surveys. Santos does, however, recognise that disturbance to fishers is likely to have occurred during this period, and that these more localised and temporal disturbances are not identifiable from the available data. It is acknowledged that each seismic survey may have resulted in operational inconveniences (e.g. maneuvering around the seismic vessel) to temporary loss of access to fishing areas (i.e. displacement).

The spatial areas associated with these historic and proposed surveys, and their overlap with the PMTIMF fishery and fished areas are shown in **Table 6-16**. The following conclusions are drawn from this table:

- The PMTIMF has historically been subject to 3D seismic surveys overlapping up to 13% of the fishery and 19% of fished areas, with additional areas overlapped by large scale 2D surveys (measured in thousands of kilometres).
- Between 2016 to 2018 there was either no, or a low level of 3D seismic survey effort (<3%), within the fishery and fished areas.
- The proposed 2020 to 2022 3D seismic surveys considered in this assessment (Keraudren Extension and Sauropod) overlap up to 11% of the fishery and 23% of fished areas, which is not dissimilar to historical seismic survey effort in 2015 (noting the additional 2D surveys in this year). While not shown in the table it is considered likely that the actual survey areas acquired will be less than stated, and potentially spread across multiple years.
- Since 2014, total fish catch has increased year-on-year despite the occurrence of large-scale seismic surveys.

As described in **Section 6.2.2.7**, seismic surveys have the potential to affect fish behaviour and fish spawning. Successive surveys across the PMTIMF since 2014 may have resulted, or could result, in temporary and localised disturbances to spawning fishes, but cumulative impacts are not likely to be significant for the following reasons:

- Large areas of the fishery were not/will not be overlapped by seismic surveys.
- The surveys were not/will not be concentrated along any principle depth range at which commercially important fish species may spawn.
- Most of the surveys did not occur/will not occur across the full spawning period for any commercially important fish species.

Table 6-16: Total survey areas of completed or proposed seismic surveys within the PMTIMF

Year	Total Fishery Area[1] (A) (km^2)	Total Area Fished[2] (B) (km^2)	Total Fish Caught (tonnes)	Total Fishing Days	Total 3D Seismic Surveys Overlapping the Total Fishery (A) (km^2)	Total 3D Seismic Surveys Overlapping the Total Fishery (A) (%)	Total 3D Seismic Surveys Overlapping the Area Fished (B) (km^2)	Total 3D Seismic Surveys Overlapping the Area Fished (B) (km^2)	2D Surveys Overlapping the Fishery and Area Fished[5]
2014	113,643	22,783	1,105	591	4,791	4%	1,663	7%	No
2015	113,643	22,374	1,172	NA[4]	14,209	13%	4,246	19%	Yes
2016	113,643	21,289	1,529	NA	0	0%	0	0%	Yes
2017	113,643	22,585	1,795	NA	2,787	2%	0	0%	No
2018	113,643	22,498	1,975	649	770	1%	770	3%	No
2019	113,643	NA[3]	NA	NA	3,819	3%	3,502	16%	No
2020 to 2022	113,643	NA[3]	NA	NA	12,103[6]	11%	5,064[6]	23%	No

1. Total fishery area = PMTIMF (Zone 2) including prohibited and closed areas.
2. Total area fished = The total area of all 10 nm CAES blocks with recorded fishing effort per year within PMTIMF Area 1-2, 4-5.
3. Total area fished for 2019-2021 based on the averaged area fished between 2014 to 2018.
4. Total fishing days not available due to FishCube data confidentiality. Requests made to DPIRD to obtain this data.
5. 2D surveys are measured in kilometres, hence, due to conversion difficulties are not shown as an area or percentage. Large 2D seismic surveys occurred during 2015 and 2016 (many thousands of kilometres) as illustrated in **Figure 6-12** and **Figure 6-13**.
6. 2020 to 2022 surveys include the Santos Keraudren Extension and maximum case 3D Oil Sauropod surveys. The total survey area includes the ramp-up zone and full power zone. This is considered a conservative assessment compared to the historical surveys shown in **Figure 6-11** to **Figure 6-16**, which only show the full-fold survey area (i.e. an area less than the full power zone).

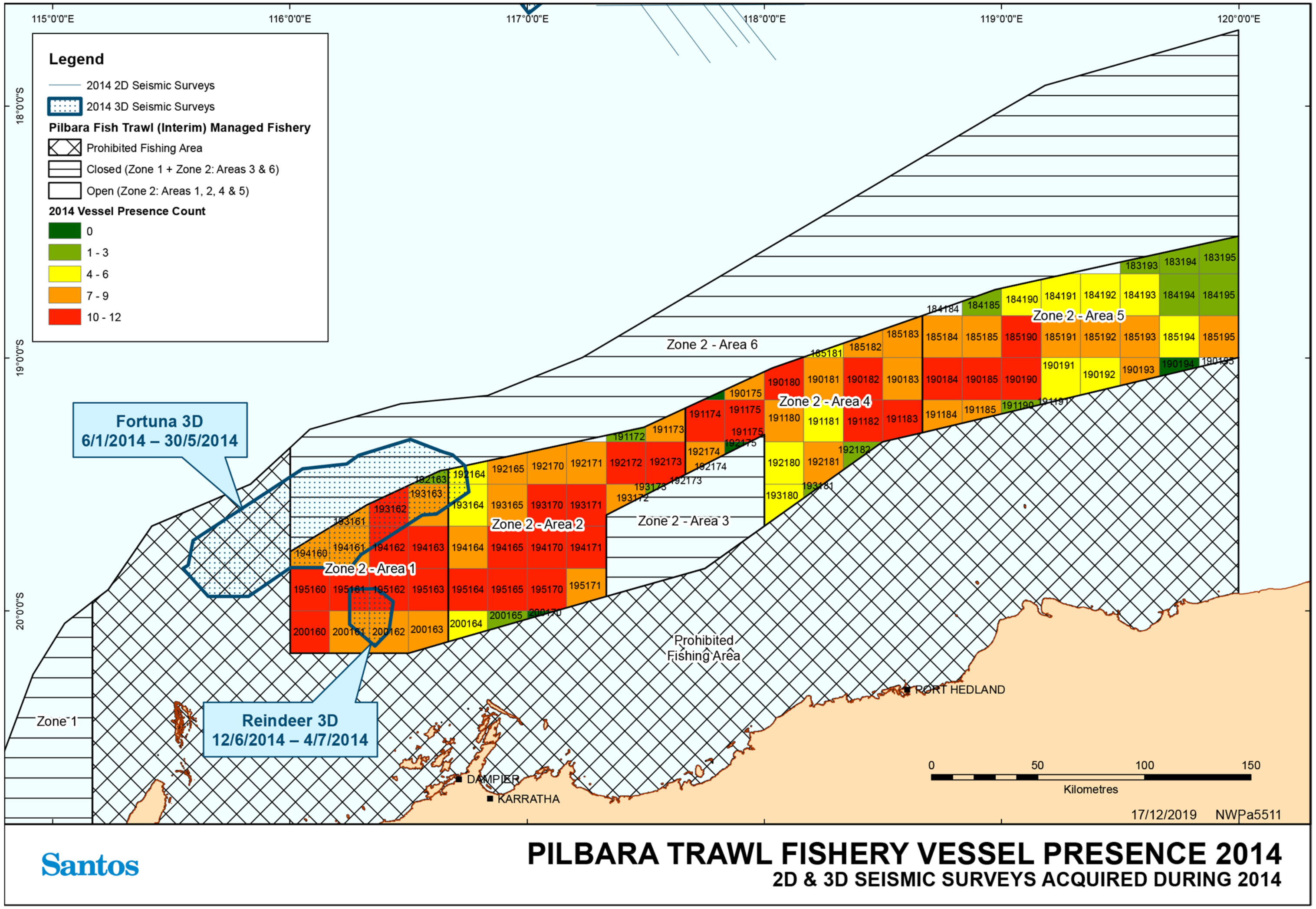

Figure 6-11: Complete 2014 seismic surveys overlapping the PFTIMF and number of months where a fishing vessel was recorded as fishing in a 10 nm CAES fishing block (0 = no months of the year with a recorded fishing vessel within the 10 nm CAES fishing block; 12 = 12 months of the year there was at least one fishing vessel present in the CAES fishing block)

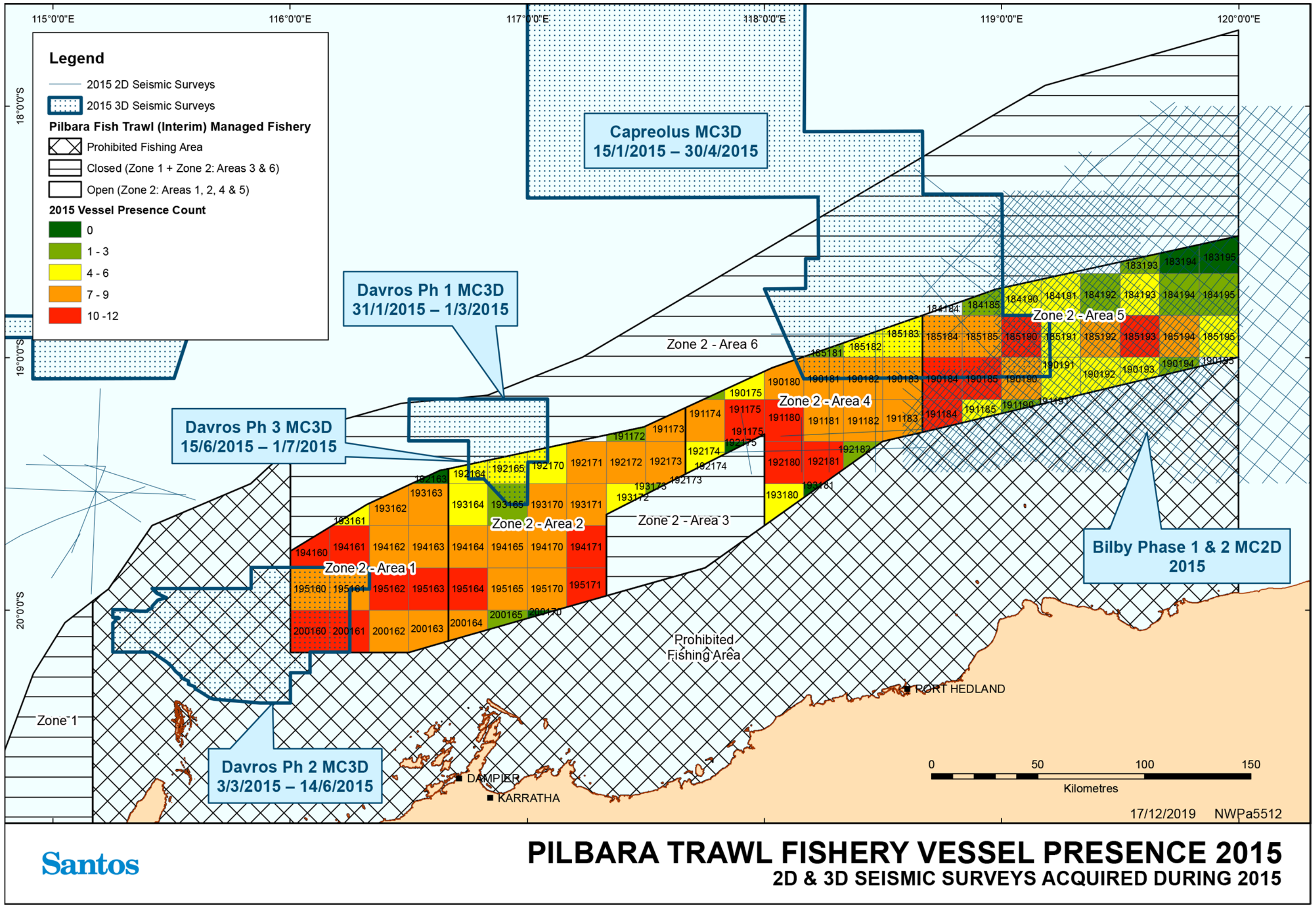

Figure 6-12: Complete 2015 seismic surveys overlapping the PFTIMF and number of months where a fishing vessel was recorded as fishing in a 10 nm CAES fishing block (0 = no months of the year with a recorded fishing vessel within the 10 nm CAES fishing block; 12 = 12 months of the year there was at least one fishing vessel present in the CAES fishing block)

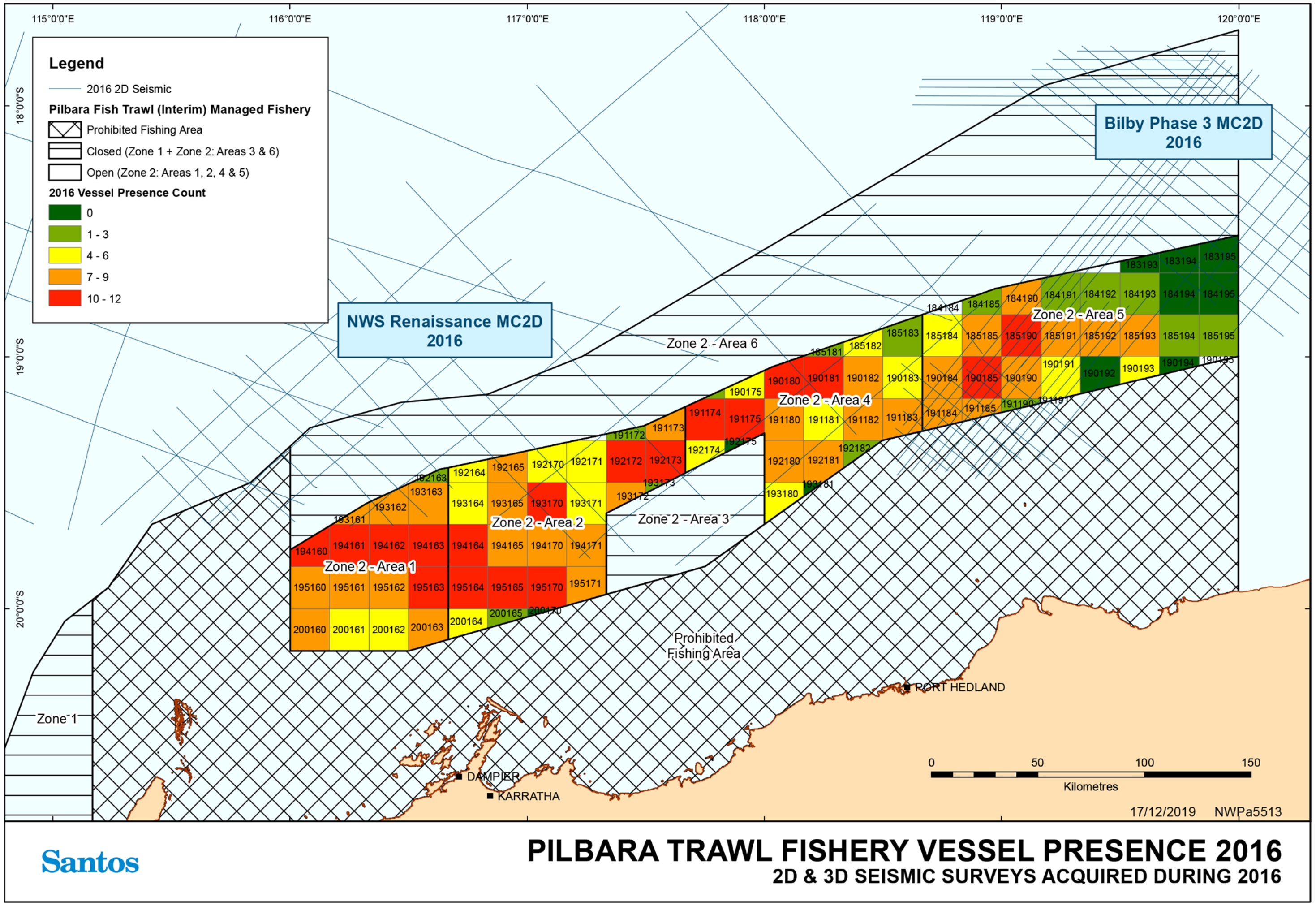

Figure 6-13: Complete 2016 seismic surveys overlapping the PFTIMF and number of months where a fishing vessel was recorded as fishing in a 10 nm CAES fishing block (0 = no months of the year with a recorded fishing vessel within the 10 nm CAES fishing block; 12 = 12 months of the year there was at least one fishing vessel present in the CAES fishing block)

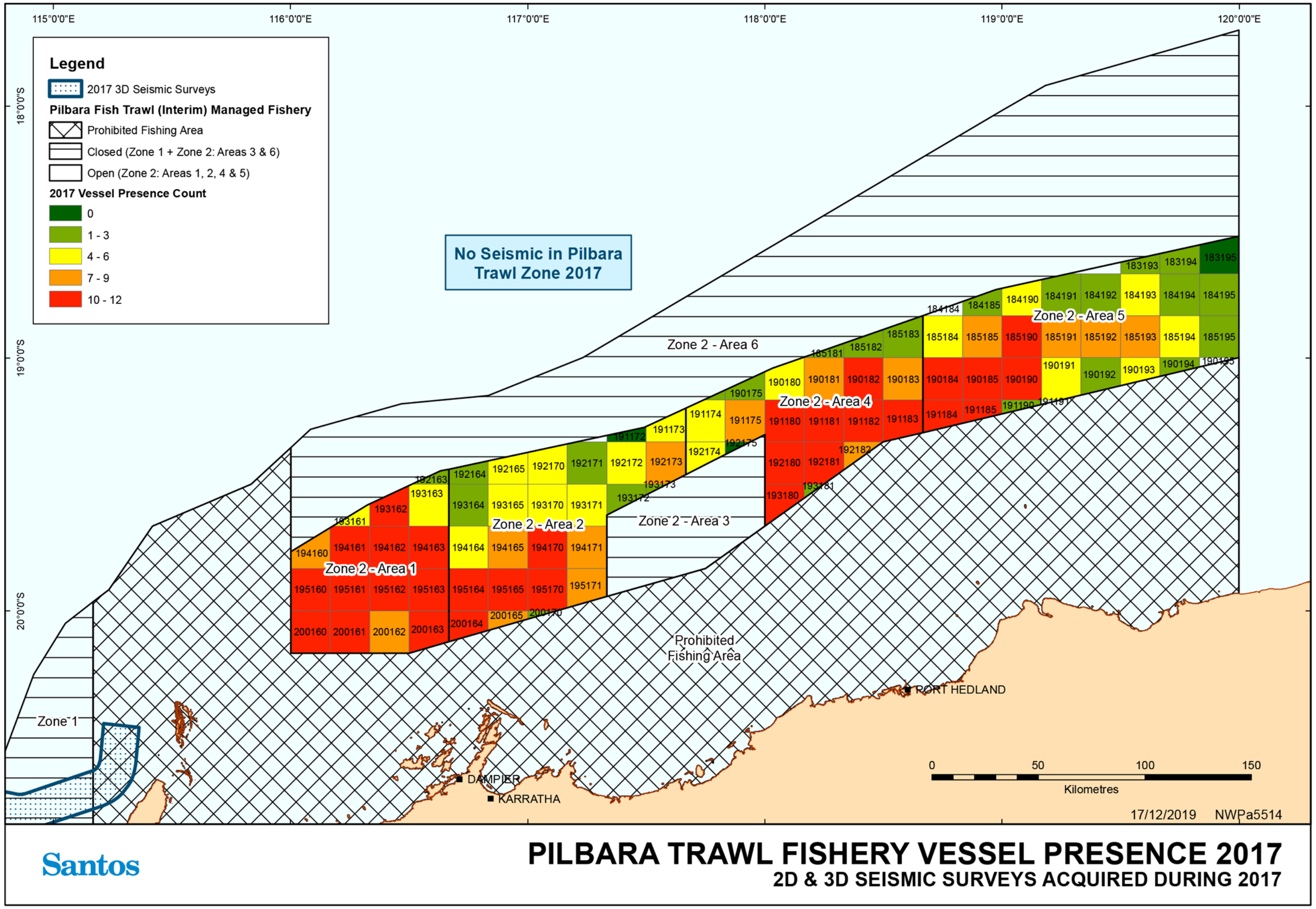

Figure 6-14: Complete 2017 seismic surveys overlapping the PFTIMF and number of months where a fishing vessel was recorded as fishing in a 10 nm CAES fishing block (0 = no months of the year with a recorded fishing vessel within the 10 nm CAES fishing block; 12 = 12 months of the year there was at least one fishing vessel present in the CAES fishing block)

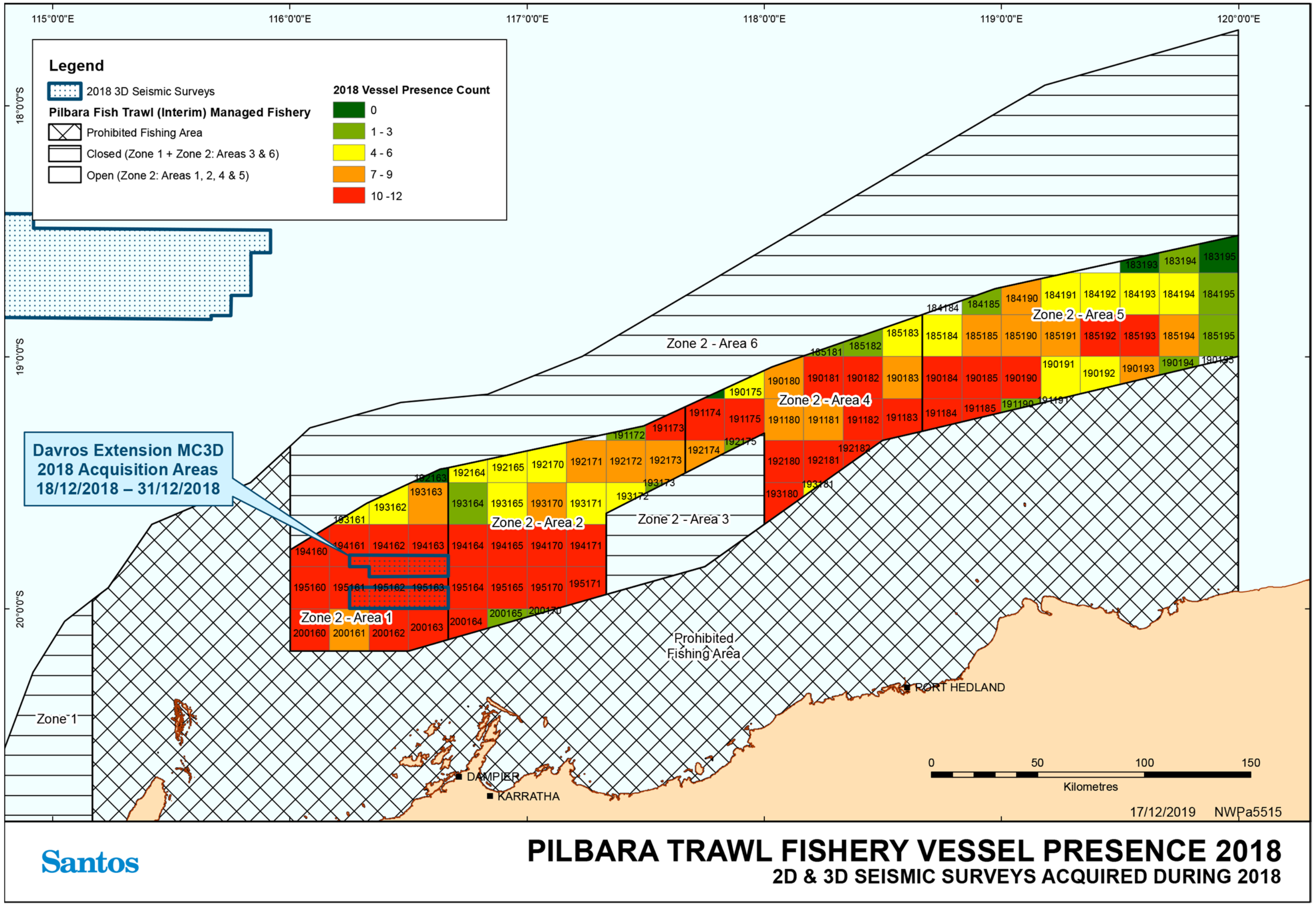

Figure 6-15: Complete 2018 seismic surveys overlapping the PFTIMF and number of months where a fishing vessel was recorded as fishing in a 10 nm CAES fishing block (0 = no months of the year with a recorded fishing vessel within the 10 nm CAES fishing block; 12 = 12 months of the year there was at least one fishing vessel present in the CAES fishing block)

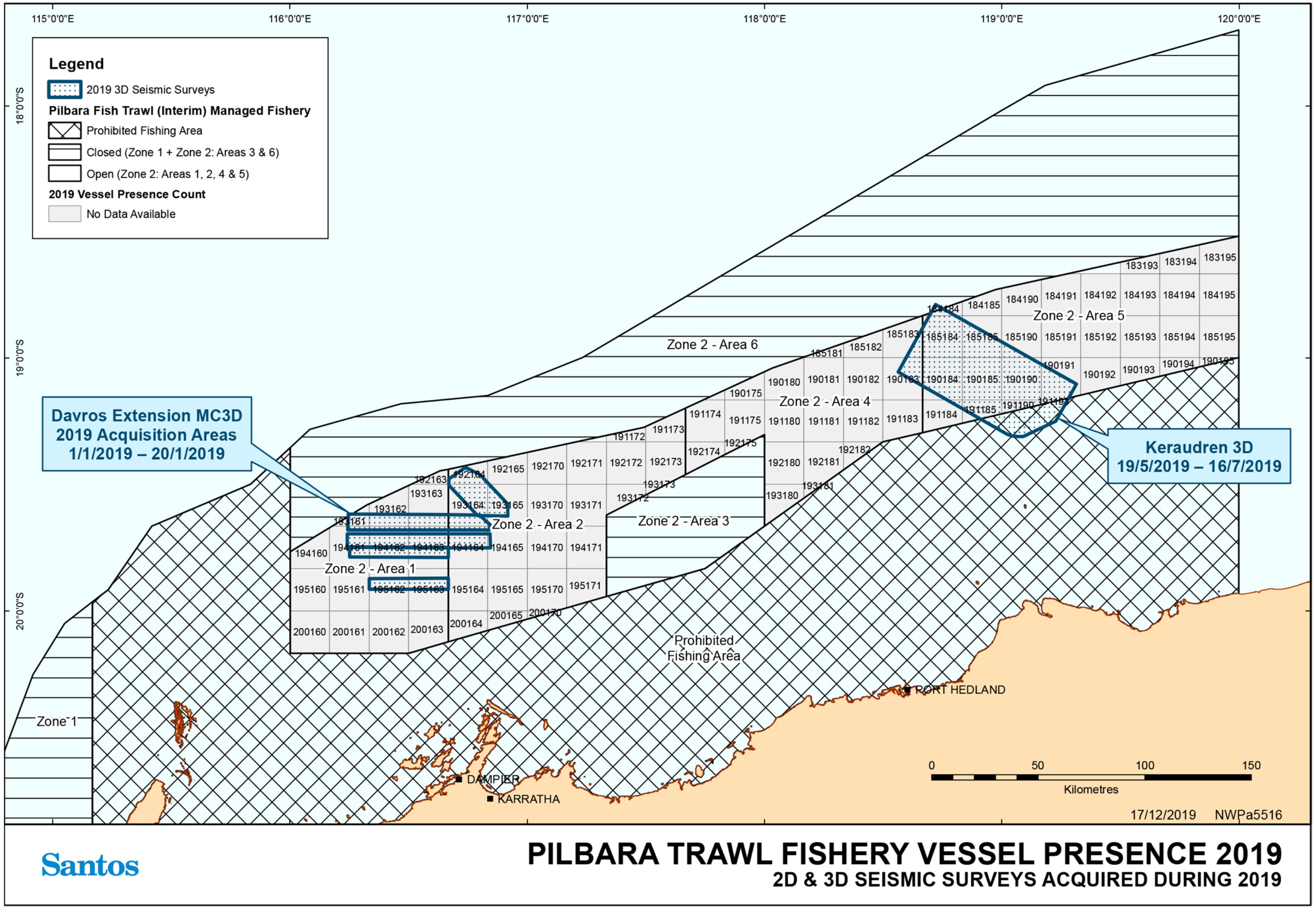

Figure 6-16: Complete 2019 seismic surveys overlapping the PFTIMF and 10 nm CAES fishing blocks (FishCube data not available for 2019)

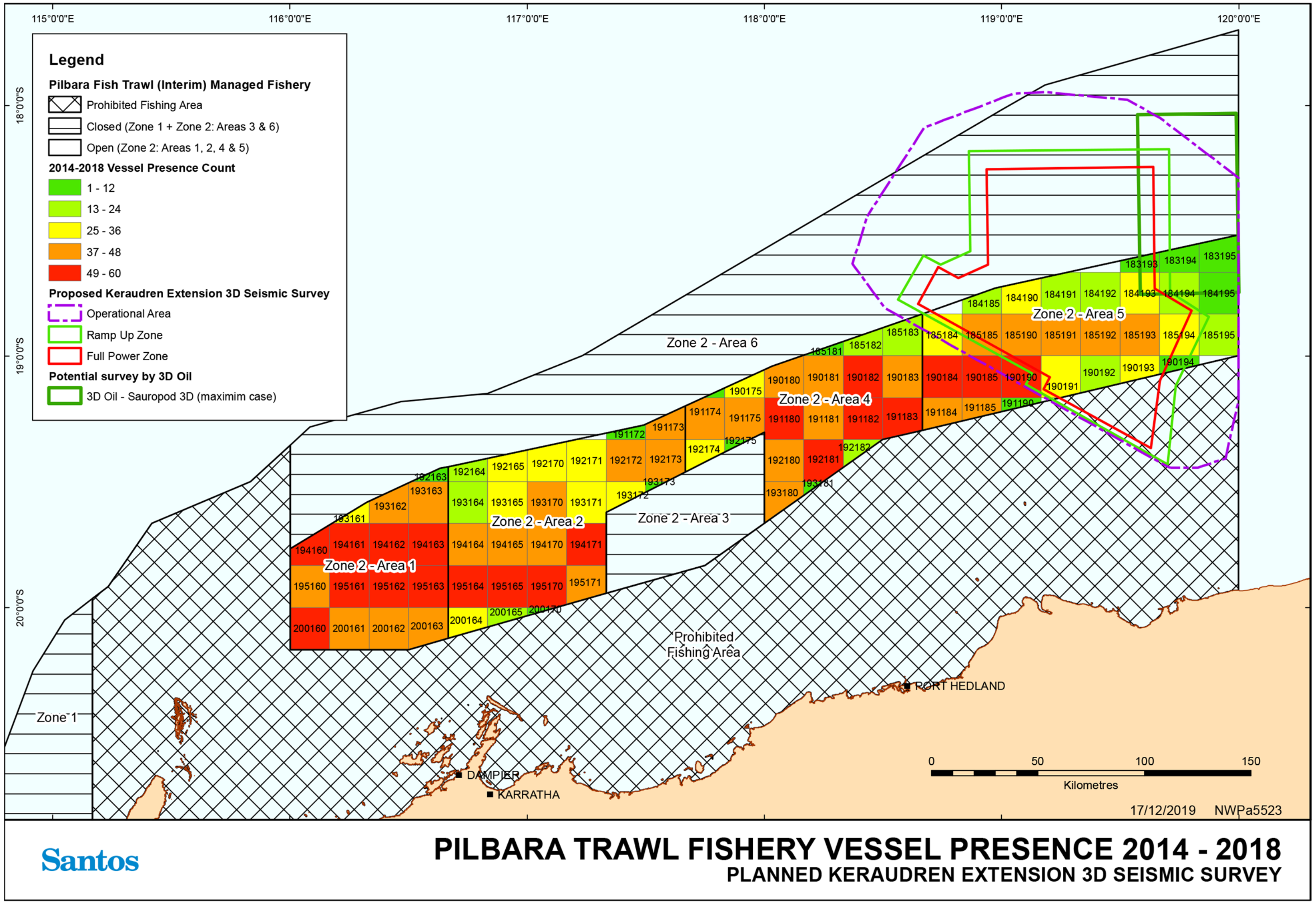

Figure 6-17: Proposed 2020-2022 seismic surveys overlapping the PFTIMF and total number of months where a fishing vessel was recorded as fishing in a 10 nm CAES fishing block between 2014-2018 (0 = no months between 2014-2018 with a recorded fishing vessel within the 10 nm CAES fishing block; 60 = 60 months between 2014-2018 there was at least one fishing vessel present in the CAES fishing block)

6.3.3 Nature and Scale of Additive Impacts

During the Keraudren Extension 3D MSS, other seismic surveys may also occur in the region (**Table 6-17**). The surveys described in this impact assessment either had EPs accepted or under assessment by NOPSEMA. Future EPs submitted to NOPSEMA will need to consider the additive impacts of the Keraudren Extension 3D MSS and other regional surveys.

It is important to note that, while some of these seismic surveys may occur at the same time as the Keraudren Extension 3D MSS, it is not credible for all the surveys to occur concurrently or in short succession; or for the entire stated maximum survey areas to be acquired. The large area multi-client surveys are only likely to occur if underwritten by oil and gas operators, and only a proportion of the large area would be acquired. For commercial reasons some of the seismic surveys may not proceed at all.

However, for the purpose of providing a conservative assessment, it has been assumed that some of the surveys could occur concurrently or shortly after the Keraudren Extension 3D MSS.

Table 6-17: Regional seismic surveys that have the potential to occur in addition to the Keraudren Extension 3D MSS

Survey Name	Survey Type	Area	Distance from the Keraudren Extension 3D MSS	Survey Timing and Duration	Seismic Source	Acquisition Lines	EP Status
Woodside North-west Australia 4D MSS	4D	Pluto: 780 km^2 Harmony: 469 km^2 Scarborough: 2,059 km^2 Laverda: 144 km^2 Cimatti: 87 km^2 Vincent: 82 km^2	Pluto: 413 km Harmony: 414 km Scarborough: 550 km Laverda: 570 km Cimatti: 560 km Vincent: 540 km	Dec 2019 – July 2020 Pluto: 28 days Harmony: 20-28 days Scarborough: 45 days Laverda: 23 days Cimatti: 11 days Vincent: 12/13 days	Pluto: 3,150 in^3 Harmony: 3,090 in^3 Scarborough: 3,150 in^3 Laverda: 2,650 in^3 Cimatti: 3,150 in^3 Vincent: 3,150 in^3	Pluto: N-S Harmony: N-S Scarborough: NE-SW Laverda: NE-SW Cimatti: NE-SW Vincent: E-W	Under assessment
TGS Renaissance North (multi-client)	3D	Max 25,000 km^2	86 km	2018 – 2020 Duration unknown	4,120 in^3	3D Azimuth unknown.	Accepted, valid to 2020.
TGS Renaissance South (multi-client)	2D & 3D	Operational area is 300,000 km^2 [no defined acquisition area]	132 km	2016 - 2021 Duration unknown.	4,120 in^3	3D racetrack. Azimuth unknown. Line plan not in the public domain. 2D orthogonal grid. Line spacing unknown.	Accepted, valid to 2021.
PGS Rollo MC MSS (multi-client)	3D	117,833 km^2 [no defined acquisition area]	0 km (acquisition area overlaps the western portion of the Keraudren MSS ramp-up zone)	2018 - 2023 25,000 km^2 per year.	3,260 in^3	3D racetrack. Azimuth unknown.	Accepted, valid to 2023.

Survey Name	Survey Type	Area	Distance from the Keraudren Extension 3D MSS	Survey Timing and Duration	Seismic Source	Acquisition Lines	EP Status
3D Oil Sauropod 3D MSS	3D	3,500 km^2	0 km (acquisition area overlaps the north-eastern portion of the Keraudren MSS ramp-up zone)	January – April 2020 or January – April 2021. Maximum of 60 days.	3,090 in^3	3D racetrack N-S	Under assessment
INPEX 2D Seismic Survey (WA-532-P, WA-533-P, WA-50-L)	2D	65,138 km^2	97 km	1 November 2020 to 31 December 2021, no acquisition between 1 June - 31 October in 2020 or 2021. Maximum of 210 days.	Approx. 3,000 in^3	2D orthogonal grid. 3-6 km line spacing	Under assessment
Shell Factory 3D MSS	3D	3,750 km^2	792 km	November 2019 – February 2020 or April 2020 – September 2020. Maximum of 73 days.	3,480 in^3	3D racetrack NW-SE	Accepted, valid to December 2020
Sapura Gem 3D MSS	3D	4,100 km^2	882 km	January 2020 – Q3 2020. Maximum of 27 days.	2,820 in^3	3D racetrack NW-SE	Under assessment
Polarcus Cygnus 3D MSS – Phase 3 South	3D	1,767 km^2	792 km	May 2019 – 31 December 2020. Maximum of 36 days.	3,090 in^3	3D racetrack NW-SE	Accepted, valid to December 2020

Survey Name	Survey Type	Area	Distance from the Keraudren Extension 3D MSS	Survey Timing and Duration	Seismic Source	Acquisition Lines	EP Status
Polarcus Petrelex 3D MSS	3D	2,900 km^2	1,100 km	September 2019 – 31 December 2020. Maximum of 64 days. No acquisition between 1 August 2020 – 30 September 2020.	2,495 in^3	3D racetrack Azimuth not yet confirmed.	Accepted, valid to December 2020

6.3.3.1 Sound fields from multiple seismic surveys

The additive effects of concurrent seismic surveys in the region include:

- the effects of multiple individual sound fields in separate geographic locations resulting in spatially separate areas of disturbance, such as when surveys occur at distance from one another; and
- the potential interaction of sound fields produced by separate seismic surveys, where sound waves from the separate seismic sources may be received either in synchrony (“in synch”) or out of synchrony (“out of synch”).

Item 2, the interaction of two seismic sound fields is a complex issue. The following approximation of the implications for the concurrent activities of multiple seismic surveys close to the Keraudren Extensions MSS was, therefore, conducted by JASCO Applied Sciences (Koessler, M. and McPherson, C., pers. comm. 9th December 2019) and ERM:

Other seismic surveys conducted in the region will be undertaken without any intended temporal synchronization between seismic impulses and the source point intervals used in each survey are often different. In addition, the duration of the seismic impulses (hundreds of milliseconds) is short compared to the source point interval of several seconds, therefore, the perfect alignment and synchronisation of impulses from two seismic sources is highly unlikely.

*JASCO Applied Sciences were previously engaged in 2018 to assess the potential overlap of seismic signals from two seismic source arrays operating within close proximity of one another (approximately 3 km) for the 2019 Santos Keraudren 3D MSS (Quijano et al. 2018). The study placed emphasis on quantifying how the use of two seismic sources might influence the received sound levels and the extent of seismic effects compared with the use of a single source. The main conclusion was that the two sources were largely non-synergetic in terms of per-pulse sound fields. An increase in sound levels may sometimes occur temporarily at locations where the received signals from each source occur in synch. However, in most instances, pulses will be out of synch and increased received per-pulse sound levels will not occur often (**Figure 6-18**).*

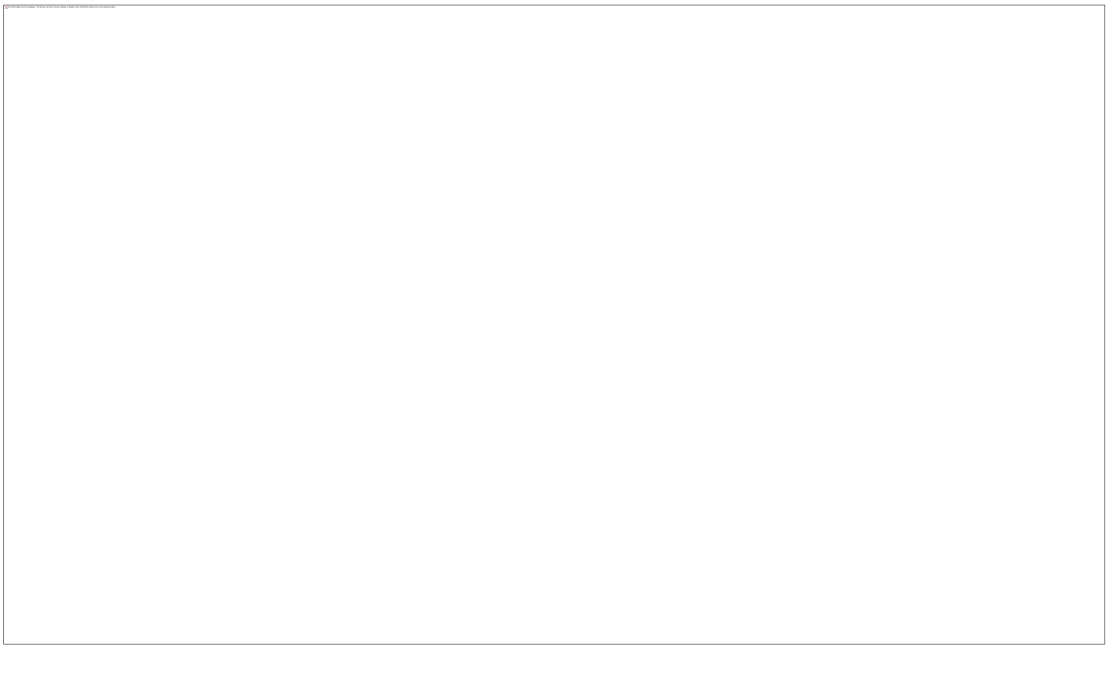

Figure 6-18: Two separate pulses of sound occurring in synch (top) and out of synch (bottom) (Quijano et al. 2018)

Given that different seismic sources are unlikely to be discharged at exactly the same time, different surveys will have different source impulse intervals, and each pulse will be a few hundred milliseconds in duration with several seconds in between, pulses will generally be out of synch with one another. While the pulses will still line up occasionally for a brief moment at some locations, unless they coincide roughly equidistant to both sources, the resulting received levels from unlikely synchronous signals will be closer to one or the other of the two sources. The amplitudes will then be too unequal for the sum level to differ much from the stronger of the two components (Quijano et al. 2018).

However, a conservative assessment would consider the unlikely case of two pulses exactly synchronised with each other. For pulses occurring simultaneously, the relative difference between received levels from the two surveys is important. To place this in context, if the received level at a nominal location of interest from each survey was to be the same, then the combined SPL would be 3 dB higher than the individual SPL, which represents a doubling of sound energy. However, the greater the difference in received SPL at a nominal receiver from each source, the smaller the resulting increase. For example, a difference of 10 dB between the received levels results in an increase equivalent to 0.4 dB for the combined level.

***Figure 6-19** and **Figure 6-20** illustrate how two pulses may combine to increase sound levels when they are exactly synchronised, with a maximum difference of 3 dB[6].*

Such an increase in sound pressure level may only be of significance within relatively short distances (i.e. several kilometres) of the seismic sources, where the sum of the two pulses may exceed behavioural effect thresholds of relevance to marine fauna. This will only be of relevance if fauna are in the same location at the same time as the received pulses from both sources.

Therefore, the sound produced by two separate sources may generally be treated as spatially separated sound fields and single pulse sound levels will not typically increase as a result of synchronous pulses of sound. However, in circumstances when two seismic sources sail within close proximity of each other, the overall area where physical or behavioural effects thresholds are exceeded will be greater. This would only occur for a relatively short period when the two survey vessels and seismic sources are operating at their closest points of approach to one another. At other times, the two seismic survey vessels may be tens or hundreds of kilometres apart.

Considering the above concepts, **Table 6-18** provides a qualitative assessment of the potential additive impacts to each receptor category.

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[6] Note that the diagrams in **Figure 6-19** and **Figure 6-20** are theoretical and for illustrative purposes only and do not represent modelled or actual sound levels or distances.

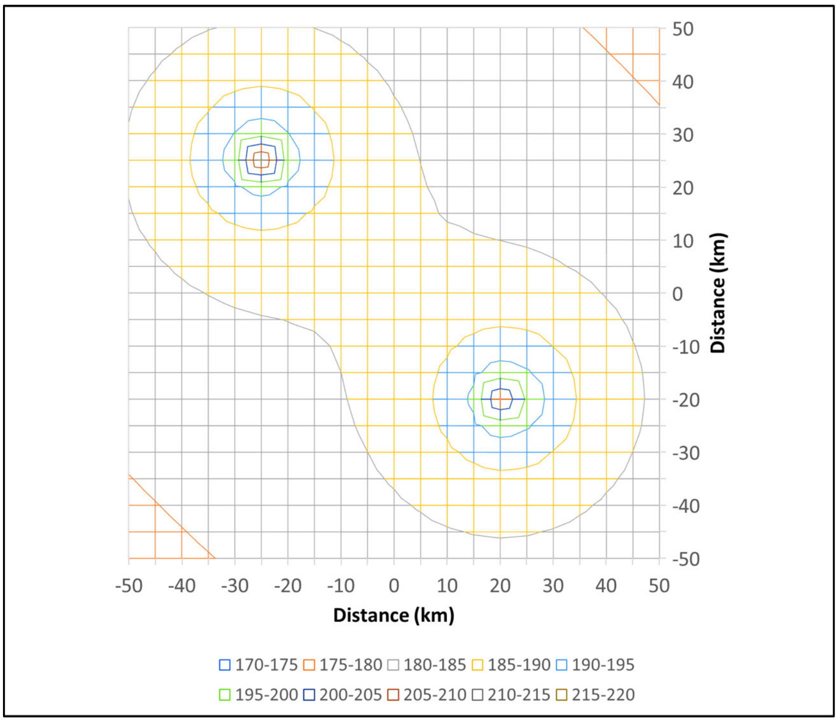

Figure 6-19: Diagram illustrating how sound waves propagating from two point-sources could hypothetically look given synchronous signals, with levels in dB

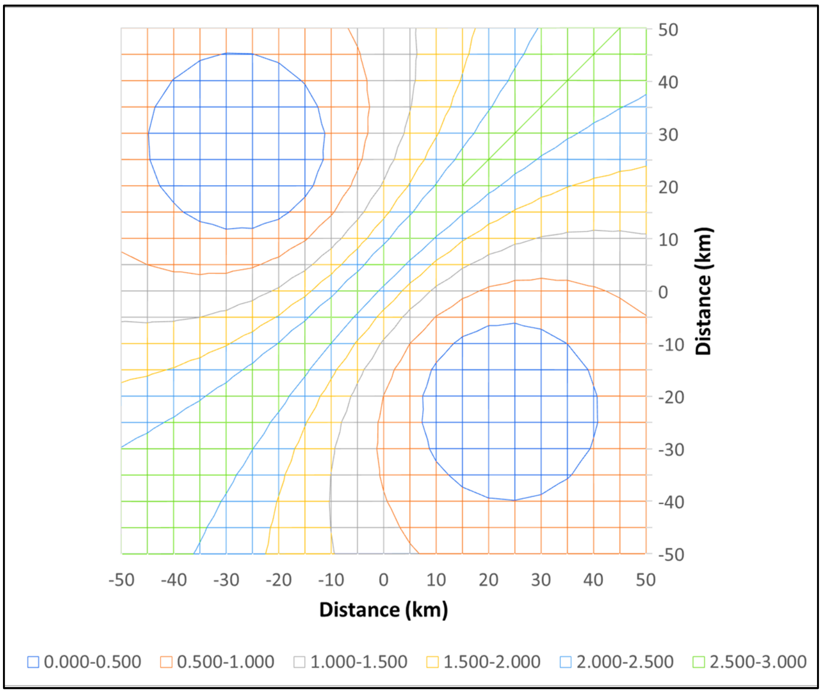

Figure 6-20: Diagram illustrating the difference (in dB) between the sound levels within each grid square for the illustration in Figure 6-19

Table 6-18: Evaluation of potential additive impacts resulting from multiple seismic surveys

Receptor category	Description of potential additive impacts
Plankton	No significant additive effects to plankton communities are expected from different surveys given the range to impact is typically tens of metres (**Section 6.2.2.5**) and planktonic communities have a rapid turnover (reproduction and mortality) rate. Even applying a highly precautionary approach accounting for impacts out to a few kilometres from the seismic source, plankton abundance is expected to return to normal levels due to recruitment from unimpacted areas before any impacted zooplankton populations move down current to another survey area (as was demonstrated by Richardson *et al*. 2017). If multiple seismic surveys occur concurrently, there may be a small additional loss of zooplankton, eggs and larvae within the separate survey areas, but with limited potential to have any discernible population level impacts given naturally high turnover rates of plankton, as well as the high fecundity and high levels of connectivity of fishes and other marine organisms that spawn throughout the region.
Invertebrates	The maximum worst case impacts reported for invertebrates include sub-lethal impacts such as statocyst impairment, temporary reduced immune response function, temporary impaired reflexes, and potentially some chronic effects that lead to mortality of a small number of sessile benthic invertebrates over and above natural mortality rates (**Section 6.2.2.6**). Such impacts are expected to occur at close range to the seismic source (i.e. tens or hundreds of metres). In the context of natural mortality, recruitment and recovery rates, the impacts to overall benthic communities are expected to be negligible and population level effects are not expected (**Section 6.2.2.6**). Benthic invertebrate communities in the area of overlap between the Keraudren Extension 3D MSS and 3D Oil Sauropod 3D MSS may be subject to repeat sound exposures which may result in an increase in chronic lethal and sub-lethal effects in a small proportion of these soft-sediment invertebrates. However, full recovery of these communities is expected in the weeks and months following the surveys due to recruitment from adjacent areas (**Section 6.2.2.6**). Other surveys within the region will also experience similar impacts within their respective survey areas, with recovery expected in the weeks and months following the surveys.

Receptor category	Description of potential additive impacts
Fish	Significant behavioural impacts in most demersal and pelagic fish are expected to occur at distances of tens or hundreds of metres from the seismic source, returning to normal within minutes or hours (**Section 6.2.2.7**). Some species of small pelagic bait fish such as herring and sardines, which have a swim bladder connection in their hearing and may therefore be more sensitive to sound, may be more sensitive to sound and may exhibit a behavioural response and some level of avoidance over several kilometres from the seismic source. Resultant changes in the distribution of fishes is likely to return to normal within days of the seismic source passing the area (**Section 6.2.2.7**). A similar level of disturbance to fishes may occur at each individual survey area in the region. Given the limited potential for the sound fields from separate surveys to combine in synchrony, with a maximum increase of 3 dB in situations when two seismic sources are in close proximity and the pulses are exactly synchronised (**Section 6.3.3.1**), there is limited potential for additional disturbance to occur if two seismic surveys are operating within very close proximity to one another (i.e. several kilometres). Such a situation may only occur if the 3D Oil Sauropod 3D MSS or PGS Rollo surveys are acquired concurrently with the Keraudren Extension 3D MSS and only during brief periods if and when the seismic vessels from each survey are operating in close proximity to one another. No discernible additive impacts to fish are expected, given the separation distances between survey vessels in most instances. Some changes in fish abundance and distribution could occur as a result of exposure from the two operating seismic surveys, but such changes are expected to return to normal within a few hours or days. Disturbance to spawning adult fishes is also possible within each survey area. Given the expected distances between surveys and because not all surveys would occur at once, large areas across genetic fish stock ranges will not be overlapped by seismic surveys. While individual surveys are unlikely to have a discernible effect on spawning, it is acknowledged that the additive effects of all surveys, in addition to natural factors and fishing catches, may contribute to some small reduction in spawning success and potential recruitment. However, these effects are considered to be temporary, and relatively minor compared with natural variations in spawning success and fish recruitment (**Section 6.2.2.7**).
Sharks	As described in **Section 6.2.2.8,** sharks have very limited sensitivity to sound pressure and may only react to seismic pulses within very close proximity to the seismic source. Sharks are also naturally vagrant and, therefore, disturbances from seismic surveys will be incidental to their normal behaviours. Whale sharks migrating and foraging within the BIA may be exposed and may exhibit a behavioural response to more than one survey, however, the risk expected to be negligible.
Cetaceans	As described in **Section 6.2.2.9**, behavioural disturbances from seismic surveys may result in cetaceans deviating from their course and avoiding the seismic source in proximity to individual survey areas. For migrating cetaceans, which may pass multiple seismic survey areas, animals may deviate from their course on several separate occasions. This may be the case for humpback whales, however, the planned seismic surveys in this region do not constrain the migration route BIA for this species in nearshore waters and so migration is not expected to be constricted, nor the population displaced from their migration route. Instead, occasional behavioural avoidance and deviations from course are expected to be small relative to the long distances over which the migration occurs and so any additional energy expenditure is expected to be limited. The proposed timing for acquisition of the Keraudren Extension 3D MSS (February to July) means that there may be overlap with the beginning of the northbound migration, which may begin in June and peak in July, continuing into August. The survey will not coincide with the southbound migration of humpback whales through the region (September to October).

Receptor category	Description of potential additive impacts
	Migrating pygmy blue whales may also experience similar disturbances as they pass other surveys in the region, however, the main migration route for the species is located over 100 km north-west of the survey area and over 30 km from the operational area of the Keraudren Extension 3D MSS. Acquisition of the Keraudren Extension 3D MSS may overlap part of the northbound migration (April to August), but avoids the southbound migration period for pygmy blue whales in the region (September to December). Therefore, no significant additive impacts are expected to occur to pygmy blue whales from the Keraudren Extension 3D MSS. As noted in **Section 6.3.3.1**, pulses from two separate surveys will rarely occur in synch and increase sound levels, where the sum of the two pulses may exceed behavioural effect thresholds of relevance to marine fauna. In the event that sound fields from separate surveys combine, there could be a maximum increase of 3 dB in situations when two seismic sources are in close proximity and the pulses are exactly synchronised. Based on the 160 dB re 1 µPa threshold for behavioural disturbance in cetaceans, it is noted that the threshold may be exceeded between approximately 5.7 and 8.8 km from the Keraudren Extension 3D MSS seismic source. A comparable sound field from an adjacent seismic survey, such as the Sauropod 3D MSS or the PGS Rollo survey may also result in these sound levels over similar distances. Therefore, at a point equidistant between the two surveys when they are approximately 12 – 18 km apart, sound levels may combine in synchrony and result in sudden increases that exceed the 160 dB re 1 µPa threshold. At closer distances, the sound levels may increase to greater sound levels. These increases will be for very brief moments, but the combination of sound fields have the potential to increase behavioural responses between two operating seismic sources. Although cetaceans are likely to be able to avoid such sound exposures, it is noted that operating within these close distances may increase the potential for behavioural impacts to listed threatened or migratory cetaceans.
Marine turtles	Short-term behavioural impacts to marine turtles may occur between 2.9 and 4.2 km from the operating Keraudren Extension 3D MSS seismic source (**Section 6.2.2.11**). Considering the potential for sound fields from another seismic survey to potentially occur in synchrony, sound levels may occasionally exceed the 166 dB re 1 µPa turtle behaviour threshold when the two seismic sources are approximately 6 – 9 km apart, although such disturbances will be very brief. When the two seismic sources are operating in closer proximity to one another, the potential for behavioural disturbance to turtles increases. The Keraudren Extension 3D MSS will not be acquired within turtle internesting Habitat Critical during the internesting periods. Similarly, other surveys will also avoid turtle internesting habitats. Therefore, interactions between the surveys and turtles will occur in offshore waters where animals are expected to be transient. Despite the increased potential for occasional behavioural disturbances to some animals, no changes to migration or other important life stages are expected.

Receptor category	Description of potential additive impacts
Commercial fisheries	In addition to the potential additive effects to target fish stocks considered above, multiple seismic surveys operating concurrently have the potential to reduce the area available for fishing. As described in **Section 6.2.2.13**, the potential overlap between seismic survey activities and fishing activities has been evaluated based on the area where fishers may be displaced from during one week's worth of acquisition (i.e. 1 week of racetrack). A further indicative 5 km buffer was applied to this area to represent the area where fish catch levels may be affected and the stand-off distance that fishing vessels may be asked to give to the seismic survey vessel while towing the seismic source and streamers. As the survey vessel moves over the survey area, an equivalent area will be acquired. As already summarised in **Table 6-14**, one week of acquisition during the Keraudren Extension 3D MSS would result in a maximum spatial overlap with the Mackerel Managed Fishery (Area 2) and the Pilbara Fish Trawl Interim Managed Fishery (the two most active fisheries operating within the operational area) of 2.5% and 6% respectively. Should other seismic surveys (e.g. 3D Oil Sauropod and PGS Rollo) occur concurrently with or shortly after Keraudren Extension 3D MSS within the same fisheries then it is reasonable to estimate similar spatial overlaps. Santos considers it highly unlikely that more than three seismic survey vessels would be operating across these fisheries in any one year. While large areas of the commercial fisheries exist outside of these week-long spatial overlaps, the multiple surveys may result in an increased level of interference with commercial fishers and increased likelihood of temporary displacement and/or loss of catch. Santos will manage the potential impacts of its own activities with commercial fisheries through established communication protocols and the commercial 'make good' arrangements identified in **Section 6.2**.
Other socio-economic	Given the distance of the surveys offshore from potential dive sites and pearl diving / farming operations, no further additive impacts are expected beyond those already assessed for the Keraudren Extension 3D MSS. Other socio-economic activities in the region (e.g. recreational fishing and diving) are unlikely to be exposed to more than one seismic survey at a time, with the exception of commercial shipping. Commercial vessels may traverse more than one survey area during a voyage, each requiring the vessel to deviate from its course to give-way to the seismic vessel while towing equipment and restricted in its ability to manoeuvre. However, this is standard maritime practice and the impact would be negligible.

6.3.4 Environmental Performance and Control Measures

Environmental Performance Outcomes (EPOs), Control Measures and Environmental Performance Standards (EPSs) for managing the interaction with other marine users (including commercial fishers) and noise emissions are described in **Section 6.1.3**, **Section 6.2.4 and Section 8.6.1**, and are not restated in this section.

Additional Environmental Performance Outcomes (EPOs) relating to the management of cumulative and additive seismic survey impacts include:

- Potential additive impacts from concurrent seismic survey operations are identified and reduced as far as reasonably practicable (EPO-23).

The Control Measures considered for this Activity are shown below, with Environmental Performance Standards and Measurement Criteria for the EPOs described in **Section 8.6.1**.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
Commercial Fisheries				
CM-20	Management of concurrent seismic surveys within Pilbara commercial fisheries	Commercial fishing operations may be frustrated by concurrent seismic survey vessels operating within their fishery. To this end, prior to commencing a stage of the Keraudren Extension MSS, Santos will consult with other seismic survey operators potentially operating in the same fishery and discuss practicable ways to minimise interference with commercial fishing vessels. It is through open communication channels with other seismic survey operators and awareness of seismic survey vessel plans and locations that Santos can take action to minimise interference with commercial fishing vessels potentially interacting with multiple seismic survey vessels within their fishery.	Consultation with other seismic operators and development of vessel communication and interaction protocols can be undertaken at minimal cost.	**Adopted** – Reducing interference with commercial fishing vessels, wherever practicable, is a priority for Santos.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	Further reducing the months in which the survey can be acquired (Feb to July) because of potential additive impacts to spawning periods of commercially important key indicator fish species (as identified in consultation with DPIRD).	Reducing the number of months that the Keraudren Extension 3D MSS can be acquired in any year may minimise potential additive impacts from multiple seismic surveys on spawning fish of commercial importance and their fish larvae and eggs.	Survey would not be able to occur due to combined spawning of commercially important fish species occurring year-round. Further reduction in the proposed operating window (Feb to July) may mean multiple years of surveys at a cost to Santos.	**Not Adopted** – Survey cannot be timed to avoid all spawning periods due to the species present. Santos has committed to no seismic acquisition between August to January to minimise the survey overlap with commercial key indicator fish species spawning months, as well as whale migration periods (late July through to October). There have been no requests from DPIRD nor commercial fishers to further reduce the proposed operating window, acknowledging that a further reduction would increase the likelihood of surveys occurring over multiple years given the time required to acquire the data. Reducing the survey window by one or two months over one or two survey years is unlikely to have a detectable benefit to fish stock levels of commercial importance, particularly in consideration of natural levels of variability in fish spawning and recruitment.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	Reduce the survey area because of potential additive impacts to commercial fisheries	Reducing the size of the Keraudren Extension 3D MSS survey area may minimise potential additive impacts from multiple seismic surveys on commercial fishery operations (e.g. vessel interference), and spawning fish of commercial importance and their fish larvae and eggs.	Would not achieve the survey objectives.	**Not Adopted** – This will prevent acquisition over all geological targets of the required data, which will likely result in additional future surveys being required. The additional surveys would result in additional costs to Santos, as well as additional impacts and risks associated with vessel presence. While a reduction in survey area would reduce the potential overlap with commercial fisheries, the impact assessment presented above does not predict significant impacts to commercial fishing or fish resources. Furthermore, any short-term loss of catch or displacement will be managed via a 'make good' payment framework to ensure commercial fishers are no worse off (further detail is provided in **Section 8.6.2**).
N/A	Requiring the survey to be staged over multiple years because of potential additive impacts to commercial fisheries	Breaking the survey area into smaller areas and requiring the survey to be staged over multiple years may minimise potential additive impacts from multiple seismic surveys on commercial fishery operations (e.g. fish disturbance and loss of catch), and spawning fish of commercial importance and their fish larvae and eggs.	May result in consecutive years of potential interference with commercial fishers. Additional total survey costs due to multiple mobilisations/demobilisation. May mean that seismic survey data will not be available in the time frames required by Santos. Potential data quality/compatibility issues if different seismic survey	**Not Adopted** – Santos intends to acquire the data as quickly and efficiently as possible. The same amount of time is required to acquire the full survey regardless if the survey is acquired over one or many years, hence, the commercial fisher interaction risks are not considered to be materially different. The survey will overlap the same total area regardless if the survey is

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			vessels and equipment are used to acquire the data.	acquired over one or many years, hence, risks to fish stocks and commercial fisheries are not considered to be materially different. There have been no requests from DPIRD nor commercial fishers to split the survey over multiple years. Santos is planning to acquire some of the survey in 2020 (May to July), however, will not have time to acquire the full survey. If successful, the remaining survey area would be acquired in 2021 (i.e. a staged approach). If unsuccessful, Santos would aim to acquire the full survey in 2021. At this point in time 2022 is considered a contingency year should the full survey not be acquired in 2020-2021. For these reasons Santos rejects the requirement to conduct the survey over multiple years, noting its Santos intention to acquire the survey as soon as possible in 2020 and 2021.
N/A	Not overlapping with nearby seismic surveys to minimise potential cumulative impacts	Reducing the amount of seismic survey area overlap may reduce potential cumulative impacts to ecological receptors and commercial fisheries.	Reducing the survey area would mean survey objectives will not be met.	**Not Adopted** – At this point in time the only potential overlap is with the 3D Oil Sauropod survey area. The amount of overlap, with the maximum case survey, is relatively small (868 km^2). The specific details of this survey are unknown; hence, the amount of overlap could actually

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				be smaller than that displayed in their pending environment plan. To achieve the survey objectives by obtaining full-fold seismic coverage over the hydrocarbon-prospective geology within Santos' permit area, the full power zone and ramp-up zone need to extend into the neighbouring permit area. Santos will endeavour to further optimise the amount of overlap but rejects the requirement to avoid any overlap on the basis that the overlap is small and any cumulative impacts (e.g. to benthic communities) would be minor.
Marine Fauna				
CM-21	Seismic source separation distance during concurrent surveys: minimum 20 km while operating.	Based on the potential distance at which sound fields from two separate surveys may combine in synchrony and result is momentary increase in sound levels above the 160 dB re 1 µPa behavioural response threshold for cetaceans (12 – 18 km apart), a separation distance of 20-km between operating seismic sources is proposed. This is considered a conservative measure to avoid increased behavioural responses from listed threatened or migratory cetaceans (or other marine fauna) located between the two seismic sources (vessels).	In the event that the Keraudren Extension 3D MSS commences at the same time as the 3D Oil Sauropod 3D MSS or a PGS Rollo seismic survey, separation distances may result in delays due to vessel downtime or loss of survey area.	**Adopted** – Despite potential significant costs associated with vessel downtime, Santos will adopt this control to limit the potential additive impacts to all marine fauna receptors. This distance will be reviewed once the final seismic sources have been selected for the survey and sound levels confirmed.

6.3.5 Impact and Consequence Ranking

Receptor	Consequence Level
Threatened / Migratory Fauna	*Plankton* Multiple survey will result in localised mortalities to plankton; however, losses will be negligible in the context of natural turnover rates and variability. The consequence level is assessed as **negligible.** *Invertebrates* Some sublethal effects and chronic mortality may occur to a small proportion of the benthic invertebrates in each survey area. Benthic invertebrate communities in the area of overlap between the Keraudren Extension 3D MSS and other surveys may result in increased levels or mortality or impairment, however, benthic communities are expected to recover in the weeks and months following the surveys. The consequence level is assessed as **negligible.** *Fish* No significant discernible additive impacts to fish are expected, given the separation distances between survey vessels in most instances. Some changes in fish abundance and distribution could occur as a result of exposure from multiple operating seismic surveys, but such changes are expected to return to normal within a few hours or days. Potential disturbances to spawning fishes are also expected to be minor given the large genetic stock ranges of the commercially significant demersal and pelagic species, and temporal nature of seismic surveys. Based on the impact assessment, no long term or population impacts to individual fishes or fish stocks are predicted. The consequence level is assessed as **minor**. *Sharks* Based on the impact assessment no long term or population impacts to whale sharks, or other shark species, are predicted thus the consequence level is assessed as **minor**. *Cetaceans* Migrating cetaceans, such as humpback whales, may be exposed to multiple seismic survey areas, resulting in multiple deviations from their course on several separate occasions. Such are expected to be small relative to the long distances over which the migration occurs. Santos will avoid peak humpback whale migration periods. Brief increase in sound levels as a result of sound fields from multiple surveys may result in cetacean behavioural responses when surveys are approximately 12 – 18 km apart. However, the proposed 20 km separation distance is intended to void such additional behavioural impacts from occurring. The consequence level is assessed as **minor.** *Marine turtles* Sound field interactions between multiple surveys and turtles will occur in offshore waters where animals are expected to be transient. Therefore, despite the increased potential for occasional behavioural disturbances to some animals, no changes to migration or other important life stages are expected. The consequence level is assessed as **minor.**
Physical Environment/ Habitat	Impacts to the physical attributes of the ancient coastline at 125 m depth contour KEF or other areas of seabed habitat are not expected. .
Threatened ecological communities	Not applicable – no threatened ecological communities identified in the area over which the survey will be conducted are expected.
Protected Areas	No cumulative impacts are expected within any AMP. Potential future surveys will be undertaken outside of the Eighty Mile Beach AMP and additive effects are not expected within the AMP with the proposed control measures

	in place. Multiple seismic surveys may affect the same values of the AMP network but impacts to marine fauna are expected to be limited to short-term behavioural impacts in waters outside of the AMP boundaries. As such, the values of the AMP network will be protected, and the conservation objectives will be met. The consequence level is assessed as **negligible.**
Socio-economic receptors	Potential impacts to fishers include potential repeat disruptions to their activities and displacement from multiple areas if multiple seismic surveys occur concurrently. Based on the potential short-term (weeks to months) effects and some potential temporary loss of value to commercial fishers, the consequence level is assessed as **minor**. Should a loss of catch be demonstrated as a result of the Keraudren 3D MSS then commensurate 'make good' payments will be made by Santos. Other socio-economic receptors are not expected to be significantly impacted.
Overall worst-case consequence	B – Minor Based on the maximum consequence ranking by receptor, the overall consequence is minor.

6.3.6 ALARP Evaluation

Santos has adopted an additional seismic source separation control to avoid increased behavioural responses from listed threatened or migratory cetaceans (or other marine fauna) located between the two seismic sources (vessels).

No alternative options to the use of a seismic source are possible in order to undertake the Activity. Alternative options to the survey design have been assessed by Santos. In regard to survey design options, Santos has attempted to optimise the survey to minimise the operational area size and seismic survey duration, and defined a set window during which the seismic survey will be completed (1 February to 31 July). A further reduction in survey area and duration would mean that the survey objectives would not be met, or the survey would need to be conducted over multiple years.

Reduction of the survey area or a limit to the area / number of days that may be acquired in any year was considered. To reduce the survey area would prevent acquisition over all geological targets of the required data. This will likely result in additional future surveys and defer potential impacts and risks to a future time (including future additional interference with commercial fishing licence holders). The survey has been optimised to acquire data over specific geological trends, changing the survey direction or shape to potentially reduce impacts to commercial fishing effort will cause the survey to become less efficient and more time consuming, leading to greater cost and more noise emissions. Limiting the area / number of days that may be acquired in any year provides no practicable benefit as it is impossible to predict the schedules of future surveys. Deferring acquisition to another year also does not necessarily provide a benefit as potential impacts may occur in consecutive years.

In the event that other surveys occur concurrent with the Keraudren Extension 3D MSS, Santos will consult with other seismic operators to identify ways of minimising interference with commercial fishers and will establish vessel interaction protocols. Santos will notify commercial fishers of the survey and provide ongoing communications regarding survey progress to minimise the disruption to their fishing effort during the survey. Santos has also made an overarching commitment that commercial fishing licence holders will be no worse off as a result of the seismic survey, and will implement the commercial fishers payment claim ('make good') protocol (refer to **Section 8.6.2**). Therefore, the proposed control measures are considered appropriate to manage the consequence of cumulative and additive acoustic impacts to ALARP.

6.3.7 Acceptability Evaluation

Is the consequence ranked as A or B?	Yes – Maximum consequence from noise emissions is B (Minor).
Is further information required in the consequence assessment?	The greatest uncertainty associated with the assessment of cumulative and additive impacts is the scheduling of future seismic surveys. Therefore, in the presence of this uncertainty, a precautionary impact assessment approach has been applied. In accordance with **Section 8.16.2**, Santos will maintain up-to-date information on completed and proposed seismic surveys, and assess this information prior to conducting any stage of the Keraudren Extension 3D MSS. As such, no further information is currently required.
Are performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	There are no specific standards or requirements in Australia relating to the management of cumulative or additive impacts from multiple seismic surveys. Santos has therefore proposed management measures to limit the potential impacts.
Are performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance standards consistent with stakeholder expectations?	Yes – Where concerns have been raised by stakeholders Santos has attempted to understand these concerns and has included additional controls where requested and reasonably practicable. Santos understands that commercial fishers have concerns regarding the impacts of seismic surveys on access to fishing grounds, catchability and fish stock. To ensure potential impacts to commercial fishers are as low as reasonably practicable (ALARP), Santos has made a commitment that no commercial fishing licence holder will be worse off as a result of the Keraudren Extension 3D MSS. This commitment entails the implementation of an evidence-based commercial fishers payment claim ('make good') protocol.
Are performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above)

6.4 Light Emissions

6.4.1 Description of Event

Aspect	During the Activity, safety and navigational lighting on the vessels will generate light emissions that may potentially affect marine fauna behaviour. The minimum level of lighting proposed is required for safety and navigational purposes on board vessels, therefore it cannot be eliminated if the proposed Activity is to proceed. The *Navigation Act 2012* requires vessels to be well lit for safe navigation. Vessels are required to show lights when operating at night to indicate their position and seismic survey vessels must indicate their limited ability to manoeuvre. Spot lighting may also be used on an as-needed basis e.g., streamer deployment and retrieval. Lighting will typically consist of bright white (i.e., metal halide, halogen, fluorescent) lights.
Extent	Direct light spill on surface waters will be limited to the area directly adjacent to the vessels and would not directly spill outside of the operational area.

Duration	Artificial lighting will be required on a 24-hour basis for the duration of the Activity, which will occur for up to approximately 162 days.

6.4.2 Nature and Scale of Environmental Impacts

Potential adverse impacts on marine fauna from artificial lighting during seismic surveys are well understood and in Western Australia there are guidelines for mitigating impacts from artificial lighting (WA EPA 2010). In addition, National Light Pollution Guidelines for Wildlife have also been published in draft (Commonwealth of Australia 2019). According to the draft National Light Pollution Guidelines for Wildlife, a 20 km threshold provides a precautionary limit based on observed effects of sky glow on marine turtle hatchlings demonstrated to occur at 15-18 km and fledgling seabirds grounded in response to artificial light 15 km away. The effect of light glow may occur at distances greater than 20 km for some species and under certain environmental conditions (Commonwealth of Australia 2019).

Artificial light is considered to potentially have a significant impact in areas adjacent to sensitive habitats (e.g. turtle and seabird nesting sites). Given the distance of the seismic survey area from emergent land (approx. 45 km to Bedout Island, 56 km to Eighty Mile Beach and 87 km to North Turtle Island) and the associated nearshore waters where these taxa breed, light is not considered to have a significant potential for impact. There is no evidence to suggest that artificial light spill adversely affects the migratory, feeding or breeding behaviours of cetaceans. Cetaceans predominantly utilise acoustic senses to monitor their environment rather than visual cues (Simmonds *et al*. 2004), therefore, impacts are considered to be unlikely.

<u>Potential Receptors: Fish and sharks, Marine Turtles and Seabirds</u>

Continuous lighting may result in localised alterations to normal marine fauna behaviours, as discussed below for each fauna group. Potential impacts are more likely in instances when the light source is stationary, which is not the case during an MSS activity when the vessels are constantly moving. The combination of colour, intensity, closeness, direction and persistence of a light source are key factors in determining the magnitude of environmental impact (EPA, 2010; Commonwealth of Australia 2019). Given the distance of the Activity location and the closest turtle nesting site (56 km to Eighty Mile Beach), lights (and light glow) will not be visible from nesting beaches or the surrounding sea.

Fish and sharks

The response of fish to light emissions varies according to species and habitat. Experiments using light traps have found that some fish and zooplankton species are attracted to light sources (Meekan *et al*. 2001), with traps drawing catches from up to 90 m away (Milicich *et al*. 1992). Lindquist *et al*. (2005) concluded from a study that artificial lighting associated with offshore oil and gas activities resulted in an increased abundance of clupeids (herring and sardines) and engraulids (anchovies) around lighted structures; these species are known to be highly photopositive. Attraction of fish to light may increase predation from larger fish and sharks in the immediate vicinity.

Overall, a short-term localised increase in fish activity as a result of vessel lighting is expected to occur, however, with negligible impacts.

Marine turtles

Artificial light can disrupt marine turtles wherever it is stronger than natural light sources (Commonwealth of Australia 2017a). For a vessel at sea, light is most likely to affect turtles and seabirds at breeding sites through direct light shining on nesting beaches or nearshore dispersal areas (Commonwealth of Australia 2017a). Light emissions from the vessel will not be visible at nesting beaches or nearshore dispersal areas (i.e. closest nesting beach is 56 km from the operational area).

The Recovery Plan for Marine Turtles in Australia: 2017-2027 (DoEE, Commonwealth of Australia 2017a) highlights artificial light as one of several threats to marine turtles. Specifically, the plan indicates that artificial light may reduce the overall reproductive output of a stock, and therefore recovery of the species, by:

- inhibiting nesting by females;
- creating pools of light that attract swimming hatchlings and increase their risk of predation; and
- disrupting hatchling orientation and sea finding behaviour. Once in the ocean, hatchlings are thought to remain close to the surface, orient by wave fronts and swim into deep offshore waters for several days to escape the more predator-filled shallow inshore waters. During this period, light spill from coastal port infrastructure and ships may ‘entrap’ hatchling swimming behaviour, reducing the success of their seaward dispersion and potentially increasing their exposure to predation via silhouetting (Salmon *et al*., 1992).

Several species of marine turtle may be present in the operational area. Hawksbill, green, leatherback and loggerhead turtles are unlikely to be encountered in large numbers given the operational area is not located in proximity to nesting, internesting or important foraging habitat for these species. The operational area overlaps an internesting BIA for flatback turtles that extends out from Eighty Mile Beach (**Figure 3-7**). There is also a very small overlap with an internesting area for flatbacks defined as Habitat Critical for the survival of the species, which encompasses a 60 km radius around nesting beaches in the Recovery Plan for Marine Turtles in Australia: 2017-2027 (DoEE, Commonwealth of Australia 2017a) (**Figure 3-7**). It is therefore possible that individual flatback turtles may be encountered in the operational area, however, timing of the Activity is after the peak of the nesting season for this species (December to January).

The Recovery Plan for Marine Turtles in Australia: 2017-2027 specifies the following priority actions for the Pilbara genetic stock of flatback turtles in relation to artificial light:

- Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.

The operational area is located 56 km from Eighty -Mile Beach. At this distance vessel light emissions will not be visible from turtle nesting beaches. Additionally, since the vessels will be continually moving while acquiring, and only a small proportion of the operational area overlaps with the BIA and Habitat Critical, the duration of the Activity that could lead to potential impacts to flatback turtles will be reduced. Should hatchling turtles be attracted to vessel lights and be silhouetted, they may be exposed to increased predation in the operational area (Thums *et al*., 2016), although this likelihood is reduced considering the constantly moving light source and the slow swimming speed of turtle hatchlings once in offshore waters.

The potential impacts of light emissions to turtles, including flatback turtles, from the activities are expected to be restricted to localised attraction and temporary disorientation, with no long term or residual impact due to the continual movement of the vessels, small overlap with the flatback turtle BIA and Habitat Critical, timing of the Activity to avoid peak nesting/internesting season (December to January); and the unlikely presence of hatchlings due to the distance from the nearest shorelines. It is considered that the Activity will not compromise the objectives as set out in the Recovery Plan for Marine Turtles and the impact of lighting associated with the Activity to turtles is negligible.

Seabirds

Studies conducted between 1992 and 2002 in the North Sea confirmed that artificial light was the reason that birds were attracted to and accumulated around illuminated offshore infrastructure (Marquenie *et al*. 2008). The light sources associated with the vessels may also provide enhanced capability for seabirds to forage at night. The vessels will be in the operational area for up to 162 days, however, will be continually moving and are therefore unlikely to attract large numbers of seabirds.

6.4.3 Environmental Performance and Control Measures

During the evaluation of the potential impacts of light emissions as a result of the Activity, it was determined that no control measures were required as the inherent consequence of light emissions is expected to be negligible and does not compromise any management plans or objectives in place for protected fauna. Vessel lighting will be limited to that required for safe navigation under: Marine Order Part 30 (Prevention of Collisions) 2016.

As no control measures have been identified to manage light emissions during the Activity, there is no requirement for EPOs or EPSs to be set in accordance with Regulation 13(7)(a) of the OPGGS(E)R.

Control Measures considered but not adopted for this Activity are shown below.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
None				
Additional control measures				
N/A	Review lighting and change to a type (colour) that has less impact.	Could reduce potential impacts of artificial light on certain fauna.	High cost to complete lighting change-out on vessels in area of low sensitivity.	**Not Adopted** – Cost outweighs the benefit.
N/A	Limit or exclude night-time operations.	Would eliminate potential impacts of artificial light during hours of darkness when light sources are more apparent and potential impacts are greatest.	Would double duration of Activity; increase impacts or potential impacts in other areas including increase in waste, air emissions, risk to navigation and increase potential for vessel collision.	**Not Adopted** – Given the minimal risk of impacts to turtles occurring, the costs of extending Activity duration outweigh the benefits.
N/A	Schedule to avoid sensitive windows at location.	Potential reduction in impact of light to some sensitive receptors (e.g. turtles during nesting season).	Activity schedule largely dictated by vessel availability with high costs to amend schedule. Delay of the survey could influence future drilling campaigns with significant additional costs.	**Partially Adopted** – Given the operational area is located 56 km from the nearest turtle nesting beach (Eighty Mile Beach) (the main sensitivity at risk from lighting), and already avoids the peak flatback turtle nesting period (December to January), costs of rescheduling the Activity outweighs the benefits.

6.4.4 Impacts and Consequence Ranking

Receptor	Consequence Level
Light emissions	
Threatened / Migratory Fauna	Continuous lighting in the same location for an extended period of time may result in alterations to normal marine fauna behaviour. Sensitive receptors that may be impacted include fish at the surface, marine turtles and mammals, and seabirds. Given that the Activity will involve vessels that are continually moving, is for a limited duration, and is located 56 km from the nearest nesting beach (Eight Mile Beach), at these distances lighting is unlikely to be at a level that could impact nesting turtles or hatchlings (Commonwealth of Australia 2019). Given a small proportion of the operational area is located within the flatback turtles BIA (**Figure 3-7**), individuals may occur in the operational area although large numbers are not expected. The nearest nesting beach (Eighty Mile Beach) is located 56 km from the operational area, therefore flatback hatchlings are not expected to be impacted by light emissions from the activities. Marine mammals are not known to be significantly attracted to light sources at sea and therefore disturbances to behaviour are unlikely to occur. Fish and birds have been shown to be attracted to artificial light sources, however, the low level of light emitted from vessels is unlikely to lead to large scale changes in species abundance or distribution (Commonwealth of Australia 2019). Impacts to transient fish and seabirds will therefore be limited to short-term behavioural effects with no decrease in local population size, area of occupancy of species or loss or disruption of Habitat Critical / disruption to the breeding cycle.
Physical Environment/ Habitat	Not applicable – no physical environments and/or habitats are identified in the area where light emissions could occur other than open water, which will not be impacted.
Threatened ecological communities	Not applicable – no threatened ecological communities are identified in the area where light emissions could occur.
Protected Areas	Not applicable – no protected areas are identified in the area where light emissions could occur.
Socio-economic receptors	Not applicable – lighting is not expected to cause an impact to socio-economic receptors other than as a visual cue for avoidance of the area.
Overall worst-case consequence	A – Negligible Given the considerable distance offshore from turtle and seabird nesting sites and associated nearshore waters, disruption to nesting activities are not be expected. There is a low probability that individual turtles and seabirds will be attracted by the moving light source at sea for a short period.

6.4.5 ALARP Evaluation

There are no safe alternatives to the use of artificial lighting on the vessels. Artificial lighting is required on a 24-hour basis for navigational safety in the area and additional light is required to allow the Activity to proceed safely on a 24- hour basis for occupational health and safety reasons. Santos has considered the actions prescribed in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) to minimise lighting impacts on marine turtles, especially flatback turtles. The impacts of lighting to the receiving environment are well understood and the consequence is expected to be low. As the operational area is 56 km from the nearest nesting beach (Eighty Mile Beach), and this distance is considerably further than the EPA's estimated light influence distance of approximately 1.5 km (EPA, 2010) and the draft National

Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2019) precautionary threshold of 20 km, impacts are not expected on fauna including turtles at nesting beaches (inter/nesting adults or emerging hatchlings) and impacts will be limited to short-term behavioural effects observed in transient fish and seabirds. Therefore, the risks of using 24-hour artificial lighting at an intensity to allow work to proceed are considered ALARP. Given the nature and scale of the Activity, no control measures specific to the reduction of impacts related to light emissions have been adopted. Controls considered but not adopted are detailed in **Section 6.4.3**. The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk.

6.4.6 Acceptability Evaluation

Is the consequence ranked as A (Negligible) or B (Minor)?	Yes – maximum consequence from light emissions is A (Negligible).
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks are well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with *Navigation Act 2012,* Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) and draft National Light Pollution Guidelines for Wildlife (DoEE, 2019)
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

The potential consequences of an anthropogenic light source in the operational area are likely to be insignificant in nature and restricted to turtle, fish and bird species that are resident in the area. The scale of the anticipated impacts is not expected to be significant, with a small number of individual turtles, fish and birds that may potentially be affected in the immediate area; the nature of the impact will generally be restricted to behavioural effects. Given the temporary nature of the Activity, as well as the anticipated negligible consequences of lighting from the Activity, the Activity is considered to be conducted in a manner that is consistent with the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a), and the impacts of lighting to the receiving environment are considered environmentally acceptable.

6.5 Planned Operational Discharges

6.5.1 Description of Event

Aspect	During the seismic survey, the vessels will routinely discharge non-toxic substances to the marine environment as described below. The vessels will not be stationary during the Activity, so the discharge location will be constantly changing. Sewage The volume of sewage is directly proportional to the number of persons on-board the vessels. Approximately 170 L of sewage/ greywater will be generated per person per day. Treated sewage will be disposed in accordance with MARPOL Annex IV. Food waste Putrescible waste will consist of approximately 1 L of food waste per person per day. Food waste will be disposed of in accordance with MARPOL Annex V.

	Brine Brine generated from the water supply systems on-board the vessels will be discharged to the ocean at a salinity of approximately 10% higher than seawater. The volume of the discharge is dependent on the requirement for fresh (or potable) water and would vary between vessels and the number of people on-board. Cooling water Seawater is used as a heat exchange medium for the cooling of machinery engines. Seawater is drawn from the ocean and flows counter-current through closed-circuit heat exchangers, transferring heat from the vessel engines and machinery to the seawater. The seawater is then discharged to the ocean (i.e. it is a once-through system). Cooling water temperatures vary depending upon the vessel's engine work load and activity. Deck drainage Deck drainage from sea spray, rainfall or wash-down operations would discharge to the marine environment. The deck drainage would contain particulate matter and residual chemicals such as cleaning chemicals, oil and grease. Assessment of an unplanned spillage of other environmentally hazardous chemicals and liquid waste are discussed in **Section 7.4**. Oily water (i.e. bilge water) discharges While in the operational area, the vessels may discharge oily water after treatment to <15 ppm oil-in-water content in a MARPOL approved oily water filter system separator.
Extent	The small volumes discharged may cause localised nutrient enrichment, organic and particulate loading, toxic impacts to marine fauna, thermal impacts and increased salinity.
Duration	During the Activity, localised impacts to water quality will occur; however, water quality conditions will return to normal within minutes to hours of cessation of discharges.

6.5.2 Nature and Scale of Environmental Impacts

The potential environmental impacts from routine operational discharges include:

- temporary localised decline in water quality in the immediate vicinity of the discharge;
- localised increase in biological oxygen demand (BOD);
- localised increase in turbidity of surrounding waters;
- temporary toxicity to marine flora and fauna (bilge water discharges);
- temporary and localised increase in sea surface water temperature; and
- temporary and localised increase in sea surface salinity.

Potential Receptors: Water Quality, Fish (Pelagic) & Sharks, Marine Mammals, Marine Turtles and Seabirds

Planned discharges associated with the Activity will be small and intermittent, with volumes dependent on a range of variables. The discharge point will be "moving", as the vessels are not stationary. The discharge of non-hazardous wastes to the marine environment may result in a localised reduction in water quality in the vicinity of the release location. This would be expected to be temporary (minutes to hours) and localised. The discharges are expected to be dispersed and diluted rapidly, with concentrations of discharges significantly dropping within a short distance from the discharge point. Changes to ambient water quality outside of the operational area is considered unlikely to occur.

Eutrophication

The discharges of treated sewage and grey water may result in localised increases in nutrient concentrations, exert Biological Oxygen Demand (BOD) on the receiving waters and may promote localised elevated levels of phytoplankton and bacteria activity due to nutrient inputs. However, dispersion and dilution of discharges is expected to be rapid as the discharges are of low volume and short duration, and the operational area is located in water depths of between 40 to 250 m dominated by open ocean currents, resulting in short-term changes to the surface water quality within the operational area.

Salinity Increases

The desalination of seawater results in a discharge of brine with a slightly elevated salinity (around 10% higher than seawater). Once discharged to the marine environment, the desalination brine, being of greater density than seawater, will sink and disperse in the currents. On average, seawater has a salt concentration of 35 ppt. The volume of the discharge is dependent on the requirement for fresh (or potable) water and the number of people on board the vessel.

Most marine species are able to tolerate short-term fluctuations in salinity in the order of 20–30% (Walker and McComb 1990), and it is expected that most pelagic species would be able to tolerate short-term exposure to the slight increase in salinity caused by the discharged brine.

Given the relatively low volume of discharge, low salinity increase and, open water surrounding the vessels, impact on the water quality in the operational area is expected to be negligible, temporary and localised.

Changes in Temperature

Cooling water will be discharged at a temperature above ambient seawater temperature. Upon discharge, it will be subjected to turbulent mixing and transfer of heat to the surrounding waters.

Temperature dispersion modelling shows that the water temperature of discharged water will decrease rapidly as it mixes with the receiving waters, with discharge waters being less than 1°C above background levels within less than 100 m (horizontally) of the discharge point. Vertically, the discharge will be within background levels within 10 m (Woodside 2008).

Given the relatively short duration of the Activity, low volume of cooling water, temperature differential, the deep open water surrounding the vessels, impact on water quality is expected to be low and short-term and within the immediate vicinity of the discharge.

Oily Water

Oily water discharged from vessels will be treated to a concentration (<15 ppm of oil-in-water content) that is unlikely to lead to any impacts to the receiving environment. The low concentrations of any oil and grease residues in deck drainage and bilge water discharged to the marine environment, will rapidly dilute and disperse, therefore the potential for toxicity from hydrocarbon residues is considered low.

6.5.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- Discharges to sea meet legislated permissible discharge requirements (EPO-4).

The Control Measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

Reference No	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-22	General chemical management procedures.	Potential impacts to the environment are reduced through following correct procedures for the safe handling and storage of chemicals.	Personnel costs associated with ensuring procedures are in place and implemented during inspections.	**Adopted** - benefits of ensuring procedures are followed and measures implemented outweigh the costs.
CM-23	Hazardous chemical management procedures.	Reduces the risk of spills and leaks (discharges) of hazardous chemicals to the sea by controlling the storage, handling and clean up.	Cost associated with permanent or temporary storage areas.	**Adopted** - benefits of ensuring procedures are followed and measures implemented outweigh the costs.
CM-24	Sewage treatment system.	Reduces potential impacts of inappropriate discharge of sewage. Ensure compliance with Marine Order 96 and MARPOL requirements as appropriate for vessel class.	Personnel cost in ensuring vessel certificates are in place during vessel contracting and in pre-mobilisation audits and inspections, and in reporting discharge levels.	**Adopted** - benefits of ensuring vessel is compliant outweigh the minimal costs.
CM-25	Waste (garbage) management procedure.	Reduces probability of garbage being discharged to sea, reducing potential impacts to marine fauna. Stipulates putrescible waste disposal conditions and limitations. Ensure compliance with Marine Order 95 and MARPOL requirements as appropriate for vessel class.	Personnel cost of pre-mobilisation audits and inspections, and in reporting discharge levels.	**Adopted** - benefits of ensuring vessel is compliant outweigh the minimal costs.
CM-26	Oily water treatment system.	Reduces potential impacts of planned discharge of oily water to the environment.	Additional time and personnel costs in maintaining oil record book.	**Adopted** – benefits of ensuring vessel is compliant outweigh the minimal costs.

Reference No	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		Ensure compliance with Marine Order 91 and MARPOL requirements as appropriate for vessel class.		
CM-27	Deck cleaning product selection procedure.	Improves water quality discharge (reduces toxicity) to the marine environment. Only environmentally acceptable chemicals would be released overboard.	Personnel costs of implementing procedure. Potential additional cost and delays of deck cleaning product substitution.	**Adopted** - Benefits of ensuring discharges have negligible impact outweigh costs.
CM-28	Clean up of oil/ lubricant spills to deck in accordance with vessel Shipboard Oil Pollution Emergency Plan (SOPEP).	Improves water quality discharge (reduces toxicity) to the marine environment.	Personnel costs of implementing procedure.	**Adopted** - Benefits of ensuring discharges have negligible impact outweigh costs.
Additional control measures				
N/A	Scupper plugs continuously in place to prevent deck drainage.	Would eliminate potential impacts of contaminants being discharged to sea in rainwater.	Increased health and safety risks from wet deck not draining. Large amounts of water on a seismic or support vessel deck can also cause stability issues (free-surface effect).	**Not Adopted** – safety considerations outweigh the benefit given small volumes of contaminants.
N/A	Mandatory closed drain system to prevent deck drainage discharged overboard.		Increased cost due to treatment system required, modifications to vessels, storage space required for containment of drained liquids, increase in transfers to vessels resulting in increased potential impacts and risks. Increased transfers result in increased fuel usage, increased safety risks to personnel during transfer (e.g. crushing between skips), increase in crane movements.	**Not Adopted** – Cost outweighs the benefit given the low impact expected from planned discharges and high potential impacts from risk transfer.

Reference No	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	Storage of all wastes on-board (e.g. oily water and sewage) for disposal onshore.	Would eliminate any discharge to sea, reducing potential impacts to the marine environment.	Storage space required for containment of waste. Requirement for transfers to vessels resulting in increased potential impacts and risks. Increased transfers may result in increased fuel usage, increased safety risks to personnel during transfer (e.g. crushing between skips), increase in crane movements.	**Not Adopted** – Cost outweighs the benefit given the low impact expected from planned discharges and high potential impacts from risk transfer.
N/A	Discharge cooling water above sea level to allow it to cool further before mixing at sea surface.	Reduce potential impacts associated with discharge of higher temperature water into the marine environment.	High costs to alter vessels to allow for discharge of cooling water at different height, not feasible. Reduction in temperature would be minimal compared to cost of altering the discharge height.	**Not Adopted** – Cost outweighs the benefit given the low impact expected from planned discharges
N/A	Storage of cooling water on-board, prior to discharge onshore	Reduce potential impacts associated with discharge of higher temperature water into the marine environment.	Storage space required for containment of cooling water.	**Not Adopted** – Cost outweighs the benefit given the low impact expected from planned discharges.
N/A	Re-design desalination plant discharge system.	Limited benefit to be gained given low environmental impact from brine discharge.	High costs associated with modifications to vessels and may not be feasible on the vessels.	**Not Adopted** – Cost outweighs the benefit given the low impact expected from planned discharges.
N/A	Restrict use of desalination plant.	Limited benefit to be gained given low environmental impact from brine discharge.	Health risks associated with limited potable water as well as high costs associated with modifications to vessels and may not be feasible.	**Not Adopted** – Health risks and cost outweighs the benefit given the low impact expected from planned discharges.
N/A	Storage of brine on-board prior to discharge onshore.	Would eliminate any discharge to sea, reducing potential impacts to the marine environment.	High costs associated with modifications to vessels and may not be feasible.	**Not Adopted** – Cost outweighs the benefit given the low impact expected from planned discharges.

6.5.4 Impact and Consequence Ranking

Receptor	Consequence Level
Operational discharges	
Threatened / Migratory Fauna Physical Environment/ Habitat	Operational discharges may result in localised water quality perturbations and alteration to marine fauna behaviour, however, given that vessels will be continually moving within the operational area, any effect will be temporary in nature. Sensitive receptors that may be impacted include pelagic fish and sharks at the sea surface, marine turtles, and marine mammals, and seabirds. Given that the Activity will be for a limited duration (162 days) from a moving discharge point, in deep waters (40 m – 250 m), impacts will be limited to short-term water quality impacts and temporary behavioural effects observed in fish and seabirds. Impacts to water quality will be experienced in the discharge mixing zone, which will be localised and will occur only as long as the discharges occur (i.e. no sustained impacts), therefore, recovery will be measured in hours to days. Only short-term behavioural impacts are expected with no decrease in local population size / area of occupancy of species / loss or disruption of Habitat Critical / disruption to the breeding cycle / introduction of disease. Planned operational discharges are therefore not expected to significantly impact marine fauna within the receiving environment nor compromise the objectives of Recovery Plans for threatened and migratory marine fauna.
Socio-economic receptors	Not applicable – operational discharges are not expected to impact on socio-economic receptors.
Threatened ecological communities	Not applicable – no physical environments and/or habitats identified in the area where operational discharges are expected to disperse other than open water, which will not be impacted.
Protected Areas	Not applicable – no protected areas are identified in the area where operational discharges could occur.
Overall worst-case consequence	A - Negligible Given the distance offshore, the small volumes discharged, the moving discharge point and the well-mixed waters of the operational area.

6.5.5 ALARP Evaluation

Vessels are required to undertake the seismic survey. On-board treatment of most wastes and subsequent discharge to the marine environment, are considered to be the most environmentally sound method of disposal.

Considering that the discharge streams will either be treated to a level unlikely to cause significant environmental harm or will be of a nature not considered to pose significant risk to the receiving environment; the assessed residual consequence for this impact is negligible and cannot be reduced further. Vessels will operate in accordance with relevant regulations and legislation as detailed in **Section 6.5.3**. Additional controls were identified and considered, but not adopted as detailed in **Section 6.5.3**. The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. The proposed control measures are considered appropriate to manage the risk to ALARP.

6.5.6 Acceptability Evaluation

Is the consequence ranked as A (Negligible) or B (Minor)?	Yes – maximum planned operational discharge consequence is rated A (negligible).

Is further information required to support or validate the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes - Management consistent with Protection of the Sea (Prevention of Pollution from Ships) Act 1983, MARPOL Annex I, Annex IV and Annex V, and/or Marine Orders 94, 95 and 96 as appropriate, and relevant recovery plans.
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

The potential impacts of routine discharges from vessels to the marine environment are well understood and there are legislative requirements in place to manage risks. The application of legislative requirements is considered appropriate to manage the impact; particularly due to the well-mixed offshore marine waters (40 – 250 m) of the operational area. Small volumes of wastewaters discharged into open ocean conditions will be rapidly diluted and dispersed.

Release of non-hazardous discharges into the sea from vessels in Australian waters is permissible under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983, which reflects MARPOL Annex I, IV and V and Marine Orders 91, 95 and 96 as requirements. The operational discharges are not expected to significantly impact the receiving environment with control measures proposed and compliance with all MARPOL requirements. The MARPOL standard is considered to be the most appropriate standard given the nature and scale of the Activity. These standards are internationally accepted and utilised industry-wide, therefore compliance with the relevant and appropriate MARPOL requirements and standards is expected to reduce the potential for environmental impacts to a level which is considered environmentally acceptable.

Deteriorating water quality is identified as a potential threat to turtles, some birds and shark species according to their relevant Recovery Plan or Approved Conservation Advice (**Table 3-7**). However, the operational discharges are not expected to significantly impact the receiving environment, resulting in short term and localised water quality deterioration only. The Activity will be conducted in a manner that is considered acceptable and consistent with identified Recovery Plans and conservation advice.

6.6 Atmospheric Emissions

6.6.1 Description of Event

Atmospheric Emissions	
Aspect	The use of fuel (specifically MDO/MGO) to power vessel engines, generators, mobile and fixed plant and equipment will result in emissions of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), along with non-GHG such as sulphur oxides (SO_x) and nitrous nitrogen oxides (NO_x). Vessels may also use an incinerator for waste combustion during the Activity. Vessels may utilise ozone-depleting substances (ODS) in closed-system rechargeable refrigeration systems.
Extent	Gaseous emissions, under normal circumstances, may cause localised reduction in air quality, quickly dissipating into the surrounding atmosphere.
Duration	During the Activity, localised and temporary impacts to air quality will occur.

6.6.2 Nature and Scale of Environmental Impacts

Potential Receptors: Seabirds and Humans

Hydrocarbon combustion may result in atmospheric emissions of GHG (such as CO_2, CH_4 and N_2O) and non-GHG (such as NO_X and SO_X). Air emissions will be similar to other vessels operating in the region for both petroleum and non-petroleum activities.

Atmospheric emissions have the potential to result in a temporary, localised reduction of air quality in the environment immediately surrounding the discharge point during the Activity which could affect seabirds and humans in the immediate vicinity. Atmospheric emissions also have the potential to add to the national GHG loadings.

Seabirds may traverse the operational area, however, are not expected in large numbers. Given the potential reduction in air quality will be localised, impacts to individual or populations are not expected should seabirds avoid the area in response to changes in air quality.

As the activities will occur in offshore waters, the combustion of fuels and incineration in such remote locations will not impact on air quality in coastal towns, the nearest being Port Hedland (141 km south). The quantities of gaseous emissions are relatively small and will quickly dissipate into the surrounding atmosphere.

Accidental release and fugitive emissions of ODS has the potential to contribute to ozone layer depletion. Maintenance of refrigeration systems containing ODS is on a routine, but infrequent basis, and with controls implemented, the likelihood of an accidental ODS release of material volume is considered rare.

6.6.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- Emissions to air meet legislated requirements (EPO-5).
- No unplanned objects, emissions or discharges to sea or air (EPO-6).

The Control Measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-29	Waste incineration managed in accordance MARPOL and Marine Orders as appropriate.	Reduces potential impacts due to inappropriate incineration (e.g. wastes not burning correctly), inadequately maintained machinery.	Cost of maintaining and using incinerators in compliance with MARPOL.	**Adopted** – benefit to air quality outweighs the costs associated with MARPOL certification.
CM-30	MARPOL-compliant fuel oil (MDO/MGO) will be used during the Activity.	Use of MDO/MGO reduces the potential impacts to marine environment in the event of unplanned hydrocarbon spills or leaks during bunkering.	Additional personnel costs of ensuring vessels are using the required fuel.	**Adopted –** benefits of ensuring procedures are followed outweighs the minimal costs of personnel time.
CM-31	Air pollution prevention certification.	Reduces probability of potential impacts to air quality due to ODS emissions, high NOx, SOx and incineration emissions.	Personnel cost of ensuring vessels have current International Air Pollution Prevention (IAPP) certificate or equivalent during vessel contracting procedure and in pre-mobilisation audits/ inspections.	**Adopted** - benefits of ensuring vessels are is compliant outweighs the minimal costs.
CM-32	Ozone-depleting substance handling procedures.	Reduces probability of potential impacts to air quality due to ODS emissions.	Personnel cost of maintaining ODS record book/recording system.	**Adopted** - benefits of ensuring vessels are is compliant outweighs the minimal costs.
CM-33	All vessel engines to be maintained in accordance with manufacturers specifications.	Ensures engines are operating efficiently to design specifications.	Personnel costs associated with undertaking maintenance as per the Planned Maintenance System (PMS).	**Adopted** - benefits of ensuring vessel engines are maintained outweigh the minimal costs.
Additional control measures				
N/A	Removal of all ODS containing equipment prior to undertaking activities.	Eliminates potential of ODS emissions occurring and impacting on air quality.	ODS is rarely found on vessels. If there are ODS containing equipment would be costly to replace for a short duration activity.	**Not Adopted** – based on cost to replace all equipment and low potential for ODS releases.

N/A	Use incinerators and engines with higher environmental efficiency.	Improves air quality by more efficient burning or fuel combustion.	Significant cost in changing unknown vessel equipment.	**Not Adopted -** Cost grossly disproportionate to low environmental benefit (impact rated negligible).
N/A	No incineration during Activity.	Eliminate the potential for emissions due to waste incineration to impact air quality.	Increase in health risk from storage of wastes. Increase in risk due to transfers (increased fuel usage, potential increase in collision risk, disposal on land).	**Not Adopted** – Health and safety risks outweigh the benefit given the offshore location. Cost associated with transporting waste to shore for landfill and/or incineration outweighs on-board incineration.
N/A	Alternative fuel type selected for all vessels and helicopters.	Could reduce level of pollutants released to the environment during fuel combustion.	Practical and reliable alternative fuel types and power sources for the helicopters and support vessels have not been identified. If an alternative was available, vessels have fuel specification for equipment, change of fuel may require further modifications to equipment.	**Not Adopted –** not feasible.

6.6.4 Impact and Consequence Ranking

Receptor	Consequence Level
Air emissions	
Threatened / Migratory Fauna	Short term behavioural impacts to seabirds could be expected if they overfly the vessels; they may avoid the area. No decrease in local population size / area of occupancy of species / loss or disruption of Habitat Critical / disruption to the breeding cycle / introduction of disease.
Physical Environment / Habitat	No or negligible reduction in physical environment/ habitat area/ function.
Threatened ecological communities	Not applicable – these receptors will not be impacted by air emissions.
Protected Areas	
Socio-economic receptors	As the activities occur in offshore waters, the combustion of fuels and ODS releases in these remote locations will not impact on air quality in coastal towns. The quantities of gaseous emissions are relatively small and will under normal circumstances, quickly dissipate into the surrounding atmosphere. The highly dispersive nature of local winds (i.e. strong and consistent) is expected to reduce potentially harmful or 'noticeable' gaseous concentrations within a short distance from the vessels.
Overall worst-case consequence level	A – Negligible Given the short duration of the survey, and constant movement of the vessel, emissions from the combustion of fuel and ODS releases on board the vessels, will be localised and rapidly disperse and not affect sensitive receptors in the vicinity of the survey area (including the health or amenity of the nearest towns).

6.6.5 ALARP Evaluation

Power generation through combustion of fossil fuels is essential to undertaking the Activity to power the vessels and equipment on-board. Given the routine maintenance of these closed systems by suitably qualified personnel, all practicable management measures are considered to have been implemented and the likelihood of significant impacts occurring have been reduced to ALARP.

There are no other control measures that may practicably or feasibly be adopted to reduce impacts further, additional controls were identified and considered but not adopted, as detailed in **Section 6.6.3**. The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. The proposed control measures are considered appropriate to manage the risk to ALARP.

6.6.6 Acceptability Evaluation

Is the consequence ranked as A (Negligible) or B (Minor)?	Yes – maximum consequence from atmospheric emissions is A (Negligible).
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks are well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with Protection of the Sea (Prevention of Pollution from Ships) Act 1983, MARPOL Annex VI and/or Marine Order 97, as appropriate.
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.

Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

Atmospheric emissions from vessels are permissible under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983, which reflect MARPOL Annex VI and Marine Order 97 requirements. The vessels will use MDO/MGO, which is lower in sulphur compared to heavy fuel oil (HFO). The fuel oil will meet regulated sulphur content levels in order to control emission quality. As an internationally accepted standard that is utilised industry wide, compliance with MARPOL standards is considered to be an appropriate management measure in this case. Vessels may also use an incinerator to dispose of combustible waste when outside of 500 m of other facilities.

The overall impacts to the atmosphere and sensitive receptors are expected to be negligible if the emission management is adhered to and impacts from emissions that are generated by the Activity are considered environmentally acceptable.

7. Environment Assessment of Unplanned Events

OPGGS(E)R 2009 Requirements
Regulation 13. Environmental assessment.
Evaluation of environmental impacts and risks (5) The environment plan must include: d) details of the environmental impacts and risks for the Activity; e) an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk; and f) details of the control measures that will be used to reduce the impacts and risks of the Activity to as low as reasonably practicable and an acceptable level. (6) To avoid doubt, the evaluation mentioned in paragraph (5)(b) must evaluate all the environmental impacts and risks arising directly or indirectly from: c) all operations of the Activity; and d) potential emergency conditions, whether resulting from accident or any other reason. *Environmental performance outcomes and standards* (7) The environment plan must: d) set environmental performance standards for the control measures identified under paragraph (5)(c); e) set out the environmental performance outcomes against which the performance of the titleholder in protecting the environment is to be measured; and f) include measurement criteria that the titleholder will use to determine whether each environmental performance outcome and environmental performance standard is being met.

Santos' environmental assessment identified seven potential sources of environmental risks associated with the unplanned events for this Activity. The results of the environmental assessment are summarised in **Table 7-1**. A comprehensive risk and impact assessment for each of the unplanned events, and subsequent control measures proposed by Santos to reduce the risk and impacts to ALARP, are detailed in the following sub-sections.

Table 7-1: Summary of the environmental risks for events associated with unplanned events

Hazard	Consequence	Likelihood	Residual Risk Level
MDO/MGO release from vessel collision (surface)	C (Moderate)	1 (Rare)	Low
Minor hydrocarbon release	A (Negligible)	3 (Unlikely)	Low
Spill response operations	B (Minor)	3 (Unlikely)	Low
Hazardous and non-hazardous unplanned discharges – liquid	A (Negligible)	2 (Very Unlikely)	Low
Hazardous and non-hazardous unplanned discharges - solid	A (Negligible)	2 (Very Unlikely)	Low
Marine fauna collisions	A (Negligible)	2 (Very Unlikely)	Low
Introduction of invasive marine species	C (Moderate)	1 (Rare)	Low

7.1 Marine Diesel Oil/Marine Gas Oil (MDO/MGO) Release from Vessel Collision (Surface)

7.1.1 Description of Event

Hydrocarbon spills from a ruptured vessel fuel tank as result of a collision, a refuelling incident and other minor MDO/MGO spills	
Event	MDO/MGO spills have the potential to impact on the marine environment through reduction in water quality and exposure to fauna and habitats. *Worst-Credible MDO/MGO Spill* There is a possibility of a vessel collision occurring within the operational area between an Activity vessel and a passing third party vessel. The worst-case environmental incident resulting from a vessel collision is the rupturing of a vessel fuel tank resulting in the release of MDO/MGO to the environment. Vessel collision could occur due to factors such as human error, poor navigation, vessel equipment failure or poor weather. The maximum credible spill from a collision can be determined from the usable volume of the largest single fuel tank. A maximum credible spill volume has been determined for the Activity being 1,065 m^3. A tank rupture as a result of vessel grounding is not considered a credible scenario as the water depths are approximately 40 – 250 m and there are no emergent features within the operational area. It is noted that in addition to MDO/MGO, small volumes of unused IFO and HFO could be stored on the vessels. However, restrictions will be in place limiting volumes and requiring storage to be restricted to tanks that do not have direct exposure to the marine environment (as described in **Section 7.1.4**). Therefore, a spill of IFO/HFO is not considered credible for this assessment.
Extent	**<u>Environment that May be Affected</u>** A spill of 1,065 m^3 MDO/MGO has been modelled at two release locations, one at the northern extent of the operational area and one at the southern extent of the operational area (GHD 2019) (**Section 7.1.2**). The spill locations are approximately 150 km apart. It is noted that while the assessment of impacts from the spill in this section is primarily based on the modelling outcomes for the two release locations, the modelling has also been interpolated to other locations within the operational area. This wider area is defined using low hydrocarbon exposure values in order to identify the full potential extent of the EMBA (as described in **Section 3**). The EMBA is illustrated in **Figure 3-1**. While the EMBA represents the largest possible spatial extent that could be affected by the worst-case hydrocarbon spill event, it is important to understand that the stochastic modelling used to define the EMBA considers 120 different simulations for any one spill event. In reality, an actual spill event is more likely to be represented by only one of the simulations and hence, have a much smaller spatial footprint. An example of a single simulation modelled (i.e. a deterministic model) for this Activity is illustrated in **Figure 3-1** to demonstrate a more realistic spatial extent for any hydrocarbon phase of the worst-case spill scenario (i.e. a deterministic EMBA). **<u>Modelled Extent of a Spill</u>** The potential extent of an MDO/MGO spill described here is based on the low hydrocarbon exposure values from the spill modelling for surface, in-water (entrained and dissolved) and accumulated shoreline hydrocarbons, as described in **Section 7.1.2.3**. The low exposure values are used to identify all values and sensitivities that may be contacted in the event of a spill. It is noted that moderate and high exposure values are used in this assessment to identify the potential for ecological impacts to sensitive receptors (**Section 7.1.2.3**). The potential extent of floating MDO/MGO at or above the low exposure value of 1 g/m^2, is a maximum of approximately 250 km from the southern release location and approximately 350 km from the northern release location in any season. Total water accommodated fraction (WAF) in the water column above the low exposure value of 10 ppb is predicted to occur up to approximately 250-260 km from the release site in any season for both the northern and southern release location. Similarly, dissolved WAF in the water column above the low exposure value of 10 ppb is predicted to occur up to approximately 250-260 km from the release site in any season for both the northern and southern release location. Time-integrated

	dissolved WAF above the low exposure value of 4,800 ppb.hr was predicted to occur only in sparse patches within approximately 60-70 km of both the northern and southern release sites. Accumulation of hydrocarbon on shorelines at the low exposure value (10 g/m^2) is predicted to potentially occur between Bedout Island, approximately 100 km to the west-southwest of the release location, and Roebuck-Eighty Mile Beach, approximately 250 km to the northeast, from the southern release location. From the northern release location Rowley Shoals (Mermaid Reef AMP, Clerke Reef and Imperieuse Reef (Rowley Shoals Marine Park)) and Eighty Mile Beach are predicted to potentially be exposed at the low exposure value. Refer to **Table 7-3** for the exposure values used in the MDO/MGO Spill Modelling. **Appendix J** further describes the environmental significance of the selected exposure values. Refer to **MDO/MGO Spill Modelling Results** summary (**Section 7.1.2.5**).
Duration	MDO/MGO fuel at the sea surface will spread rapidly in the direction of the prevailing wind and surface currents. Evaporation contributes to a substantial proportion of removal of the spilled MDO/MGO on the sea surface during calm conditions, while entrainment of droplets within the water column will increasingly contribute to removal of surface oil as wind speed increases. There is a very low chance for emulsion formation. It is estimated through modelling under realistic weather conditions that surface hydrocarbons would decrease to below 1% of the total mass within 3 days (in moderate wind conditions, 5 m/s) through dispersion and evaporation. In conditions of sustained energetic winds (10 m/s), the surface oil is expected to be entirely evaporated and dispersed after 12 hours. Refer to **MDO/MGO Spill Modelling Results** summary (**Section 7.1.2.5**).

7.1.2 Quantitative Spill Modelling

7.1.2.1 Type of Release

All vessels will use MDO/MGO, the largest usable volume within a fuel tank of any vessel used during the Activity will be 1,065 m^3. GHD (2019) uses Marine Diesel (IKU) analogue from the SINTEF Oil Weathering Model to inform the hydrocarbon characteristics for the modelling. The characteristics of the Marine Diesel (IKU), selected as the analogue for the MDO/MGO release is presented in **Table 7-2**. Marine Diesel (IKU) is a mixture of predominantly semi-volatile and low-volatility hydrocarbons, with a low percentage of volatile C4 to C10 hydrocarbons (3%) and a greater proportion moderate to very low volatile C11 to C20 hydrocarbons (97%). IKU Marine diesel has no residual persistent hydrocarbons after weathering (GHD, 2019). The heavier (low volatile) components of the oil have a tendency to entrain into the upper water column due to wind-generated waves but can subsequently resurface if wind waves abate.

Table 7-2: Characteristics of MDO/MGO

Oil Type	Initial density (g/cm^3) (20°C)	Viscosity (cP) (20°C)	Component	Volatiles (%)	Semi-volatiles (%)	Low Volatility (%)	Residual (%)	Aromatics (%)
			Boiling Points (°C)	<175	175-275	275-375	>375	Of whole oil <380 °C BP
				NON-PERSISTENT			PERSISTENT	
Marine Diesel (IKU) [SINTEF modelling analogue]	0.843	3.9	% of total	3	52	45	0	2.9

Source: GHD (2018)

7.1.2.2 Modelling Inputs

To determine the spatial extent of a potential MDO/MGO hydrocarbon spill, GHD conducted modelling of a 1,065 m^3 MDO/MGO release. Modelling was conducted at two release locations, one along the northern extent of the operational area and one along the southern extent of the operational area. The selection of two release locations ensures the modelled spill trajectories determine the potential hydrocarbon oil exposure to environmental sensitivities from the diesel spill within the survey operational area. The northern release point provides the potential worst case contact with receptors (Rowley Shoals) to the north of the operational area (refer to **Table 7-5**, **Figure 7-4** and **Figure 7-5**). The southern release point (the closest point of the operational area to the mainland) provides for the worst case contact with shorelines to the south of the operational area (refer to **Table 7-4, Figure 7-2** and **Figure 7-3**). For conservatism, and to assess the full extent and potential environmental impact of an MDO/MGO release for any release location within the survey operational area, the spill trajectories were overlaid on the eastern-most and western-most extents of the operational area for the Activity. This method was applied, rather than modelling at numerous locations, as there are no significant features within the area or nearby that would create a significant difference in the model output. No additional shoreline receptors were contacted as a result of overlaying the spill trajectories along these boundaries and therefore the metrics relating to shoreline accumulation (volume and time) from the modelled scenarios along the northern and southern extents remain applicable.

Key parameters considered for the MDO/MGO spill modelling are:

g) API gravity: 36.4^o;

h) Pour point: -36^{o}C;

i) Duration of spill: Instantaneous (conservative modelling approximation);

j) Location of release: Surface spill;

k) Volume of hydrocarbon: 1,065 m^3; and

l) Time of year: any month of the year.

Stochastic Modelling

Stochastic modelling was performed on an instantaneous surface release of 1,065 m^3 of MDO/MGO with 120 stochastic model simulations, with a simulation period of 4 weeks allowing sufficient duration for modelled hydrocarbon concentrations to drop below the minimum exposure values (refer to **Section 7.1.2.3).** Modelling was conducted at any time of year to ensure weather and hydrodynamic conditions provide the worst-case extent of the hydrocarbon release scenario, ensuring conservatism in the modelling. It is noted that the EMBA from the stochastic modelling covers a larger area than the area that would be affected during any single spill event. The EMBA therefore represents the predicted maximum extent where exposure values could be exceeded from all modelling runs under different weather and metocean conditions (120 runs per release location in total).

Deterministic Modelling

In addition to the stochastic modelling, single-trajectory modelling (deterministic) was also undertaken to provide an example of the EMBA for a single spill and to characterise shoreline loading (i.e. loads) and the mass balance of the released oil in the marine environment (e.g. proportion of released oil lost to decay or volatilisation, and proportion remaining as droplets). The deterministic simulation is therefore representative of single spill event under certain wind and current conditions. The stochastic trajectory selected to run in deterministic mode was that with the largest predicted volume ashore from a single model run across all geographic receptors. The selected simulation was from the southern release location, resulting in a predicted accumulated oil mass of 358 tonnes at Eighty Mile Beach.

7.1.2.3 Exposure Values

The outputs of the quantitative hydrocarbon spill modelling are used to assess the environmental risk, if a credible hydrocarbon spill scenario occurred, by defining which areas of the marine environment could be exposed to hydrocarbon levels exceeding exposure values that may result in impact to sensitive receptors. The degree of impact will depend on the sensitivity of the biota contacted, the duration of the contact (exposure) and the toxicity of the hydrocarbon mixture making the contact. The toxicity of a hydrocarbon will change over time, due to weathering processes altering the composition of the hydrocarbon.

The modelling considered four key physical or chemical phases of hydrocarbons that pose differing environmental and socioeconomic risks: surface hydrocarbons, total water accommodated fraction (WAF; or entrained hydrocarbons), dissolved water-accommodated fraction and shoreline accumulated hydrocarbons. The modelling used defined hydrocarbon exposure values, as relevant for risk assessment and oil spill planning, for the various hydrocarbon phases. To ensure conservatism in the environmental assessment process, the exposure values applied to the model are selected to adopt the most sensitive receptors that may be exposed, the longest likely exposure times and the more toxic hydrocarbons.

Exposure values applied for surface hydrocarbons, total water accommodated fraction (WAF) hydrocarbons (entrained), dissolved WAF and accumulated hydrocarbons ashore used in the modelling study are summarised in **Table 7-3**. The adopted exposure values are based primarily on the exposure values defined in NOPSEMA Bulletin #1 Oil Spill Modelling (April 2019). The environmental significance of these exposure values is described in **Appendix J.**

Table 7-3: Summary of the exposure values applied in the GHD (2019) modelling

Exposure Values			Description
Surface hydrocarbons (floating) (g/m^2) [1]	Low	1	This value represents the area where a visible sheen may be present on the surface but is below concentrations at which ecological impacts are expected to occur. It predicts the potential for some socio-economic impact (visual/aesthetic).
	Moderate	10	This represents the minimum oil thickness at which ecological impacts (e.g. to birds and marine mammals) are expected to occur.
	High	50	This value is the estimated minimum floating hydrocarbon threshold for containment and recovery and informs response planning.
Total water accommodated fraction (entrained) (ppb) [1]	Low	10	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.
	Moderate	100	This represents potential toxic effects, particularly sublethal effects to sensitive species.
	High	-	N/A
Dissolved water	Low	10	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.

accommodated fraction (ppb) [1]	Moderate	50	This represents potential toxic effects, particularly sublethal effects to highly sensitive species.
	High	400	This value represents toxic effects including lethal effects to sensitive species.
Time-integrated dissolved water accommodated fraction (ppb.hrs)[2]	Low	-	N/A
	Moderate	4,800	Time-based exposures are based on the instantaneous exposure values integrated across a 96-hour interval. They are considered more representative of the potential for toxic effects to sensitive species than using the instantaneous exposure, which are considered highly conservative.
	High	38,400	
Accumulated hydrocarbons (shoreline) (g/m^2) [1]	Low	10	This value represents light oiling (equivalent to 2 teaspoons of oil per m^2) and predicts the potential for some socio-economic impact (visual/aesthetic).
	Moderate	100	This represents the minimum oil thickness at which potential lethal ecological impacts (e.g. to intertidal invertebrates) may occur. It also predicts areas likely to require clean-up effort
	High	1000	This value predicts areas likely to require intensive clean-up effort.

[1] Instantaneous exposure values sourced from NOPSEMA Bulletin #1 Oil Spill Modelling (April 2019)

[2] Ecological receptors may not be impacted instantaneously. Toxicity effects from hydrocarbons occur based upon the rate of uptake of toxic compounds (primarily the dissolved aromatic hydrocarbons), the duration of exposure and the rate the organism is able to metabolise hydrocarbons. Toxicity to aquatic organisms is, therefore, dependent on duration of exposure, such that a brief exposure may not affect an organism, but prolonged exposure may result in toxicity effects. The exposure values used for the in-water concentrations of dissolved aromatic hydrocarbons consider a time-integrated exposure (a concentration multiplied by the number of hours exposed at that concentration), in the units of parts per billion multiplied by hours (ppb.hrs), which is an appropriate criterion for identifying potential impacts on the marine environment comparative to peak instantaneous concentrations (French-McCay 2002, 2016).The 96-hour exposure interval is representative of acute exposures, whereas some chronic toxicity effects may require a longer exposure duration.

7.1.2.4 MDO/MGO Weathering Assessment

A preliminary analysis of MDO/MGO weathering was undertaken with the SINTEF Oil Weathering Model (GHD, 2019). Oil Weathering Model (OWM) predicts the weathering (i.e. mass balance partitioning) of hydrocarbons under steady state met-ocean conditions. The OWM simulation was run for sustained wind speeds of 1 m/s (low wind conditions), 5 m/s (moderate wind conditions) and 10 m/s (high winds). The simulation is based on a standard test case of 100 m^3 of hydrocarbon released instantaneously onto the sea surface. The 100 m^3 volume is a GHD internal standard for consistency between weathering assessments, findings are applied to the 1,065 m^3 credible spill. The result of the analysis is presented in **Figure 7-1** for Marine Diesel (IKU) (the SINTEF oil library modelling analogue). Marine Diesel (IKU) has a similar density to light crude oils.

Under low winds (1 m/s), 60% of the surface slick is predicted to remain after 120 hours (5 days). Under moderate winds, 40% of the initial surface slick is predicted to remain after 24 hours, decreasing further to ~10% after 48 hours and ~1% after 72 hours. With sustained high winds (10 m/s), the surface slick is predicted to have been almost entirely evaporated and dispersed after 12 hours. It should be noted that extreme wind conditions are not likely to be sustained for long periods in normal metocean conditions. The hydrocarbon has a very low tendency for emulsion formation, with only ~1% water content entrained into the surface slick after 120 hours for all wind conditions assessed.

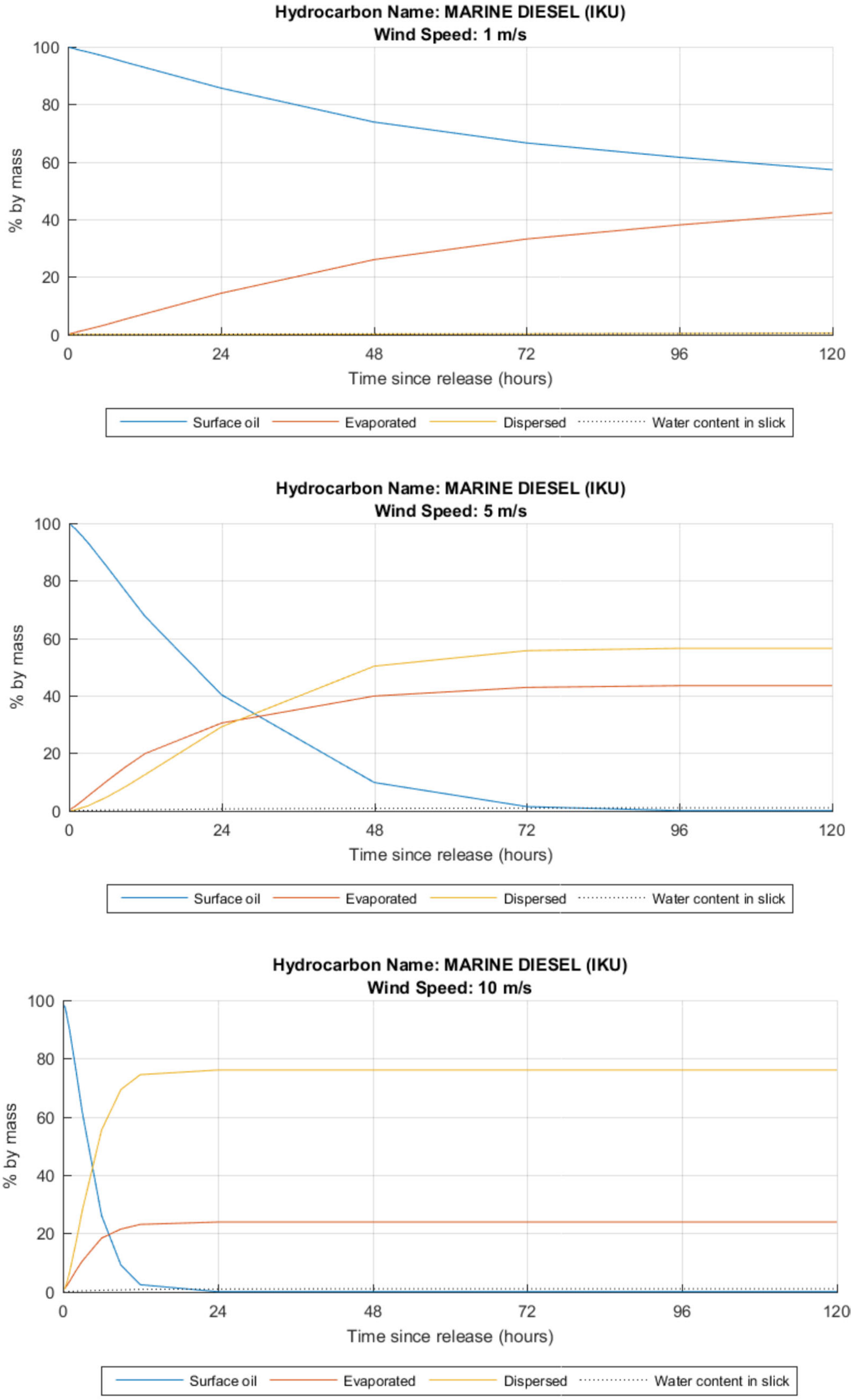

Figure 7-1: Simulated weathering of the SINTEF Marine Diesel (IKU) hydrocarbon for constant wind speeds of 1 m/s (top), 5 m/s (middle) and 10 m/s (bottom)

7.1.2.5 Stochastic Spill Modelling Results

A summary of the stochastic spill modelling results is provided below, with a tabulated summary of the results provided in **Table 7-9**.

Sea Surface Hydrocarbons

Surface oiling was assessed at three exposure values representing low exposure (1 g/m^2, visual/aesthetic impacts), moderate exposure (10 g/m^2, lower limit for potential ecological impacts), and high exposure (50 g/m^2, approximating concentrations that can be effectively targeted during spill response).

<u>Southern Release location</u>

Surface oil above the low exposure value (1 g/m^2) was predicted to extend up to a maximum of approximately 250 km from the southern release location (refer to **Table 7-4** and **Figure 7-2**). The maximum spatial extent for the moderate (10 g/m^2) and high (50 g/m^2) exposure values were predicted to reduce to approximately 200 km and 170 km, respectively. Key receptors (as defined by Santos for the purpose of oil spill impact assessment and response planning) predicted to be contacted by surface hydrocarbons above the moderate exposure value (10 g/m^2) include Eighty Mile Beach AMP (with a contact probability of 64% and a minimum time to contact of 0.3 days); Eighty Mile Beach (with a contact probability of 11% and a minimum time to contact of 2.3 days); the coastal area between Port Hedland and Eighty Mile Beach, and Bedout Island (both with a contact probability of 1.7% and a minimum time to contact of 2.3 to 2.4 days).

<u>Northern Release Location</u>

Surface oil above the low exposure threshold (1 g/m^2) was predicted to extend up to approximately 350 km from the northern release location (**Table 7-5** and **Figure 7-4**). The maximum spatial extent for the moderate (10 g/m^2) and high (50 g/m^2) thresholds were predicted to reduce to approximately 200 km and 160 km, respectively. Key receptors predicted to be contacted by surface oil above the moderate exposure value (10 g/m^2) include the Rowley Shoals Surrounds (with a contact probability of 25% and a minimum time to contact of 0.6 days); and Mermaid Reef AMP, Imperieuse Reef and Clerke Reef (Rowley Shoals Marine Park) (with a contact probability of less than 2.5% and a minimum time to contact of 2.3 to 6.6 days).

Hydrocarbons Ashore

Shoreline oiling was assessed at three contact thresholds representing low exposure (10 g/m^2, visual/aesthetic impacts), moderate exposure (100 g/m^2, generally requiring clean-up effort), and high exposure (1,000 g/m^2, requiring intensive clean-up effort).

<u>Southern Release location</u>

Shoreline accumulation at the low exposure value (10 g/m^2) was predicted to occur between Bedout Island (14% probability), approximately 100 km to the west-southwest of the release location, and Roebuck-Eighty Mile Beach (21% probability), approximately 250 km to the northeast (refer to **Table 7-4** and **Figure 7-2**). Shoreline accumulation above the moderate and high exposure values (100 g/m^2 and 1,000 g/m^2 respectively) was predicted at Bedout Island (1-4% probability) and mainland shorelines (8-12% probability). However, accumulation along mainland shorelines reduced in spatial extent to an area of approximately 160-180 km along Eighty Mile Beach to the east of the release location.

The maximum predicted shoreline loading across all shorelines was approximately 358 tonnes, which occurred entirely at Eighty Mile Beach at the low exposure value. Lower maximum shoreline loadings were also predicted for the shoreline between Port Hedland and Eighty Mile Beach (approximately 22 tonnes, noting the very low (<1 %) contact probability) and Bedout Island (approximately 12 tonnes) at the low exposure value.

Minimum arrival times of less than 1 week were predicted for most contacted shorelines. The fastest predicted arrival time was 2.2 days at Bedout Island (low exposure threshold).

Northern Release Location

Shoreline loading at low exposure (10 g/m^2) was predicted to occur at the Rowley Shoals emergent/intertidal features of Mermaid Reef AMP (27% probability), Clerke Reef (31% probability) and Imperieuse Reef (29% probability) (Rowley Shoals Marine Park), located in relative proximity to the release location (80-100 km away) (**Figure 7-4**). Low exposure was predicted with a very low probability at Eighty Mile Beach (1% probability) and Roebuck-Eighty Mile Beach (2% probability), approximately 250 km to the southeast. Shoreline contact at the medium (100 g/m^2) and high (1,000 g/m^2) thresholds was predicted to occur at the three Rowley Shoals receptors only (1-10% probability), with no mainland loadings.

The maximum predicted shoreline loading across all shorelines was approximately 335 tonnes, which occurred primarily at Imperieuse Reef (Rowley Shoals Marine Park) at the low exposure threshold. The maximum predicted total accumulated load at this receptor for the high exposure threshold was similar (approximately 330 tonnes), indicating the vast majority of all oil on the shoreline during this realisation was present above the 1,000 g/m^2 exposure threshold. Lower maximum accumulated shoreline loadings were also predicted for Mermaid Reef AMP (approximately 152 tonnes) and Clerke Reef (approximately 70 tonnes) at the low exposure threshold, with very low loadings at Eighty Mile Beach (approximately 0.04 tonnes) and Roebuck – Eighty Mile Beach (approximately 0.7 tonnes).

Short minimum arrival times of approximately 3 days were predicted for the Rowley Shoals receptors, with longer minimum arrival times of approximately 12 days for Eighty Mile Beach and Roebuck - Eighty Mile Beach at the low exposure threshold.

Total Water Accommodated Fraction

The total water-accommodated fraction (total WAF) was assessed at two contact thresholds representing low exposure (10 ppb, potential exceedance of water quality triggers) and moderate exposure (100 ppb, potential effects).

Southern Release location

Entrainment of the surface slicks resulted in total WAF concentrations above the low exposure value (10 ppb) primarily up to 250 km from the southern release site. Some isolated exceedances of the low exposure value were predicted up to approximately 350 km away (**Figure 7-3**). Exceedances of the moderate exposure value (100 ppb) were predicted to occur up to a maximum of approximately 210 km from the southern release site.

Key receptors predicted to be contacted by entrained oil plumes above the moderate exposure value (100 ppb) include Eighty Mile Beach AMP (with a contact probability of 65% and a minimum time to contact of 0.3 days); Eighty Mile Beach (with a contact probability of 7% and a minimum time to contact of 2.3 days); the coastal area between Port Hedland and Eighty Mile Beach, and Bedout Island (both with a contact probability of 1.7% and a minimum time to contact of 2.3 to 3 days).

Northern Release Location

Entrainment of the surface slicks resulted in total WAF concentrations above the low exposure value (10 ppb) primarily up to 260 km from the northern release site. However, some isolated exceedances of the low exposure value were predicted up to approximately 500 km away (**Figure 7-5**). Exceedances of the moderate exposure value (100 ppb) were predicted to occur up to a maximum of approximately 180 km from the northern release site.

Key receptors predicted to be contacted by entrained oil plumes above the moderate exposure value (100 ppb) include Rowley Shoals surrounds (with a contact probability of 23% and a minimum time to contact of 0.7 days); Imperieuse Reef and Clerke Reef (Rowley Shoals Marine Park) (with a contact probability of less than 2.5% and a minimum time to contact of 2.3 to 8.7 days).

Dissolved WAF

Dissolved WAF was assessed at three contact thresholds representing low exposure (10 ppb, potential exceedance of water quality triggers), medium exposure (50 ppb, potential sub-lethal toxic effects to sensitive species) and high exposure (400 ppb, potential toxic lethal effects to sensitive species). Time-integrated dissolved WAF was also assessed at two exposure values, namely a low exposure value of 4,800 ppb.hr and a high exposure value of 38,400 ppb.hr.

Southern Release location

Dissolved WAF above the low and moderate exposure values (10 and 50 ppb respectively) was predicted to occur to a maximum distance of approximately 220 km from the southern spill location (**Figure 7-3**). Concentrations above the high exposure value (400 ppb) were predicted to occur in sparse patches typically within approximately 100 km of the release location.

Key receptors predicted to be contacted by dissolved WAF above the moderate exposure value (50 ppb) include Eighty Mile Beach AMP (with a contact probability of 64% and a minimum time to contact of 0.3 days); Eighty Mile Beach (with a contact probability of 7% and a minimum time to contact of 2.3 days); the coastal area between Port Hedland and Eighty Mile Beach, and Bedout Island (both with a contact probability of 1.7% and a minimum time to contact of 2.2 to 2.4 days).

Time-integrated dissolved WAF above the low exposure value (4,800 ppb.hr) was predicted to occur only in sparse patches within approximately 70 km of the southern spill site. There were no exceedances of the high threshold (38,400 ppb.hr) predicted by the modelling. The only receptor predicted to be contacted at the low exposure value was Eighty Mile Beach AMP, with a contact probability of 8%.

Northern Release Location

Dissolved WAF above the low exposure value (10 ppb) was predicted to occur to a maximum distance of approximately 250 km from the northern spill location (**Figure 7-5**). Concentrations above the moderate (50 ppb) and high (400 ppb) exposure values were predicted to extend to approximately 180 km and 150 km of the northern release location respectively.

Key receptors predicted to be contacted by dissolved WAF above the moderate exposure value (50 ppb) include Rowley Shoals surrounds (with a contact probability of 22% and a minimum time to contact of 0.7 days); Imperieuse Reef and Clerke Reef (Rowley Shoals Marine Park) (with a contact probability of less than 2.5% and a minimum time to contact of 2.3 to 6.6 days).

Time-integrated dissolved WAF above the low exposure value (4,800 ppb.hr) was predicted to occur only in sparse patches within approximately 60 km of the northern spill site. There were no exceedances of the high threshold (38,400 ppb.hr) predicted by the modelling. The only receptor predicted to be contacted at the low exposure value was Rowley Shoals surrounds, with a contact probability of 2%.

Table 7-4: Probability of contact by hydrocarbons exceeding exposure values applied in the GHD (2019) modelling for the Southern release location

Sensitive Receptor Location	Total Contact Probability (%) (NC = No Contact)												
	Surface Hydrocarbons			Hydrocarbons Ashore			Total WAF (Entrained)		Dissolved WAF			Time-Integrated Dissolved WAF	
	>1 g/m^2	>10 g/m^2	>25 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 ppb	>100 ppb	>10 ppb	>50 ppb	>400 ppb	>4,800 ppb.hr	>38,400 ppb.hr
Port Hedland-Eighty Mile Beach	2.5	1.7	NC	0.8	0.8	0.8	3.3	1.7	1.7	1.7	NC	NC	NC
Eighty Mile Beach	20.8	10.8	4.2	20.8	11.7	7.5	22.5	6.7	17.5	6.7	NC	NC	NC
Eighty Mile Beach AMP	69.2	64.2	53.3	NC	NC	NC	85.0	65.0	71.7	64.2	34.2	7.5	NC
Roebuck - Eighty Mile Beach	NC	NC	NC	0.8	NC	NC	NC	NC	NC	NC	NC	NC	NC
Bedout Island	2.5	1.7	0.8	14.2	4.2	0.8	10.8	1.7	3.3	1.7	NC	NC	NC
Rowley Shoals surrounds	NC	NC	NC	NC	NC	NC	0.8	NC	NC	NC	NC	NC	NC

Table 7-5: Probability of contact by hydrocarbons exceeding exposure values applied in the GHD (2019) modelling for the Northern release location

Sensitive Receptor Location	Total Contact Probability (%) (NC = No Contact)												
	Surface Hydrocarbons			Hydrocarbons Ashore			Total WAF (Entrained)		Dissolved WAF			Time-Integrated Dissolved WAF	
	>1 g/m^2	>10 g/m^2	>25 g/m^2	>10 g/m^2	>100 g/m^2	>1,000 g/m^2	>10 ppb	>100 ppb	>10 ppb	>50 ppb	>400 ppb	>4,800 ppb.hr	>38,400 ppb.hr
Mermaid Reef AMP	2.5	1.7	0.8	26.7	10.0	2.5	16.7	2.5	3.3	1.7	NC	NC	NC
Clerke Reef MP	1.7	0.8	NC	30.8	10.0	0.8	20.0	0.8	2.5	0.8	NC	NC	NC
Imperieuse Reef MP	3.3	2.5	1.7	29.2	5.8	1.7	17.5	2.5	3.3	2.5	NC	NC	NC
Rowley Shoals surrounds	29.2	25.0	18.3	NC	NC	NC	54.2	23.3	28.3	21.7	13.3	1.7	NC
Eighty Mile Beach	NC	NC	NC	0.8	NC	NC	NC	NC	NC	NC	NC	NC	NC
Roebuck - Eighty Mile Beach	NC	NC	NC	1.7	NC	NC	NC	NC	NC	NC	NC	NC	NC
Kimberley AMP	0.8	NC	NC	NC	NC	NC	2.5	NC	NC	NC	NC	NC	NC
Glomar Shoals	NC	NC	NC	NC	NC	NC	0.8	NC	NC	NC	NC	NC	NC
Scott Reef South	NC	NC	NC	NC	NC	NC	0.8	NC	NC	NC	NC	NC	NC

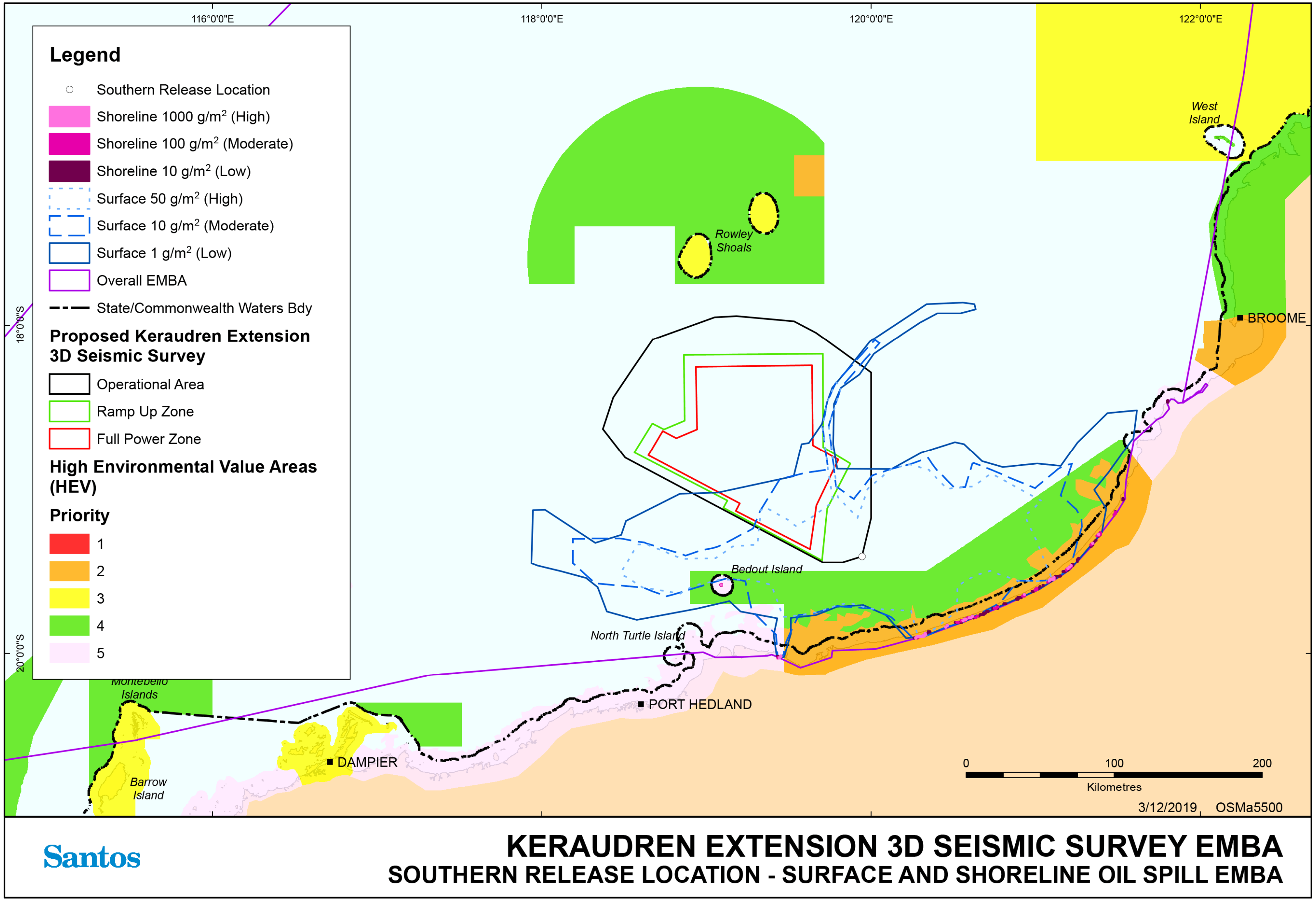

Figure 7-2: Modelled EMBA from the southern release location of MDO/MGO (diesel) spill for low, moderate and high exposure values of surface oil and shoreline accumulation)

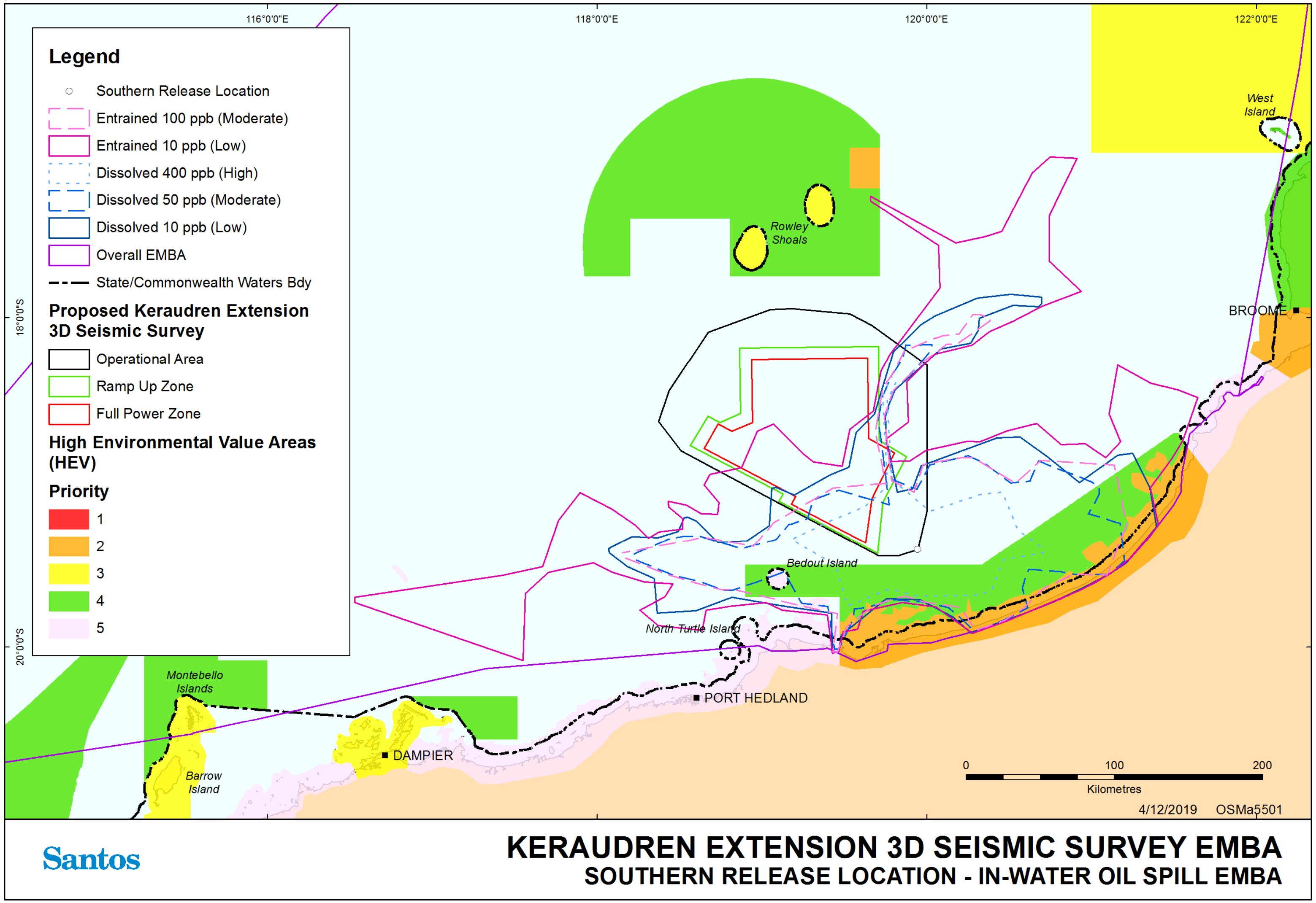

Figure 7-3: Modelled EMBA from the southern release location of MDO/MGO (diesel) spill for low, moderate and high exposure values of entrained (total WAF) and dissolved oil

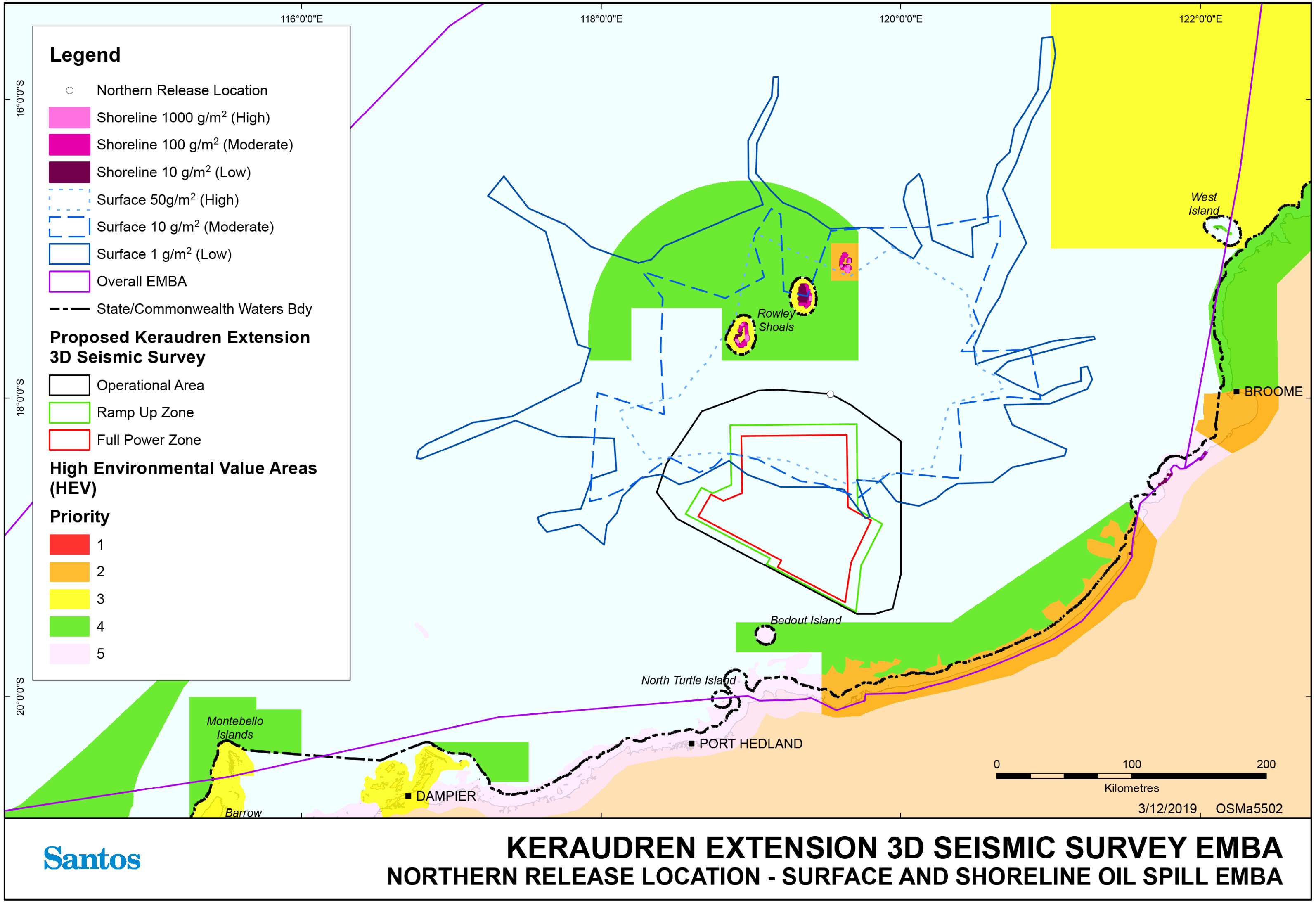

Figure 7-4: Modelled EMBA from the northern release location of MDO/MGO (diesel) spill for low, moderate and high exposure values of surface oil and shoreline accumulation)

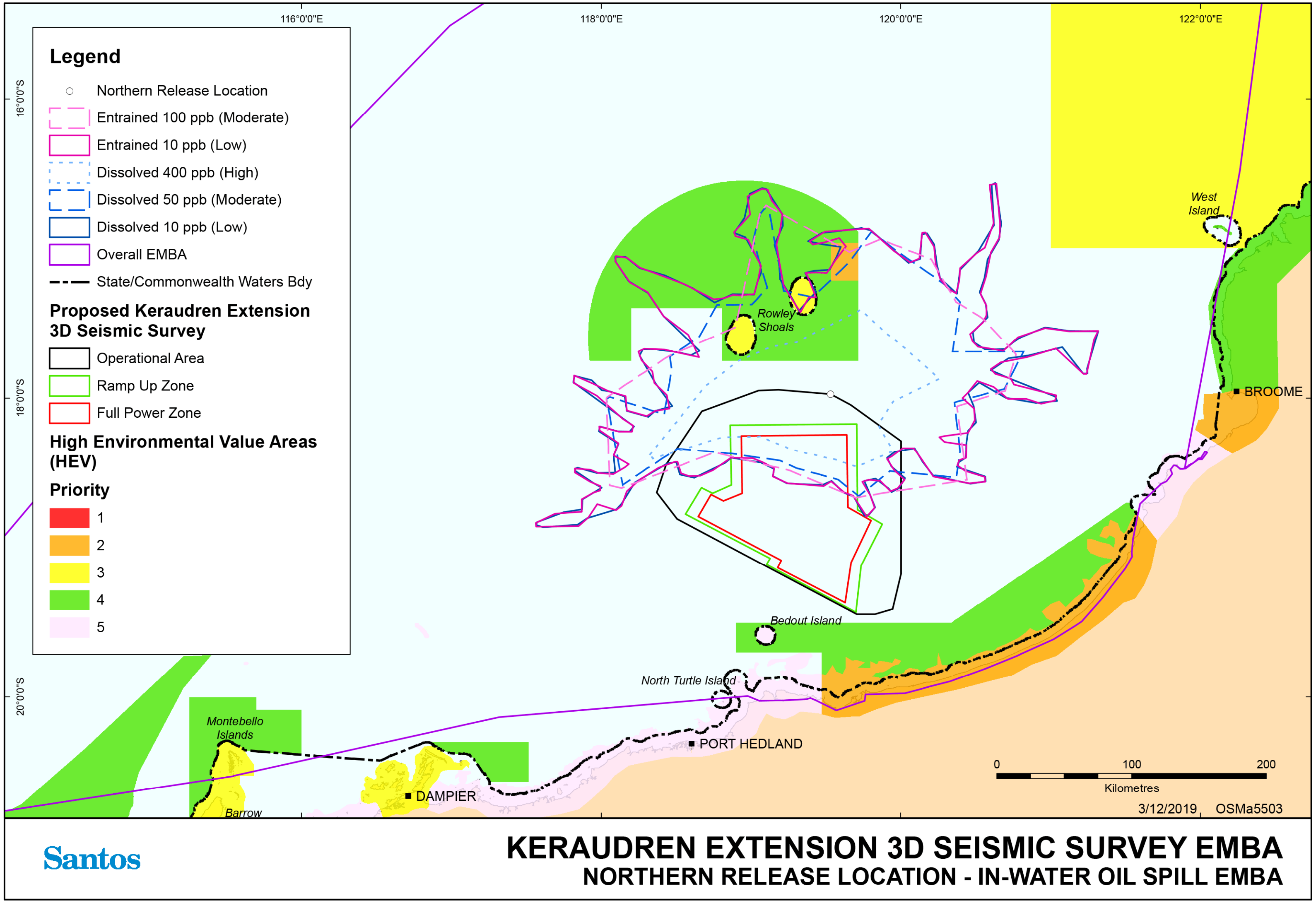

Figure 7-5: Modelled EMBA from the northern release location of MDO/MGO (diesel) spill for low, moderate and high exposure values of entrained (total WAF) and dissolved oil

7.1.2.6 Deterministic Spill Modelling Results

For the single trajectory modelled in deterministic mode, the surface oil, total WAF and dissolved WAF is predicted to be transported to the southwest towards Eighty Mile Beach, arriving at the shoreline after 6 days (refer to **Figure 3-1**). Snapshot outputs at 1-week post-release reveal the influence of the shoreline washing mechanism in the deterministic simulation which results in localised remobilisation of a portion of the oil from the shoreline into a surface slick, total WAF, and dissolved WAF. This remobilised portion of oil is transported back towards the northwest by prevailing currents and winds after 1 week for time-averaged surface oil concentrations of surface oil greater than 1 g/m^2).

Eighty Mile Beach was the only receptor contacted by shoreline oil above the low exposure threshold of 10 g/m^2 for this single spill trajectory. Shoreline oiling was predicted to reach a peak load of 358 tonnes at 7.5 days. Weathering processes over the following approximately 3 weeks were predicted to reduce the shoreline oil mass to approximately 210 tonnes by day 28.

7.1.3 Nature and Scale of Environmental Impacts

Hydrocarbon spills will cause a decline in water quality and can cause chemical (e.g. toxic) and physical (e.g. coating of emergent habitats, oiling of wildlife at sea surface) impacts to marine species. The severity of the impact of a hydrocarbon spill depends on the magnitude of the hydrocarbon spill (i.e. extent, duration) and sensitivity of the receptor.

Potential Receptors: Fish, sharks, cetaceans, marine reptiles, seabirds and shorebirds. Shorelines habitats and associated fauna and flora.

A loss of MDO/MGO to the marine environment would result in a localised reduction in water quality in the upper surface waters of the water column. Transient fauna may traverse the area and may also be potentially impacted by a spill. A general description of potential pathways and impacts to sensitive receptors through hydrocarbon exposure and potential toxicity effects is provided in **Table 7-6** (refer to **Appendix J** for further detail). It is noted that contact with hydrocarbons above the moderate exposure values is considered to be the minimum concentrations to potentially result in ecological impacts.

Potential impacts of MDO/MGO to sensitive receptors found within the EMBA are summarised in **Table 7-7**. For the purposes of this table, the EMBA is defined as the overall EMBA based on a spill that could occur anywhere within the operational area, rather than the EMBAs from the individual spill modelling scenarios (**Figure 7-2** to **Figure 7-5**).

Table 7-6: Physical and chemical pathways and oil impacts to marine organisms

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
Rocky shore	Shoreline loading and attachment may result in thin and sporadic coating of MDO/MGO residue. Degree of oil coating is dependent upon the energy of the shoreline area, the type of the rock formation and continual biodegradation of the MDO/MGO.	Impacts to flora and fauna, where relevant for the habitat type, as per below.	Adsorption via cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation. Impacts to flora and fauna as per below.	Impacts to sessile flora and fauna (invertebrates) where relevant for the habitat type, as per below.
Sandy shore	Shoreline loading and water movement may allow MDO/MGO residue to filter down into sediments, continue to biodegrade on the surface or remobilise into surf zone. Degree of loading is dependent upon the energy and tidal reach of the shoreline, the type of the sandy shore and continual weathering of the MDO/MGO.	Indirect impacts to nesting and foraging habitats for birds and turtles. Direct impacts to infauna.	Adsorption via cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation.	Indirect impacts to nesting and foraging habitats for birds and turtles. Direct impacts (mortality) to infauna through toxic effects and smothering.
Intertidal flats	Shoreline loading and water movement may allow MDO/MGO residue to filter down into sediments or continue to biodegrade on the surface or remobilise into surf zone. Degree of loading is dependent upon the energy and tidal reach of the shoreline, the type of the substrate and continual weathering of the MDO/MGO.	Indirect impacts to foraging habitats for birds and turtles. Direct impacts to infauna.	Adsorption via cellular membranes and soft tissue, ingestion, irritation/burning on contact and inhalation.	Indirect impacts to foraging habitats for birds. Direct impacts (mortality) to infauna through toxic effects and smothering.
Mangroves	Coating of root system reducing air and salt exchange. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the substrate and continual weathering of the MDO/MGO.	Yellowing of leaves. Defoliation. Increased sensitivity to stressors. Tree death. Reduced growth. Reduced reproductive output.	External contact by oil and adsorption across cellular membranes.	Yellowing of leaves. Defoliation. Increased sensitivity to stressors. Tree death. Reduced growth. Reduced reproductive output.

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
		Reduced seed viability.		Reduced seed viability. Growth abnormalities.
Algae and seagrass	Coating of leaves/thalli reducing light availability and gas exchange. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the MDO/MGO.	Bleaching or blackening of leaves. Defoliation. Reduced growth.	External contact by oil and adsorption across cellular membranes.	Mortality. Bleaching or blackening of leaves. Defoliation. Disease. Reduced growth. Reduced reproductive output. Reduced seed/ propagule viability.
Hard corals	Coating of polyps, shading resulting in reduction on light availability. Degree of coating is dependent upon the metocean conditions, dilution, if corals are emergent at all and continual weathering of the MDO/MGO.	Bleaching. Increased mucous production. Reduced growth.	External contact by oil and adsorption across cellular membranes.	Mortality. Cell damage. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Reduced egg/larval success. Growth abnormalities.
Invertebrates	Coating of adults, eggs and larvae. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the MDO/MGO.	Mortality Behavioral disruption Impaired growth	Ingestion and inhalation. External contact and adsorption across exposed skin and cellular membranes. Uptake of dissolved aromatic hydrocarbons across cellular membranes. Reduced mobility and capacity for oxygen exchange.	Mortality. Cell damage. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Reduced egg/larval success. Growth abnormalities.

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
				Behavioural disruption.
Fish, sharks and rays	Coating of adults but primarily eggs and larvae - Reduced mobility and capacity for oxygen exchange.	Mortality. Oxygen debt. Starvation. Dehydration. Increased predation. Behavioural disruption.	Ingestion. External contact and adsorption across exposed skin and cellular membranes. Uptake of dissolved aromatic hydrocarbons across cellular membranes (e.g. gills).	Mortality. Cell damage. Flesh taint. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Reduced egg/larval success. Growth abnormalities. Behavioural disruption.
Birds	Light coating. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the MDO/MGO.	Feather and skin irritation and damage. It is commonly thought that MDO/MGO does not cause problems to wildlife due to the lack of visible oiling, however, may be toxic (WAOWRP 2014).	Ingestion (during feeding or preening). External contact and adsorption across exposed skin and membranes.	Mortality. Cell damage, lesions. Secondary infections. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth. Reduced reproductive output. Growth abnormalities. Behavioural disruption.
Marine reptiles	Light coating. Degree of coating is dependent upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the MDO/MGO.	Behavioural disruption. It is commonly thought that MDO/MGO does not cause problems to wildlife due to the	Inhalation. Ingestion. External contact and adsorption across exposed skin and membranes.	Mortality. Cell damage, lesions. Secondary infections. Reduced metabolic capacity. Reduced immune response.

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
		lack of visible oiling, however, may be toxic (WAOWRP 2014).		Disease. Reduced growth. Reduced hatchling success. Reduced reproductive output. Growth abnormalities. Behavioural disruption.
Marine mammals	Light coating – fur damage and matting, reduced mobility and buoyancy (for applicable species). Coating of feeding apparatus in some species (i.e. baleen whales).	It is commonly thought that MDO/MGO does not cause problems to wildlife due to the lack of visible oiling, however, may be toxic (WAOWRP 2014).	Inhalation. Ingestion. External contact and adsorption across exposed skin and membranes.	Mortality. Cell damage, lesions. Secondary infections. Reduced metabolic capacity. Reduced immune response. Disease. Reduced growth Reduced reproductive output. Growth abnormalities. Behavioural disruption.

Table 7-7: Potential for exposure of sensitive receptors found within the overall EMBA to hydrocarbons

Receptor	**Impacts of MDO/MGO**
Marine fauna	
Plankton (including zooplankton; fish and coral larvae)	The hydrocarbon spill EMBA has the potential to overlap with spawning of some fish species given the year round spawning of some species, and overlap in peak spawning periods of others (**Table 3-12**). Coral spawning in the region occurs during the proposed Activity (**Table 3-12**), however, no significant coral reef habitat exists in the EMBA. In the unlikely event of a spill occurring, fish larvae may be impacted by MDO/MGO entrained in the water column. However, following release, the MDO/MGO will rapidly evaporate and disperse in the offshore environment, reducing the concentration and toxicity of the spill. Given duration of fish spawning periods, lack of suitable habitat for aggregating fish populations near the surface, combined with the quick evaporation and dispersion of MDO/MGO, impacts to overall fish populations are not expected to be significant.
Marine mammals	Eleven migratory cetacean species were identified by the EPBC Protected Matters search within the EMBA (**Section 3**). Of these, one is listed as endangered (blue whale (considered to be the pygmy blue whale sub-species)) and three as vulnerable (humpback whale, fin whale and sei whale). The hydrocarbon spill EMBA overlaps with the pygmy blue whale distribution and migration BIA and humpback migration BIA. Large number of individuals of either species are not expected to pass through the area, since the Activity will not overlap spatially with the pygmy blue whale migration BIA and the Activity will not take place within peak humpback whale migration. There is a minor overlap with a foraging BIA for Dugong along the Kimberley coast within the overall EMBA. It is noted that there is no contact for surface or in-water hydrocarbons predicted by spill modelling at the southern or northern release location, above moderate exposure values that may result in ecological impacts. Impacts to dugong habitat within the BIA are therefore not expected. Other migratory cetaceans may encounter either surface or water column MDO/MGO, however, the absence of any known feeding, resting or breeding areas within the EMBA means significant numbers are unlikely to be impacted. For environmental impacts through hydrocarbon exposure and toxicity to marine mammals, refer to **Table 7-6.**
Marine reptiles	Eight species of threatened marine reptile were identified as possibly being impacted by a spill. Short-nosed seasnake, flatback, hawksbill, leatherback, green, olive ridley and loggerhead turtles are widely dispersed at low densities across the NWS and in the unlikely event of a MDO/MGO spill occurring, individuals traversing open water may come into contact with water column or surface MDO/MGO. The presence of saltwater crocodile is restricted to the shoreline locations close to Broome (particularly around creeks and estuarine habitat), where they may come into contact with accumulated hydrocarbons. The hydrocarbon spill EMBA overlaps with the flatback, green, loggerhead and hawksbill BIAs as well as habitat designated as critical for internesting flatbacks such as that adjacent to Eighty Mile Beach. As such there is a risk of transient adults encountering surface and in-water MDO/MGO. Modelling results indicate a shoreline loading of approximately 358 tonnes (GHD 2019) in the worst-case scenario (with probability of up to 21% for oiling greater than 10 g/m^2). For environmental impacts through hydrocarbon exposure and increased toxicity to marine reptiles, refer to **Table 7-6**. The Recovery Plan for Marine Turtles in Australia: 2017-2027 (Commonwealth of Australia 2017a) highlights acute chemical discharge as one of several threats to marine turtles.
Seabirds and shorebirds	Twelve threatened species, as identified by the EPBC Protected Matters database search, may be encountered during the Activity, of which eight have a BIA for breeding within the hydrocarbon spill EMBA. Seabird BIAs include lesser frigate bird, brown booby, lesser crested tern, white-tailed tropicbird, roseate tern, little tern, wedge- tailed shearwater and osprey breeding, with either egg laying or chick provisioning possibly occurring during the Activity. Surface and entrained MDO/MGO is unlikely to impact

Receptor	Impacts of MDO/MGO
	nesting or egg laying individuals in colonies, however, it is possible that breeding individuals could come into contact with surface or entrained MDO/MGO while foraging. Given the rapid evaporation and dispersion of MDO/MGO (99% of the hydrocarbon expected to evaporate or disperse after 3 days under moderate winds), significant impacts at the population level are not anticipated and therefore the risk of surface and entrained MDO/MGO to seabirds is considered low. Potential impacts to seabirds/shorebirds from exposure/contact with MDO/MGO are further detailed in **Table 7-6.**
Fish and sharks	The NWS supports a diverse assemblage of fish, including 456 species of finfish, particularly in shallower water near the mainland and islands. Threatened species identified by the EPBC Protected Matters search include the white shark, whale shark, grey nurse shark green, freshwater and dwarf sawfish, northern river shark; and two conservation dependent species (scalloped hammerhead shark and bluefin tuna) which may be present in the affected area. Given the absence of critical habitat for most of these species, significant numbers are not expected to be impacted. The Activity operational area overlaps with the whale shark foraging BIA and the whale shark peak post-aggregation migrating presence in the EMBA (May – June). While this BIA is for foraging, it is not for high density prey where congregations are expected, so impacts would be limited to transient migrating individuals. Given the distance to the nearest whale shark aggregation location (Ningaloo Marine Park, 490 km southwest of the operational area) and due to the nature of the hydrocarbon release (99% of the hydrocarbon expected to evaporate or disperse after 3 days under moderate winds) significant impacts to whale sharks are not expected. White sharks and sawfish could be present at low densities all year round within the operational area and EMBA, however, the absence of any known feeding, resting or breeding areas means significant numbers are unlikely to be impacted if an unplanned release were to occur. For further detailed environmental impacts through hydrocarbon exposure and toxicity effects, refer to **Table 7-6.**
Socio-economic	
Fisheries	MDO/MGO in the water column can have toxic effects on fish (as outlined above) reducing catch rates and rendering fish unsafe for consumption. In addition to the effects of total WAF and dissolved WAF, exclusion zones surrounding a spill can directly affect fisheries by restricting access for fishers. Both water column and surface MDO/MGO have the potential to lead to temporary financial losses.
Tourism	Aquatic recreational activities such as boating, diving and fishing occur around Bedout Island or Eighty Mile Beach but are concentrated in the vicinity of the population centres such as Dampier, Onslow and Broome **(Table 3-9**). Tourism in Port Hedland is less prolific and given the small volumes potentially accumulated, any impacts are likely to be temporary and localised. In the waters within and immediately surrounding the operational area, tourism activities are expected to be low, however exclusion zones surrounding a spill will reduce access for vessels for the duration of the response undertaken for spill clean-up (if applicable).
Shipping	The operational area overlaps two designated shipping routes, and is adjacent to another (**Figure 3-19**) with two north-south oriented lanes servicing Port Hedland. Exclusion zones surrounding a spill will reduce access for shipping vessels for the duration of the response undertaken for spill clean-up (if applicable); vessel may have to take large detours leading to potential delays and increased costs.
Defence	No designated defence areas overlap the operational area and there is only a minor overlap of defence areas by the western portion of the EMBA, therefore interference of defence activities due to an MDO/MGO spill is likely to be minimal.
Shipwrecks	Surface hydrocarbons will have no impact on shipwrecks. Hydrocarbons in the water column from a vessel collision will remain in the surface waters and is

Receptor	Impacts of MDO/MGO
	therefore unlikely to have an impact on shipwrecks.
Indigenous	The level of activities undertaken by indigenous users is expected to be low, if any, therefore interference due to an MDO/MGO spill are likely to be minimal, however in event there is a requirement for land based response activities/ disturbance, relevant representatives will be contacted as outlined in Section 5 of the Oil Pollution Emergency Plan.
Existing oil and gas activity	Exclusion zones surrounding spills will reduce access potentially leading to delays to work schedules with subsequent financial implications. Although other Santos activities may occur in the operational area, no operating facilities occur in the operational area. Other operating facilities occur in the EMBA with the closest being Woodside's Angel oil field and associated infrastructure, located approximately 280 km from the operational area (beyond the area predicted to be contacted by surface hydrocarbons). Impacts to other oil and gas operators are therefore considered unlikely.
KEFs	KEFs overlapping the EMBA are described in **Section 3.2.2** and **Appendix B** and are summarised below. Ancient Coastline at 125 m Depth Contour Contributes to higher diversity and enhanced species richness relative to soft sediment habitat Attracts opportunistic feeding by larger marine life including humpback whales, whale sharks and large pelagic fish Mermaid Reef and Commonwealth waters surrounding Rowley Shoals Regionally important in supporting high species richness, higher productivity and aggregations of marine life associated with the adjoining reefs Glomar Shoals A submerged feature situated at a depth of 33–77 m Regionally important for potentially high biological diversity and localised productivity Known to be an important area for a number of commercial and recreational fish species Continental Slope Demersal Fish Communities Provides important habitat for demersal fish communities, characterised by high endemism and species diversity Other KEFs identified within the EMBA are located more than 390 km from the operational area and are therefore not expected to be contacted by hydrocarbons exceeding thresholds that may result in ecological impacts. These include: • Canyons linking the Argo Abyssal Plain with the Scott Plateau • Seringapatam Reef and Commonwealth waters in the Scott Reef Complex • Exmouth Plateau. The values and sensitivities of the KEFs are generally related to benthic habitats and communities which support areas of enhanced diversity and productivity. A loss of MDO/MGO to the marine environment would result in a localised reduction in water quality in the upper surface waters of the water column and therefore impacts to the habitats of the KEFs is not considered likely. Impacts to sensitivities within the upper waters above the KEFs are outlined above.
Protected areas	Protected areas are described in **Section 3.2.2** and potential impacts to protected areas are discussed in **Section 7.1.6.** Protected areas within the EMBA

Receptor	Impacts of MDO/MGO
	include: • Eighty Mile Beach AMP and State Marine Park • Mermaid reef AMP • Argo-Rowley Terrace AMP • Rowley Shoals State Marine Park • Kimberley AMP • Bedout Island Other protected areas identified within the EMBA are located more than 250 km from the operational area and are therefore not expected to be contacted by hydrocarbons exceeding thresholds that may result in ecological impacts or impacts to socio-economic or heritage receptors (refer to the stochastic modelling results in **Section 7.1.2.5**). These include: • Montebello AMP and Montebello Islands State Marine Park • Gascoyne AMP • Lacepede Islands • Scott Reef

7.1.4 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- No physical injury to marine fauna during the Activity (EPO-7);
- No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (EPO-3); and
- No unplanned objects, emissions or discharges to sea or air (EPO-6).

The Control Measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Section 8.6.1**.

CM Reference	Control measure (CM)	Environmental benefit	Potential cost/issues	Evaluation
CM-1	Maritime notices (Notice to Mariners and AUSCOAST warnings)	Ensures other marine users are aware of the presence of the seismic vessel and trailing streamers, and the relatively slow speed and restricted manoeuvrability of the seismic vessel.	Costs associated with the personnel time in issuing notifications and closing out queries and responses	**Adopted** – benefits considered to outweigh negligible costs. Maritime requirement to issue marine notices.
CM-3	Exclusion zone established to reduce potential for collision or interference with other marine user activities.	Requested 3 nm (5.6 km) exclusion zones around the seismic vessel and trailing streamers prevents other vessels from getting too close and causing damage to equipment of either party.	No additional costs to Santos. Other marine users may be temporarily excluded from areas, disrupting their activities.	**Adopted** – The requested exclusion of other marine users is temporary. Marine users will still be able to access the operational area. Normal navigation at sea process whereby shipping vessels avoid navigational risks. Hence, the safety benefits to all marine users outweighs any potential costs.
CM-4	Navigation equipment and procedures	Reduces the risk of interference and collisions with other marine users.	Negligible costs of acquiring and operating navigation equipment, as required by maritime law.	**Adopted** – The safety benefits of having navigation equipment and procedures outweighs any cost. This is a maritime requirement.
CM-5	Support vessel in place during Activity to reduce potential for collision or interference with other marine users	Identifies and communicates with approaching third-party vessels to ensure exclusion (safety) zone is observed, preventing potential interaction or interference.	Additional costs of contracting a support vessel.	**Adopted** – the benefits from having a support vessel during the Activity to assist with managing third-party vessels outweighs the cost.
CM-6	Constant bridge watch	Crew of support vessels and the seismic vessel will maintain constant bridge watch, including for third party vessels which may be approaching or enter the exclusion zone.	No additional costs.	**Adopted –** no additional costs. This is a maritime requirement.
CM-7	Vessels fitted with AIS systems and radars	Reduces risk of impact from vessel collisions.	Negligible as the seismic vessel should be fitted with AIS.	**Adopted** – The safety benefits of having AIS outweigh any costs. This is a maritime requirement.

CM Reference	Control measure (CM)	Environmental benefit	Potential cost/issues	Evaluation
CM-30	MARPOL-compliant fuel oil (MDO/MGO) will be used during the Activity	Use of MDO/MGO reduces the potential impacts to marine environment in the event of unplanned hydrocarbon spills or leaks during bunkering.	Additional personnel costs of ensuring vessels are using the required fuel.	**Adopted** – benefits of ensuring procedures are followed outweighs the minimal costs of personnel time.
CM- 34	Restrictions on how small volumes of unused IFO and HFO must be stored on a vessel, including restricting volumes and limiting storage to tanks that do not have direct exposure to the marine environment. If IFO or HFO is proposed to be on board then this will be risk assessed. For the vessel to store IFO or HFO then the risk assessment must conclude that the high cost of removing and disposing of the IFO or HFO onshore is grossly disproportionate to the low risk of a vessel collision and rupture of an in-board fuel tank containing small volumes of the fuel.	Restricting volumes of unused IFO and HFO and limiting storage to tanks that do not have direct exposure to the marine environment minimises the risk of a spill. Retaining the fuel oil on-board eliminates the need to transfer the fuel onshore as a waste product.	Additional costs associated with removal and disposal of IFO or HFO onshore if requirements for onboard are unable to be met.	**Adopted** – benefits of restricting volumes of unused IFO and HFO stored onboard and limiting storage to tanks that do not have direct exposure to the marine environment outweighs the potential costs of removal for onshore disposal if these requirements are unable to be met.
CM-35	Oil pollution emergency plan (OPEP)	The OPEP outlines response plans to be implemented in the event of an unplanned hydrocarbon release quickly and efficiently in order to reduce impacts to the marine environment.	Administrative costs of preparing documents and large costs of preparing for and implementing response strategies.	**Adopted** - benefits of ensuring procedures are developed and followed and measures implemented outweighs the costs.
CM-36	Vessel spill response plans (SOPEP/SMPEP)	Vessel spill response plans (SOPEP/SMPEP) outline responses to be implemented in the event of an	Administrative costs of preparing documents and large costs of implementing response strategies.	**Adopted** - benefits of ensuring procedures are followed and measures implemented and that the

CM Reference	Control measure (CM)	Environmental benefit	Potential cost/issues	Evaluation
		unplanned release quickly and efficiently in order to reduce impacts to the marine environment.		vessel is compliant outweighs the costs.
Additional control measures				
CM-37	Maximum volume of fuel stored in a single tank of vessels used for the Activity will not exceed 1,065 m^3	Reduces the volume of MGO/MDO that can be lost to the marine environment in event of a vessel collision.	Limits the vessels that can be contracted to undertake the Activity, could result in additional bunkering during the Activity if largest volume stored in a single fuel tank is limited to 1,065 m^3 and the tanks are larger in volume (therefore less tanks in the vessel).	**Adopted** – benefits of ensuring volume is less than 1,065 m^3 outweighs the potential to not be able to contract a vessel.
CM-16	No acquisition during peak humpback migration	Avoidance of peak humpback whale migration periods would minimise any potential impact to humpback whales during these times from a hydrocarbon spill.	Reduces the timeframe available for seismic acquisition. This may result in the survey objectives not being met should start date be delayed.	**Adopted** – control measures to reduce impacts to humpback whales from the seismic source will be implemented and are also relevant to reducing the risk of impact from a hydrocarbon spill. These include the survey ceasing on 31 July 2019, or if there are three consecutive days of no seismic acquisition due to the presence of migrating humpback whales.
N/A	Manage the timing/location of the Activity to avoid peak marine user periods (e.g. fishing)	Would eliminate potential impacts to other marine users at peak times.	Not considered feasible as marine users could potentially be in the area for a significant portion of the year and the Activity has a planned duration of 162 days. The area that stakeholders are excluded from is small when compared to the area available to other marine users and there is low fishing activity in the area as evidenced through historical consultation.	**Partially Adopted** – the Activity will be limited to a 162-day duration within a window between 1 February and 31 July, which avoids some of the peak spawning periods for commercial fish species.

CM Reference	Control measure (CM)	Environmental benefit	Potential cost/issues	Evaluation
N/A	Dedicated resources (e.g. dedicated spill response facilities on location) in the event of loss of hydrocarbons to allow rapid response	May allow for quicker response to a spill as resources will be within close proximity.	Large costs associated with mobilising a dedicated resource at the location. Modelling predicts 99% of the hydrocarbon will evaporate and entrain within 3 days under moderate winds. Therefore, dedicated response resources are unlikely to offer a net environmental benefit.	**Not Adopted -** Large cost associated with dedicated resources.
N/A	Require seismic survey vessels to be double hulled.	Reduces the likelihood of a loss of hydrocarbon inventory, minimising potential environmental impact.	Vessels are subject to availability and are required to meet Santos' standards during activities; requirement of a double hull on vessels would limit the number available to Santos; requiring vessels to be refitted to ensure double hulls would also be of high cost.	**Partially Adopted –** Large costs associated with vessel selection. However, it is noted that while not a specific requirement, it is most likely that the seismic survey vessel will have a double hull.

7.1.5 Spill Response Strategies for MDO/MGO Release from Vessel Collision

There are numerous oil spill response strategies available to be implemented in the event of a spill. These are generally strategies which have been implemented in the past or considered good industry practice. **Table 7-8** is the outcome of the first level screening undertaken based on the suitability of the broad response strategies available.

The evaluation of the suitable response strategies was conducted based on the credible spill scenarios identified. Below were the key considerations taken into account for the evaluation:

- The properties and weathering profile of the spilled oil;
- The philosophy of the responses;
- The nature and scale of the credible spill scenario; and
- The potential safety and environmental aspects, and impacts involved with the selected responses.

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Table 7-8: Spill response strategies considered for the mitigation of contact from MDO/MGO release from vessel Collision

Strategy	Description	Evaluation	Adopt/ Reject
Source Control	A vessel collision may result in the release of all or part of a storage tank or fuel tank contents, releasing hydrocarbons to the marine environment. In the event that a vessel fuel tank is ruptured, cargo of the affected tank is to be secured via transfer to another storage area on-board the vessel, transfer to another vessel, or through pumping in water to affected tank to create a water cushion (tank water bottom). Trimming the vessel may also be used to avoid further damage to intact tanks.	Through the implementation of these actions, the volume of hydrocarbons released to the marine environment may be reduced. However, there are several influencing factors that would result in delay or inability to implement controls, potentially resulting in a full discharge of a fuel tank compartment; such as a high sea state, a significantly large rupture, or injuries to personnel.	**Adopt**
Monitor and Evaluate / Surveillance	Operational monitoring is a fundamental aspect of a spill response and used to gain situational awareness of the incident through various surveillance actions. Monitoring is used to assess the nature and scale of the spill, the current and projected movement of the spill, the physical and chemical properties of the spill over time and the actual and potential contact of the spill with sensitive receptors. There are various specific control measures (vessel/aerial surveillance, tracking buoys, operational water quality monitoring, oil spill modelling, remote sensing/satellite imagery) within this response strategy which may be suitable.	The use of various operational monitoring techniques, in combination or individually, will be determined based on the spill distribution as well as other considerations such as access to locations, environmental and metocean conditions. This strategy is vital to ensure that there is sufficient information to gain situational awareness and make informed decisions on response planning and execution. Data from monitor and surveillance activities will be used to inform the NEBA and used to assist in escalating or de-escalating response strategies as required.	**Adopt**
Chemical Dispersant	Chemical dispersant is applied, either by vessel or aircraft, to break down the hydrocarbons and allow/enhance dispersion into the water column, potentially preventing/reducing shoreline contact and increasing natural rates of biodegradation.	Removes/disperses hydrocarbons from the surface and encourages entrainment into the water column, thereby enhancing biodegradation and dilution. This potentially results in increased volumes of hydrocarbon in the water column, but less on the sea surface. Therefore, there is the potential to prevent/reduce shoreline contact to sensitive receptors and a potential to result in higher entrained hydrocarbon concentrations, which may impact organism in the water column. MDO/MGO is not considered a persistent hydrocarbon and has high natural rates of evaporation and dispersion in the marine environment (99% of the hydrocarbon expected to evaporate or disperse after 3 days under moderate winds). This has been assessed through spill modelling of conservative worst-case scenarios.	**Reject**

Strategy	Description	Evaluation	Adopt/ Reject
		All spill scenarios are short term releases and oil will undergo rapid weathering of those components that dispersants are most effective on. MDO/MGO slicks will break apart into wind rows with low surface thickness (rainbow and metallic sheens) given the very low viscosity of the hydrocarbon. Chemical dispersants have a window of opportunity, after which effectiveness decreases. Modelling indicates that 99% of the hydrocarbon with naturally disperse or evaporate over 72 hours under moderate winds. Therefore, surface dispersant application is unlikely to provide any benefit over natural attrition and evaporation. Dispersant use is not considered to be effective on the spill scenarios given they are not continuous releases and slick characteristics amenable to dispersant operations will unlikely be present by the time dispersant operations are mobilised. This reasoning is consistent with ITOPF guidance (ITOPF 2011) which advises against the use of dispersant on light products such as MDO/MGO given the high natural rates of evaporation/dissipation and rapid spreading.	
Mechanical Dispersion	Physical dispersion is undertaken by running support vessels through the hydrocarbon plume and using the turbulence developed by the propellers or hydroblasting from vessel hydrants to break up the slick. Once dispersed in the water column in the form of smaller droplet sizes, biodegradation processes are enhanced.	MDO/MGO is a light oil that can be easily dispersed in the water column by running vessels through the plume and using the turbulence developed by the propellers to break up the slick. Once dispersed in the water column the smaller droplet sizes enhance the biodegradation process. Caution must be applied during the volatilisation period of the oil due to potential safety and human health issues.	**Adopt**
Containment and Recovery	Containment and recovery of hydrocarbons through the use of offshore boom and skimmers from vessels can prevent oil from reaching sensitive features. This strategy is only effective in calm conditions and may not be an effective use of resources if oil cannot be thickened to a point where worthwhile volumes are collected.	Given the fast spreading nature of MDO/MGO the expected moderate to high sea states of the area causing the slick to break up and disperse, this response is not considered to be effective in reducing the net environmental impacts of a MDO/MGO spill. The ability to contain and recover these spreading oils (i.e. surface sheens) on the sea surface is extremely limited due the very low viscosity of the fuel.	**Reject**

Strategy	Description	Evaluation	Adopt/ Reject
Shoreline Protection and Deflection	Shoreline protection and deflection activities involve the use of booms to: • Protect sensitive receptors; • Deflect spills away from sensitive receptors or shorelines; or • Deflect spills to an area that provides increased opportunity for recovery activities. This strategy is typically not effective in areas experiencing large tidal variations and associated currents.	The effectiveness of this response will be dependent on sea, current, and wind conditions. Deployment is subject to safety concerns of operation in shallow waters and possible grounding issues of vessels. Activities are focused on areas of high protection value in low energy environments based upon real time operational surveillance provided the environmental and metocean conditions are favourable for an effective implementation. Consequently, this strategy may not be applicable across all areas or receptors identified as priority for protection.	**Adopt**
In-Situ Burning	In-situ burning is a technique sometimes used in responding to an oil spill. In-situ burning involves the controlled burning of oil that has spilled at the location of the spill. When conditions are favourable and conducted properly, in-situ burning will reduce the amount of oil on the water.	MDO/MGO disperses and entrains rapidly and is not suitable to be contained by in-situ burning (as described above for containment and recovery). In addition, as the slick thins, its insulating capacity weakens and more heat is lost to the water beneath the slick, eventually resulting in insufficient heat to continue to vaporise the oil and sustain combustion.	**Reject**
Shoreline Clean-Up	During a spill response, clean-up of the oiled shorelines will be implemented using suitable methods, provided it will be beneficial to the environment based on the NEBA performed on the affected areas based on actual site conditions.	Shoreline loading was predicted at Bedout Island, Eighty Mile Beach, and at emergent/intertidal features of Mermaid Reef, Clerke Reef and Imperieuse Reef (Rowley Shoals Marine Park). Contacted shorelines will be assessed for their shoreline clean-up potential. This response has the potential to cause secondary disturbance associated with the clean-up, so applicability of the strategy is based on aerial surveillance reconnaissance, Oiled Shoreline Response Team (OSRT) observations and NEBA in the shoreline clean-up assessment.	**Adopt**
Oiled Wildlife Response (OWR)	Responding to an oiled wildlife incident will involve an attempt to prevent wildlife from becoming oiled and/or the treatment of animals that do become oiled.	The Protection Priorities identified for spill response have include sensitive fauna (e.g. protected birds and turtles) that may be seasonally abundant and undertake key lifecycle processes near shorelines. Mobilisation of experts, trained work forces, facilities and equipment will likely be needed if oil reaches shorelines and nearshore waters. Wildlife response activities may take place at sea, on shorelines and in specialised facilities further inland. Options for wildlife management have to be considered and a strategy determined guided by the Western Australian	**Adopt**

Strategy	Description	Evaluation	Adopt/ Reject
		Oiled Wildlife Response Plan (WAOWRP) and Pilbara Regional Oiled Wildlife Response Plan.	
Scientific Monitoring	This is the main tool for determining the extent, severity and persistence of environmental impacts from an oil spill and allows operators to determine whether their environmental protection outcomes have been met (via scientific monitoring activities). This strategy also evaluates the recovery from the spill.	Scientific monitoring is especially beneficial for the purpose of monitoring entrained and dissolved oil impacts as response strategies are generally targeted to manage the floating oil impacts.	**Adopt**

7.1.6 Detailed Risk Assessment for High Environmental Values

The spill risk assessment approach adopted is based on Santos WA's Oil Spill Risk Assessment and Response Planning Procedure (QE-91-II-20003). The procedure describes the spill risk assessment process as follows:

1. Identify the spatial extent of the EMBA (as defined above by spill modelling and interpolation of the results to account for a spill that could possibly occur anywhere within the operational area);
2. Identify areas of high environmental value (HEV) within the EMBA; and
3. Risk assess areas of HEV with a high probability and level of oil contact (Hot Spots).

Santos has predetermined areas of high environmental value (HEV) along the Western Australian coastline by ranking these areas based on:

- Protected area status – This is used as an indicator of the biodiversity values contained within that area, where a World Heritage Area, Ramsar Wetland and Marine Protected Area will score higher than areas with no protection assigned; and
- BIAs of listed threatened species – These are spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviour, such as breeding, feeding, resting or migration. Each one of these within the predefined areas contributes to the score.

Further input to determine areas of HEV included:

- Sensitivity of habitats to impact from hydrocarbons in accordance with the guidance document Sensitivity Mapping for Oil Spill Response produced by IPIECA, the International Maritime Organisation and International Association of Oil and Gas Producers;
- Sensitivities of receptors with respect to hydrocarbon-impact pathways;
- Status of zones within protected areas (i.e., IUCN (1a) and sanctuary zones compared to IUCN (VI) and multiple use zones);
- Listed species status and predominant habitat (surface versus subsurface); and
- Social values, i.e., socio-economic and heritage features (e.g., commercial fishing, recreational fishing, amenities, aquaculture).

Tallied scores for each predefined area along the Western Australian coastline were then ranked from 1 to 5, with an assignment of 1 representing areas of the highest environmental value and those with 5 representing the areas of the lowest environmental value.

While the entire EMBA for the MDO/MGO spill is considered in this risk assessment, the assessment is particularly focused on those parts of the EMBA that have:

- The greatest intrinsic environmental value – i.e., HEV areas ranked 1-3;
- The highest probability of contact by oil (either floating, entrained or dissolved aromatic) above contact exposure values described in **Section 7.1.2.3**; and
- The greatest potential concentration or volume of oil arriving at the area.

It is noted that the probability of contact at moderate exposure values are used to identify HEV areas within the EMBA with ecological values and sensitivities, as they represent thresholds above which there is potential for ecological impact (**Table 7-3**). The probability of exposure low exposure values for surface and accumulated hydrocarbons are used to identify HEVs with socio-economic and heritage values.

HEV areas are summarised in **Table 7-9,** including a description of values and a consequence rating for from exposure to hydrocarbons above exposure values. Potential impacts (consequence rating) were determined after considering the receptor values (protected area status, threatened species, BIAs, KEFs, social values including heritage values and concerns raised during stakeholder consultation) and the potential impacts to these (**Table 7-6** and **Table 7-7**), from the predicted concentrations/levels of MDO/MGO for each location presented in **Section 7.1.2.5**.

The following HEV areas were identified for detailed assessment in **Table 7-9**:

- Eighty Mile Beach Marine Park (State Waters - Emergent)
- Eighty Mile Beach AMP (Submerged)
- Bedout Island (Emergent)
- Mermaid Reef AMP (Emergent)
- Clerke Reef - Rowley Shoals Marine Park
- Imperieuse Reef - Rowley Shoals Marine Park
- Rowley Shoals Surrounds

Additional protected areas have been identified within the overall EMBA. They do not have predicted contact with hydrocarbons above exposure values in the spill modelling but based on the interpolated EMBA could be exposed in the event of a spill within the operational area at a different location to the two modelled release locations. Additional protected areas are as follows:

- Argo-Rowley Terrace AMP
- Kimberley AMP
- Montebello AMP and Montebello Islands State Marine Park
- Gascoyne AMP
- Lacepede Islands
- Scott Reef

The values and sensitivities of these protected areas are described in **Section 3.2.2**. With the exception of Argo-Rowley Terrace AMP and Kimberley AMP, these areas are more than 250 km from the operational area and are not expected to be contacted by oil above moderate exposure values or surface/accumulated oil above low exposure values based on the modelling presented in **Section 7.1.2.5**. While these areas fall within the wider EMBA for spill response planning (based on the low exposure values for entrained and dissolved hydrocarbons), they are not considered further in this impact assessment in relation to potential for ecological impacts or impacts to socio-economic or heritage receptors. Potential impacts to Argo-Rowley Terrace AMP and Kimberley AMP are assessed in **Table 7-9**.

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Table 7-9: Consequence summary for High Environmental Value areas in the EMBA

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
Eighty Mile Beach Marine Park (State Waters) **(Emergent)** NB. Worst case spill modelling results from the southern release location	2	Eighty Mile Beach management plan recognises oil spills as a potential pressure on emergent features: mangroves and saltmarsh, intertidal sand and mudflats (DPaW, 2014). Note that habitats and fauna usually submerged are discussed separately below in 'Eighty Mile Beach AMP (Submerged)'. Contact from floating oil is likely to impact the shoreline and result in accumulated stranded oil at discrete locations. Mangroves and intertidal areas may be impacted by being smothered, although continuous tidal movements will mobilise oil and add to dispersion. Contact from entrained oil may impact shoreline through accumulation, although constant tidal and current motions will re-mobilise oil and create further dilution Contact from floating oil is likely to impact marine fauna by smothering (causing skin/eye irritation and affect ability to thermo-regulate) and oil contact from movement across the shoreline. In addition, ingestion may occur from preening/cleaning body and/or eating oil covered food resulting in internal toxicity. Contact from entrained oil may impact marine fauna by causing skin irritation/toxicity as fauna move through water, or internal toxicity from ingesting oil tainted food. Although constant tidal and current motions will re-mobilise oil and create further dilution and fauna are mobile Oil is unlikely to contact Mandora Salt Marsh, however 'the beach' area consists of sandy beach, mangroves and intertidal mudflats which may be contacted by oil impacting upon the Ramsar values. A spill in the southern portion of the operational area may result in contact from floating oil, with potential to impact emergent features and result in stranded oil on the shoreline, although tidal movements will mobilise oil and add to dispersion of oil. Modelling results from the southern release location predict a maximum probability of contact above the 10 g/m^2 moderate exposure value (with potential to result in ecological impacts) of 11%. Although, the minimum time to contact is predicted to be 2.3 days, by which time considerable weathering will have occurred (**Section 7.1.2.4**). The maximum probability of shoreline accumulation above the moderate exposure value of 100 g/m^2 is 12%, with a maximum total of 358 tonnes from the southern release location).	Threatened / Migratory Fauna Physical Habitat Protected Areas Socio-economic and Heritage receptors	3 (Moderate) 3 (Moderate) 3 (Moderate) 3 (Moderate)	**3 (Moderate)** Due to surface impact and loading to Ramsar wetlands.

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		<u>Habitats</u> *Coral reefs* Not identified in emergent area (see Eighty Mile Beach 'AMP (Submerged) below) *Seagrasses* Not identified in emergent area (see Eighty Mile Beach 'AMP (Submerged) below) *Macroalgae* Not identified in emergent area (see Eighty Mile Beach 'AMP (Submerged) below) *Mangroves* Limited stretch along coastline and in Mandora Salt Marsh area. minor stands 10-20 km close to tidal creeks. *Intertidal mud/sand flats* 225 km intertidal mudflats provide important food source for many of the bird species from the infauna present. Mandora Salt Marsh area contains rare group of wetlands *Sandy Beaches* Sandy shores occupy the landward edge of the intertidal zone (approx.~ 220 km), provide important turtle nesting habitat and some tourism (see below). *Rocky shorelines* Not identified in emergent area <u>Invertebrates</u> Large number and diversity of invertebrates within the intertidal mudflat areas Oil can reduce invertebrate abundance or alter the intertidal invertebrate community that provides food for non-breeding shorebirds <u>Fish and sharks</u> Not discussed in emergent area, (see Eighty Mile Beach AMP (Submerged) below) <u>Birds</u> Ramsar site 97 wetland bird species, 42 of which are listed under CAMBA, JAMBA and ROKAMBA			

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		500,000 birds use the area as a migration terminus annually, key period is Aug-Nov when contact with oil spill could result in impacts at a population level <u>Marine reptiles</u> Flatback turtles nest at scattered locations along shoreline. <u>Marine mammals</u> Not discussed in emergent area, (see Eighty Mile Beach AMP (Submerged) below) <u>Cultural Heritage</u> Indigenous values: wetlands are significant to 3 three local groups, several aboriginal heritage sites present <u>Socio-Economic</u> Tourism activities include camping nearby, nature appreciation, recreational beach fishing and four-wheel driving			
Eighty Mile Beach AMP (Submerged) NB. Worst case spill modelling results from the southern release location	2	Eighty Mile Beach AMP management plan recognises oil spills as potential pressure on submerged features: water and sediment quality, filter feeding communities, macroalgae and seagrasses and coral reef communities. Potential impacts to these receptors are described in **Table 7-6**. Note that habitats and fauna not usually submerged are discussed separately above in 'Eighty Mile Beach (emergent)'. Contact from entrained and dissolved oil may impact submerged corals/seagrasses/macroalgae and filter feeding communities resulting in smothering and/or contact toxic impacts; although constant tidal and current motions will re-mobilise oil and create further dilution. Modelling results from the southern release location predict a maximum probability of contact above the moderate exposure value (which may result in ecological impacts) of 65% for both entrained and dissolved hydrocarbons. There is also a 7.5% probability of exposure to time-integrated dissolved WAF above the moderate exposure value. There is no contact predicted from a spill at the northern release location. <u>Physical Habitats</u> *Coral reefs* Subtidal filter feeding communities present, likely provide foraging habitat for flatback turtles	Threatened / Migratory Fauna Physical Habitat Protected Areas Socio-economic and Heritage receptors	3 (Moderate) 3 (Moderate) 3 (Moderate) 3 (Moderate)	**3 (Moderate)** Due to entrained oil impacts on the AMP values (foraging and habitats).

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		High diversity intertidal and subtidal coral reef communities *Seagrasses* Seasonally present but sparsely distributed Dugongs regularly found feeding on seagrass meadows here *Macroalgae* Provide habitat and feeding opportunities for fish, invertebrates and dugong *Mangroves* Not present in submerged area *Intertidal mud/sandflats* Not present in submerged area *Sandy beaches* Not present in submerged area *Rocky shorelines* Not present <u>Marine fauna</u> *Invertebrates* Several invertebrate species targeted by recreational and fisheries Important food source for waterbirds *Fish and sharks* Fish populations dependent on habitat and substrate type Several fish species targeted by recreational and commercial fisheries Sawfish foraging, nursing and pupping; diversity of sharks and rays (including protected species) Diversity of fish species provide recreational and commercial fishing opportunities *Birds* Migratory seabirds forage in the waters, peak season during Aug-Nov. High diversity of waterbirds including 42 migratory species, waterbirds are nationally and			

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		internationally important 500,000 birds use the area as a migration terminus annually, key period is Aug-Nov when contact with oil spill could result in impacts at a population level *Marine reptiles* Flatback turtles forage and inter-nest in offshore waters Green, hawksbill, loggerhead, olive ridley and leatherback may frequent the waters all year round *Marine Mammals* Humpback whale migration pathway though the AMP. Dugongs and other cetaceans inhabit or migrate through the marine park although unlikely to be larger whale species due to water depths Socio-economic Tourism: nature based, fishing and wildlife viewing from vessels. Some vessel-based fishing (mostly shore based recreational fishing in 80 Eighty Mile Beach area) Pearl Producers Association (PPA) have previously indicated this area is important as a seed stock. Diving for pearl oysters is limited to the water depths < 35m depth contour. Indigenous values The adjacent State Waters Marine Park contains land and sea important to traditional indigenous owners, 4 special purpose zones included in marine park.			
Bedout Island (Emergent) NB. Worst case spill modelling results from the southern release location	4	A spill in the southern portion of the operational area may result in contact from floating oil, with potential to impact sandy beaches resulting in smothering of coral and stranded oil on beaches, although tidal movements will mobilise oil and add to dispersion of oil. Bedout Island includes foraging and nesting areas for marine turtles and feeding/resting/breeding areas for seabirds and migratory shorebirds, potentially impacting habitat. Modelling results from the southern release location predict a maximum probability of contact above the 10 g/m^2 moderate exposure value (with potential to result in ecological impacts) of 2%. Therefore, impacts from surface oil to ecological receptors are unlikely. Furthermore, the minimum time to contact is predicted to be 2.3 days, by which time considerable weathering will have occurred (**Section 7.1.2.4**). The maximum probability of shoreline accumulation above the moderate exposure value of 100 g/m^2 is 4%, with a maximum total of 12 tonnes from the southern release location).	Threatened / Migratory Fauna	3 (Moderate)	**3 (Moderate)** Due to potential hydrocarbon impact on the migratory shorebirds.
			Physical Habitat	3 (Moderate)	
			Protected Areas	3 (Moderate)	
			Socio-economic and	3 (Moderate)	

Santos

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		<u>Physical Habitats</u> *Coral reefs* Fringing the small island (0.31 km^2) *Seagrasses* None of significance identified *Macroalgae* None of significance identified *Mangroves* None identified. *Intertidal mud/sand flats* None identified *Sandy Beaches* Sandy clay on limestone bedrock, heavily vegetated with beach spinifex *Rocky shorelines* Not present in emergent area <u>Fauna</u> <u>Invertebrates</u> None of significance identified <u>Fish</u> Pelagic fishes, stingrays and reef sharks may be present at times <u>Birds</u> Important due to brown booby breeding. Seabird breeding colonies present- island supports over 1,000 nesting pairs of brown boobies (one of the largest colonies in the world). Supports nesting of other birds as well Season for breeding: May to September <u>Marine reptiles</u> Foraging green, hawksbill and loggerhead turtles foraging may be present but not known if	Heritage receptors		

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		nesting site Marine mammals None identified Socio-economic and heritage values - Tourism - Heritage value: two shipwrecks in the surroundings waters			
Mermaid Reef AMP NB. Worst case spill modelling results from the northern release location	4	Mermaid Reef AMP management plan recognises oil spills as potential pressure on submerged features: water and sediment quality, coral reef and associated communities. Potential impacts to these receptors are described in **Table 7-6**. A spill in the northern portion of the operational area may result in contact from floating oil, with potential to impact to intertidal coral habitat resulting in smothering, although tidal movements will mobilise oil and add to dispersion of oil. Modelling results from the northern release location predict a maximum probability of contact above the 10 g/ m^2moderate exposure value (with potential to result in ecological impacts) of 2%. Therefore, impacts from surface oil are unlikely. Furthermore, the minimum time to contact is predicted to be 3.6 days, by which time considerable weathering will have occurred (**Section 7.1.2.4**). The maximum probability of accumulation of hydrocarbons on intertidal features above the moderate exposure value of 100 g/m^2 is 10%, with a maximum total of 152 tonnes from the northern release location). Contact from entrained and dissolved oil may impact submerged coral reef and associated habitat resulting in smothering and/or contact toxic impacts; although constant tidal and current motions will re-mobilise oil and create further dilution. Modelling results from the northern release location predict a maximum probability of contact above the moderate exposure value of 2.5% for entrained and 1.7 for dissolved hydrocarbons. There is no contact predicted for time-integrated dissolved WAF. Impacts from entrained and dissolved oil are therefore considered unlikely. Physical Habitats *Coral reefs* Exceptionally rich and diverse intertidal and subtidal reefs. Provide a source of invertebrate and fish recruits for reefs further south and are therefore regionally significant *Seagrasses*	Threatened / Migratory Fauna Physical Habitat Protected Areas Socio-economic and Heritage receptors	3 (Moderate) 3 (Moderate) 3 (Moderate) 3 (Moderate)	**3 (Moderate)** Due to potential for impacts on Marine Park values (Corals and associated habitat).

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		Sparse seagrass found within subtidal areas in Rowley Shoals *Macroalgae* Small patches may be present in lagoonal areas *Mangroves* None identified *Intertidal mud/sandflats* None identified *Sandy beaches* None identified *Rocky shorelines* None identified Marine fauna *Invertebrates* A number of invertebrate (echinoderms, cnidarians, molluscs and crustaceans) species commonly found at Scott Reef are also found here although in higher densities due to lack of fishing/collection. Diverse molluscan fauna on flats *Fish and sharks* Fish populations similar to those on shelf edge reefs in the Indo-Pacific region but unique in WA waters. Rich diversity of fish (500+ species) *Birds* Wide range of seabirds observed at Rowley Shoals *Marine reptiles* Green and hawksbill turtles are present at the Rowley Shoals. Reefs not known to be regionally significant turtle habitats *Marine Mammals* Northward humpback whale migration pathway adjacent to Rowley Shoals, therefore individuals may be present			

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		Variety of toothed and baleen whales likely to be visitors to the area but Rowley shoals are not a key aggregation/calving/mating/foraging area Protected Areas The Rowley Shoals Argo-Rowley Terrace AMP is in place to protect migratory seabirds and endangered loggerhead turtle, sharks, communities and habitats of 220 m-5000m, seafloor features, two KEFs and provides connectivity between Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals Marine Park and the deeper waters of the region. It is an IUCN category zoning of II and VI. Socio-economic and Tourism: nature-based tourism (charter boats, diving, snorkelling) and recreational fishing (although prohibited in certain zones) low usage given distance to mainland Sanctuary zone within marine park Heritage values Indigenous values: none identified Heritage values: none identified			
Clerke Reef and Imperieuse Reef -Rowley Shoals Marine Park NB. Worst case spill modelling results from the northern release location	2	Rowley Shoals Marine Park (State Waters) management plan recognises oil spills as potential pressure on water quality (DoE, 2007). Bedwell Island at Clerke Reef and Cunningham Island on Imperieuse Reef are recognised migratory bird resting areas. Contact from floating oil is likely to impact marine fauna by smothering (causing skin/eye irritation and affect ability to thermo-regulate), oil coating from movement across shorelines and inhalation of oil if surfacing to breathe. In addition, ingestion may occur from preening/cleaning body and/or eating tainted food resulting in internal toxicity. Contact from entrained and dissolved oil may impact marine fauna by causing skin or eye irritation/toxicity as fauna move through water, or internal toxicity from ingesting oil tainted food or breathing oil entrained water (fish). A spill in the northern portion of the operational area may result in contact from floating oil, with potential to impact emergent coral and sandy beaches resulting in smothering of coral and stranded oil on beaches, although tidal movements will mobilise oil and add to dispersion of oil. Modelling results from the northern release location predict a maximum probability of contact above the 10 g/m^2 moderate exposure value (with potential to result in ecological impacts) of 2.5%. Therefore, impacts from surface oil are unlikely. Furthermore, the minimum time to contact is predicted to be 2.3 days, by which time considerable weathering will have occurred (**Section**	Threatened / Migratory Fauna	3 (Moderate)	**3 (Moderate)** Due to potential for impacts on Marine Park values (Corals and seabirds)
			Physical Habitat	3 (Moderate)	
			Protected Areas	3 (Moderate)	
			Socio-economic and Heritage receptors	3 (Moderate)	

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		7.1.2.4). The maximum probability of shoreline accumulation above the moderate exposure value of 100 g/m^2 is 10%, with a maximum total of 334 tonnes from the northern release location). Contact from entrained and dissolved oil may impact submerged corals/seagrasses/macroalgae resulting in smothering and/or contact toxic impacts; although constant tidal and current motions will re-mobilise oil and create further dilution. Modelling results from the northern release location predict a maximum probability of contact above the moderate exposure value of 2.5% for both entrained and dissolved. There is no contact predicted for time-integrated dissolved WAF. Impacts from entrained and dissolved oil are therefore considered unlikely. Physical Habitats *Coral reefs* Exceptionally rich and diverse intertidal and subtidal reefs. Provide a source of invertebrate and fish recruits for reefs further south and are therefore regionally significant *Seagrasses* Sparse seagrass found within subtidal areas in Rowley Shoals *Macroalgae* Small patches may be present in lagoonal areas *Mangroves* None identified *Intertidal mud/sandflats* None identified *Sandy beaches* Bedwell Island (Clerke Reef) is a supratidal, unvegetated, sandy cay about 1.3 km long and 2 m high Cunningham Island (Imperieuse Reef) is a supratidal, unvegetated, sandy cay about 3.7 m high *Rocky shorelines* None identified Marine fauna *Invertebrates*			

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		A number of invertebrate (echinoderms, cnidarians, molluscs and crustaceans) species commonly found at Scott Reef are also found here although in higher densities due to lack of fishing/collection. Diverse molluscan fauna on flats *Fish and sharks* Fish populations similar to those on shelf edge reefs in the Indo-Pacific region but unique in WA waters. Rich diversity of fish (500+ species) *Birds* Bedwell island is site of second largest breeding colony of red-tailed tropic birds, an uncommon species in WA Both Bedwell Island and Cunningham Island are known resting sites for migratory birds Wide range of seabirds observed at Rowley Shoals *Marine reptiles* Green and hawksbill turtles are present at the Rowley Shoals. Reefs not known to be regionally significant turtle habitats *Marine Mammals* Northward humpback whale migration pathway adjacent to Rowley Shoals, therefore individuals may be present Variety of toothed and baleen whales likely to be visitors to the area but Rowley shoals are not a key aggregation/calving/mating/foraging area Protected Areas The Rowley Shoals Argo-Rowley Terrace AMP is in place to protect migratory seabirds and endangered loggerhead turtle, sharks, communities and habitats of 220 m-5000m, seafloor features, two KEFs and provides connectivity between Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals Marine Park and the deeper waters of the region. It is an IUCN category zoning of II and VI. Socio-economic and Tourism: nature-based tourism (charter boats, diving, snorkelling) and recreational fishing (although prohibited in certain zones) low usage given distance to mainland Sanctuary zone within marine park			

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		<u>Heritage values</u> Indigenous values: none identified Heritage values: none identified			
Rowley Shoals Surrounds	3	See information on **Mermaid Reef, Clerke Reef and Imperieuse Reef** for Rowley Shoals	See information on **Mermaid Reef, Clerke Reef and Imperieuse Reef** for Rowley Shoals	See information on **Mermaid Reef, Clerke Reef and Imperieuse Reef** for Rowley Shoals	See information on **Mermaid Reef, Clerke Reef and Imperieuse Reef** for Rowley Shoals
Argo-Rowley Terrace AMP	3	Argo-Rowley Terrace AMP is not predicted to be contacted by hydrocarbons above any of the exposure values by modelling at the either the southern or northern release location. Due to its proximity to operational area (23 km) it is included within the EMBA and there is a possibility of exposure. However, given the low probability (<2.5%) of contact at the Rowley Shoals described above by hydrocarbons above moderate thresholds at which ecological impacts may occur, and the minimum time to contact (2.3 days), it is considered unlikely that the values of the Argo-Rowley Terrace AMP would be impacted by a spill. <u>Physical Habitats</u> Seafloor features including aprons and fans, canyons, continental rise, knolls/abyssal hills and the terrace and continental slope; *Coral reefs* None identified *Seagrasses* None identified *Macroalgae* None identified *Mangroves*	Threatened / Migratory Fauna	2 (Minor)	**2 (Minor)** Due to potential for impacts on AMP values
			Physical Habitat	2 (Minor)	
			Protected Areas	2 (Minor)	
			Socio-economic and Heritage receptors	2 (Minor)	

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		None identified *Intertidal mud/sandflats* None identified *Sandy beaches* None identified *Rocky shorelines* None identified Marine fauna *Invertebrates* None of significance identified *Fish and sharks* Important habitat and foraging for sharks Provides protection for communities and habitats of the deeper offshore waters of the region *Birds* Foraging areas that are important for migratory seabirds *Marine reptiles* Foraging areas that are important for the endangered loggerhead turtle *Marine Mammals* Includes the migratory pathway for pygmy blue whales, therefore individuals may be present Variety of toothed and baleen whales likely to be visitors to the area but the deep waters of the AMP are not a known key aggregation/calving/mating/foraging area Protected Areas The AMP includes Multiple Use Zone (VI), Special Purpose Zone (Trawl) and National Park Zone (II) Two key ecological features: Canyons linking the Argo Abyssal Plain with the Scott Plateau and Mermaid Reef and Commonwealth waters surrounding Rowley Shoals Socio-economic and Tourism			

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		Overlap with commercial fisheries including the Northwest Slope Trawl Fishery Heritage values Indigenous values: none identified Heritage values: none identified			
Kimberley AMP	4	Kimberley AMP is predicted to have a very low probability of contact above low exposure values for surface (0.8%) and entrained (2.5%) hydrocarbons from the northern release location. No contact is predicted above moderate exposure values at which ecological impacts may occur from either release location. Given the minimum arrival time of more than 11 days, any hydrocarbons reaching the AMP will be highly weathered. Impacts to the Values of the AMP are therefore not expected. Physical Habitats Representation of continental shelf, slope, plateau, pinnacle, terrace, banks and shoals and deep hole/valley seafloor features *Coral reefs* Subtidal filter feeding communities present, likely provide foraging habitat for turtles Intertidal and subtidal coral reef communities *Seagrasses* Seasonally present but sparsely distributed Dugongs regularly found feeding on seagrass meadows here *Macroalgae* Provide habitat and feeding opportunities for fish, invertebrates and dugong *Mangroves* Not present in submerged area *Intertidal mud/sandflats* Not present in submerged area *Sandy beaches* Not present in submerged area	Threatened / Migratory Fauna	2 (Minor)	**2 (Minor)** Due to potential for impacts on AMP values
			Physical Habitat	2 (Minor)	
			Protected Areas	2 (Minor)	
			Socio-economic and Heritage receptors	2 (Minor)	

Hot Spot	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking and description
		Rocky shorelines Not present Marine fauna *Invertebrates* None of significance identified *Fish and sharks* Adjacent to important foraging and pupping areas for sawfish *Birds* Foraging areas that are important for migratory seabirds *Marine reptiles* Important foraging area for marine turtles Adjacent to important nesting sites for green turtles *Marine Mammals* Important foraging areas for dugongs and dolphins Migratory pathway and nursery areas for humpback whales and migratory pathway for pygmy blue whales Protected Areas The AMP includes Multiple Use Zone (VI) and National Park Zone (II) Two key ecological features: the ancient coastline at the 125 m depth contour and the continental slope demersal fish communities Socio-economic and Tourism Commercial tourism, commercial fishing, mining, recreation and traditional use Heritage values Indigenous values: The marine park also holds cultural values of Sea country, valued for indigenous cultural identity, health and well-being Heritage values: none identified			

7.1.7 Summary of Impact, Consequence and Likelihood Ranking

<table>
<tr><th colspan="2">Description</th></tr>
<tr><td>Receptors</td><td>Marine fauna – plankton, fish and sharks, marine mammals, marine reptiles, seabirds/shorebirds;
Physical Environment / Habitats;
Protected areas; and
Socio-economic and heritage receptors</td></tr>
<tr><td>Consequence</td><td>C- Moderate</td></tr>
<tr><td colspan="2">In the event of a vessel collision, the volume of hydrocarbons released would be a finite amount limited to the maximum credible spill of a full tank inventory release (1,065 m^3). Given the nature of the MDO/MGO and the distance from most shorelines, dilution and dispersion from natural weathering processes such as ocean currents indicate that the extent of exposure will be limited in area and duration.
Habitat modification/degradation/disruption/loss, deteriorating water quality and marine pollution are identified as potential threats to a number of marine fauna species in relevant Recovery Plans and Conservation Advice (Table 3-7). In addition, the Management Plan for the Eighty Mile Beach Marine Park (State Waters, including Ramsar site) states that DBCA should ensure the water and sediment quality, intertidal sand and mudflat communities, subtidal filter-feeding communities, macroalgal and seagrass communities, coral reef communities, mangrove communities and saltmarshes are not significantly impacted by human activities including oil spills. The potential for impacts to marine fauna is summarised in Table 7-6 and Table 7-7.
In the unlikely event that a vessel collision did occur within the operational area, the potential impacts to the environment would be greatest within several kilometres from the spill when the toxic aromatic components of the fuel will be at their highest concentration and when the hydrocarbon is at its thickest on the surface of the receiving waters. The MDO/MGO will also rapidly lose toxicity with time and spread thinner as evaporation continues. The potential sensitive receptors in the surrounding areas of the spill will include fish and sharks, marine mammals, marine reptiles and seabirds at the sea surface, as discussed in Table 7-7. Given that exposures would be limited in extent and duration, exposure to marine fauna from this hazard is it expected to be limited to a small number of individuals, with no impacts to regional populations.
Marine habitats may also be impacted as discussed in Table 7-6 and Table 7-7. As per Section 7.1.2, a maximum of 358 tonnes of MDO/MGO may accumulate on the shoreline of Eighty Mile Beach. Lower maximum shoreline loadings were predicted for other shorelines including Port Hedland to Eighty Mile Beach (approximately 22 tonnes, noting the very low (<1 %) contact probability) and Bedout Island (approximately 12 tonnes). Indigenous users may be impacted in the event that a land-based response is required, however consultation will ensure potential impacts are reduced to acceptable levels.
Potential impacts to protected areas identified as areas of High Environmental Value (HEV) within the EMBA, including socio-economic and heritage values, are assessed in detail in Section 7.1.6.
An overall consequence ranking of moderate was assigned to this scenario based on the potential impacts to HEV areas as described in Table 7-9. This is due to the potential for:
- Surface impact and loading to Ramsar wetlands within the Eighty Mile Beach Marine Park (emergent)
- Entrained oil impacts on the AMP values (foraging and habitats) within the Eighty Mile Beach AMP (submerged)
- Hydrocarbon impact on the migratory shorebirds at Bedout Island
- Impact on AMP values of Mermaid Reef (corals and associated habitat)
- Impacts on Marine Park values (corals and seabirds) at Clerke Reef, Imperieuse Reef and Rowley Shoals surrounds in Rowley Shoals State Marine Park
It is noted that potential impacts identified are based on stochastic modelling of 120 spill trajectories at two locations. For any single spill trajectory, impacts would not occur at all locations.</td></tr>
<tr><td>Likelihood</td><td>1 - Rare</td></tr>
<tr><td colspan="2">A hydrocarbon release resulting from a vessel collision is unlikely to have widespread ecological effects given the nature of the hydrocarbons on-board, the finite volumes that could be released, the depth and transient nature of marine fauna in this area.</td></tr>
</table>

Description	
The likelihood of a hydrocarbon release occurring due to a vessel collision is limited given the set of mitigation and management controls in place for this Activity. Consequently, the likelihood of a vessel collision releasing hydrocarbons to the environment that results in a moderate consequence is considered to be **rare**.	
Residual Risk	The residual risk associated with this hazard is Low

7.1.8 ALARP Evaluation

Vessels are required to undertake the Activity. There are no suitable alternatives to the use and number of vessels to complete the Activity. It is considered that the industry standard and activity-specific controls to reduce collision risks that have been proposed and the contingencies in place in the event of the hazard occurring reduce the likelihood and potential impacts from a loss of fuel as a result of a vessel collision to ALARP. Alternative and additional controls were considered but not adopted as detailed in **Section 7.1.4.** The proposed control measures are considered appropriate to manage the risk to ALARP.

Spill Response Measures

The state of spill response readiness Santos adopts for operational activities across the NWS is considered commensurate for the spill risk associated with the Activity based on the likelihood of a worst-case spill (Rare) and the level of potential impact associated with worst case spills (Moderate). That is, the spill risk for the Activity fits within the profile covered through existing arrangements.

Pre-deploying existing equipment/ personnel, or adding to existing readiness, in terms of additional capability or administrative planning is considered appropriate where the scale of the spill and the extent/timeframe of environmental impacts cannot be effectively mitigated through existing capacity or when the benefit of adding to readiness outweighs the cost/effort. For the spill risks associated with the current Activity, this is not considered to apply and thus the existing state of readiness is considered to reduce this risk to ALARP.

In terms of spill response activities Santos will implement oil spill response as specified within the OPEP. This includes the use of resources (equipment and personnel) owned by Santos or available through third party providers through contracts, agreements or MoUs. The proposed spill response strategies, refer to **Section 7.3** (Spill Response Operations), consider relevant values and include completion of a NEBA in the event of a spill which includes the relevant values and receptors present in the area, including AMPs. This will limit impacts to the identified AMPs thereby protecting and conserving the ecosystems, habitats and native species, consistent with the park values.

A summary of the ALARP assessment for the level of resourcing required for each of the spill response strategies adopted is provided in **Table 7-10**. This provides the incremental benefit of increasing resourcing levels for each spill response strategy and the associated upfront costs.

From this assessment it is considered that through the resourcing arrangements outlined within the OPEP (including spill response equipment and personnel from internal and external sources including Santos, AMOSC, AMSA, other operators, OSRL, and other national and international suppliers) the spill response strategies and control measures reduce spill risk to ALARP.

Table 7-10: ALARP assessment for the level of resourcing required for the selected response strategies

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
Aerial surveillance	Helicopter services available through Santos primary contracted supplier (Babcock) based out of Karratha. Ad-hoc contracts through CHC Helicopters. Initial aerial observation using helicopter pilots will occur within 3 hours of notification of the spill. Trained Aerial Observers (7) available from Day-2 of incident following activation (based Perth and Santos facilities).	Given location of spill site, mobilisation of CHC Helicopter from Karratha is considered adequate for surveillance. Endurance not considered a limiting factor at this location. Babcock run to Santos offshore facilities regularly for crew transfers. Mobilisation and refuelling from Exmouth is possible depending upon trajectory of spill. Current arrangements can provide for 2 passes (am and pm) of the spill area per day, this has been exercised as part of major spill exercises. Trained Aerial Observers can mobilise to Karratha/ Exmouth for Day 2 operations. Day 1 surveillance and recording using helicopter pilots considered adequate for initial situational awareness.	Resource not considered limiting. Primary supplier on contract with additional providers available to provide desired overpass frequency. Santos trained observers can be provided on rotation from Day 2.	No additional costs as helicopters through CHC are currently contracted for day to day operations to/from Santos facilities. In the event that additional passes are required due to data gaps the cost of the additional flights will be added to the cost of the response.	There is no value in increasing dedicated overpasses and therefore the arrangements are considered ALARP however opportunistic aerial surveillance can be provided through the shared use of aircraft deployed for other purposes.
Vessel surveillance	Activity vessels, including seismic, chase and support vessels. Vessel of opportunity (VOO) from other operators. Additional vessels contracted through Santos vessel providers out of Dampier.	The survey Activity involves multiple vessels further described in **Section 2**. Should an incident occur, those not involved in the incident can provide surveillance. The Activity area is central on the NWS and offshore from the major marine base of Dampier – additional available vessels out of Dampier can be put on hire through Santos' contracted vessel providers; mobilisation times to site can provide additional contracted	Based on the likelihood of vessels available on site, given the close proximity of the Activity to central location of the Activity relative to the main marine base of Dampier, dedicated additional vessels for the purpose of oil spill surveillance is not considered required given	The current vessels arrangements are considered to provide the required function. Dedicated vessels on standby for vessel surveillance would cost tens of thousands of dollars per day and are not considered required.	There is no benefit in having additional dedicated surveillance vessels given surveillance can be performed from any vessel and these duties will be shared amongst spill response vessels.

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
	Santos has access to AIS live vessel tracking portal to establish vessel availability. On-hire vessels supporting Santos' Varanus Island (VI) and Ningaloo Vision facilities.	vessels relatively quickly. Additional mobilisation from Exmouth can be made through Santos' contracted vessel providers. This strategy is not designed to perform 'whole of spill' coverage which is provided by aerial surveillance (i.e. it is a secondary strategy). On-contract vessels performing duties at VI and Ningaloo Vision will be available as well as vessels of opportunity from other petroleum operators.	the need is met through vessel sharing. Surveillance will also be conducted through a number of complementary strategies (aerial surveillance, oil spill trajectory modelling, tracker buoys).		
Oil spill trajectory and fate modelling	24/7 stand-by spill modelling service provider (RPS). RPS will be contacted immediately (within 2 hours) upon notification of a Level 2 or 3 spill. Spill modelling to be initiated within 24 hours. Upon activation RPS will provide trajectory models within: - 2 hours for OILMAP model for offshore and open ocean - 4 hours for OILMAP operation for nearshore	RPS is to provide at least daily updates to the IMT of trajectory model outputs to inform response planning. More frequent updates can be provided if weather conditions are highly variable or change suddenly. Operational surveillance data (aerial, vessel, tracker buoys) is to be provided to RPS APASA to verify and adjust fate predictions of the spill and improve predictive accuracy.	Predictive oil spill modelling will be used to forecast (using real-time data) the trajectory and fate of the spill. Resource is not considered limiting with no environmental benefit from dedicating additional modelling capability.	Santos pay for the provision of the service by RPS. This is considered to provide the required function.	There is no benefit in having additional modelling capability given that RPS have staff based across Australia and can provide 24/7 coverage.
Tracker buoys	Up to 12 Santos tracker buoys (at different Santos	Tracker buoys are an additional strategy to aerial surveillance to	Additional buoys are available through secondary	Santos has 12 buoys linked to a satellite	The number of buoys immediately available (2

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
	facilities), 2 buoys located on seismic support vessels, 4 are available on VI and deployment can be expected within 6 hours to track oil heading towards sensitive receptors. Subscription to tracker buoy tracking website. Santos on-hire vessels and VOO for buoy deployment. Subject to weather and vessel availability the tracker buoys can be mobilised within 2 hours upon request from IMT or on-scene commander.	provide real time verification data (particularly beneficial at night and in conditions limiting aerial surveillance). 12 x buoys is sufficient to enable timely retrieval and redeployment. Four are available on VI for deployment within 6 hours Vessels for buoy deployment will be Santos on-hire vessels and other operator VOO. Vessels can be shared across this and other tasks (e.g. surveillance).	suppliers (e.g. AMOSC, OSRL and AMSA – greater than 20 buoys available) if required. These can be registered on the Santos/JouBeh satellite tracking system within hours. Dedicated vessels are not required given need is met through vessel sharing.	tracking website designed for first strike deployment across its operational facilities. No additional buoys are required to be purchased by Santos Energy given secondary availability through AMSA, AMOSC, OSRL within days. There is no additional upfront cost for accessing these secondary buoys.	can be deployed form the seismic support vessels) and the availability of secondary buoys within days is sufficient to cover tracking of oil fronts especially given the spread of oil will be limited within the initial days of the spill. Therefore, no additional requirements and the response is considered ALARP.
Water quality monitoring (Operational and Scientific)	Fluorometers (for hydrocarbon detection) within subsea gliders or towed fluorometers. CTD (Conductivity, Temperature, Depth) probes including fluorometry and dissolved oxygen sensors. Water sampling equipment (e.g. Niskin bottles, jars) Water quality monitoring personnel. Glider Field Engineer for deployment/ recovery.	Santos has field tested deployment of subsea gliders and data transfer using local provider (Blue Ocean monitoring) with access to gliders within Australia and USA. Towed fluorometers area available through contract with OSRL – located in Singapore. CTDs with fluorometers and water sampling equipment available locally and to be arranged through Santos' contracted scientific monitoring provider. Contractual standby arrangements are in place for rapid activation, planning and deployment of	There are locally available subsea gliders and access to towed fluorometers. Water sampling equipment and CTDs are also available locally. Water sampling equipment is not considered a bottleneck to deployment. Given multiple access avenues to equipment – dedicated equipment (i.e. purchased or standby on-hire equipment) is not considered required. Deployment personnel will initially be provided through	Santos can access subsea gliders with fluorometers through Blue Ocean Monitoring and towed fluorometers through OSRL. Santos's contracted scientific monitoring provider is on an existing standby footing in Perth with mobilisation time of personnel to site within 72 hr following approval of a monitoring action plan based on the incident specifics. An enhanced	The existing arrangements are considered sufficient to provide targeted 'first strike' operational water quality monitoring to priority sites as identified through spill modelling and surveillance.

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
	Dedicated vessels for towed fluorometers, CTD deployment, water sampling. Vessels of opportunity (vessel sharing) for subsea glider deployment. Oil sample collected using a vessel opportunity and analysed in Perth.	operational water quality monitoring personnel. Subsea gliders and towed fluorometers can cover ~1 km/hr. One fluorometer could cover 24 km/day. CTDs provide discrete 'single point' readings over a depth profile. Water quality sampling at discrete locations. For subsea gliders and towed fluorometers the deployment philosophy is not to 'blindly' patrol the entire spill area. Deployments will be targeted to ground truth spill modelling predictions. That is, the predicted front(s) of entrained oil will be traversed by gliders to verify entrained oil presence. This will be prioritised where fronts are predicted to reach sensitive receptor areas. Similarly, discrete water sampling will target sites positioned to validate modelling predictions.	Santos's contracted monitoring provider and subsea glider deployment personnel.	standby with vessels, equipment and personnel all prepositioned for immediate deployment would be in order of 10s tens of thousands of dollars per day. Similarly, subsea gliders set-up and prepositioned on standby for immediate deployment would be in 10s tens of thousands of dollars.	
Mechanical dispersion	One seismic vessel and two support vessels are potentially available. Vessel of opportunity (VOO) from other operators.	Mechanical dispersion may be beneficial depending upon the state of the hydrocarbon, weather conditions and proximity of oil to sensitive receptors. It is a strategy that is therefore dependent upon situational awareness gathered at the time of the incident. This strategy targets discrete patches of oil (typically most suitable for diesel spills) in an opportunistic	Given there will be the seismic vessel and two support vessels within the operational area during the survey operations, availability of vessels to conduct mechanical dispersion will not limit the response.	The current vessels arrangements are considered to provide the required function given this strategy is applied opportunistically. Vessels and crew on standby would cost 10s tens of thousands of dollars per day and is not	The strategy is dependent on conditions at time of the spill and can be delivered by vessels co-tasked with other operations. Therefore, the ongoing vessel access arrangements and vessels contracted are considered adequate.

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
		manner and can be undertaken by vessels performing other duties. Dedicated vessels are therefore not considered to be required.	Additional vessels specifically for the purpose of mechanical dispersion is not considered required, particularly given this strategy can be tasked through vessel sharing.	considered required based on the limited value they would provide.	
Protection and deflection	Shoreline and nearshore boom + ancillary equipment AMOSC (Exmouth, Fremantle and Geelong); AMSA (Fremantle and Dampier) Boom tow-vessels Spill response teams (Santos and AMOSC core group, State Response Team) Tactical response plans in place for the deployment of booms at offshore island locations.	Shoreline and nearshore boom provided by Santos, or through AMOSC or AMSA is available from Mutual aid arrangements through AMOSC also provide access to additional boom from other operators (e.g. Chevron equipment based at Barrow Island). Response exercises deploying boom from VI and Dampier are conducted annually by Santos. Protection priorities along shorelines potentially contacted have been assessed as part of spill response planning.	Boom equipment is not considered limiting. However, the time for deployment may exceed predicted times to shoreline contact, particularly at the Bedout Islands (contact within 2-3 days). This is particularly relevant given that boom deployment locations cannot be confirmed until oil spill fate modelling and aerial/vessel surveillance data has been analysed. Prepositioning or having personnel and equipment at an enhanced standby footing would reduce deployment time. However, pre-deploying boom at sensitive locations creates potential for impacts which weighed against the uncertainty of an oil spill reaching the location are deemed to be unacceptable.	The cost of boom, vessels and personnel on an enhanced standby footing or pre-positioned boom is in the order of tens of thousands of dollars per day and considered to be of limited value based the timeframes needed to undertake oil spill modelling /surveillance activities and a NEBA in order to establish the areas to be protected by boom.	Given there is questionable environmental benefits in having additional resources or pre-positioned resources, the current arrangements are considered ALARP.

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
Shoreline clean-up	Manual clean-up and flushing equipment (Santos, AMOSC, AMSA, hardware supplies) Staging infrastructure Clean-up team leaders (Santos, AMOSC core group, AMSA) Clean-up labour personnel (labour hire as required) Vessels for transport (Santos contracted vessel providers) Equipment is prepositioned on VI so readily available.	For MDO/MGO spills, given the light/volatile nature of the hydrocarbon and the relatively low concentration/volumes predicted to arrive at shorelines under worst case conditions), intrusive and labour-intensive methods are unlikely to be favoured or required. Existing Santos equipment and that available through AMOSC/AMSA arrangements is considered to be sufficient given stockpile locations at Dampier, Exmouth and VI. Further equipment can be provided through additional Australian stockpile locations.	The main limitation of undertaking a shoreline clean-up response is based around access for plant and personnel to remote offshore island locations (Bedout Island). Provision of additional clean-up resources such as spill kits, sorbents, brooms, shovels, buckets etc. are not considered to provide an environmental benefit unless additional personnel can be mobilised.	During a spill event, the cost of additional resources is not considered the limiting factor; the limiting factor is considered to be numbers of personnel available to undertake shoreline clean-up. Mobilising additional personnel to undertake shoreline clean-up via vessel to remote offshore locations presents increased associated health and safety risks. Personnel mobilised via helicopter is limited to 10 passengers per trip. Once at the locations there is a need to provide adequate facilities.	The level of resources available are considered to be appropriate. The outcome of oil spill modelling/surveillance and a NEBA would be used to identify priorities for protection at specific locations given the time of year e.g. during turtle nesting season, where shoreline clean-up efforts would be directed at nesting beaches. Therefore, the response is considered ALARP.
Waste management	Assorted waste receptacles and trucks Waste personnel – project manager, local responsible personnel and operations personnel. Vessels for waste transport from offshore islands. Dedicated spill equipment container on VI with equipment to establish	Santos' waste service provider for spill response is North West Alliance (NWA). NWA is contracted to provide first strike and ongoing waste storage, transport and disposal requirements commensurate to a worst-case spill across Santos' operations. These resources are commensurate with those required for the worst case from the activities covered in this EP.	NWA has access to sufficient resources for the worst-case waste requirements associated with the Activity; there is no benefit to acquiring additional resources specifically for the Activity. Additional equipment to manage shoreline clean-up waste on offshore islands	Contracted resources are considered greater than required to respond to a worst-case scenario.	Resources are considered to be adequate based on worst case modelled waste requirements.

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
	waste storage areas during shoreline clean-up (e.g. collapsible bunds/absorbent rolls/drain covers/temporary fencing etc.).		can be accessed and replenished from the mainland during an ongoing response.		
Oiled wildlife response	Oiled wildlife response kits and containers (AMOSC, AMSA, DBCA, DoT) – Darwin, Broome, Exmouth, Karratha, Fremantle, Kensington. OWR personnel Level 2 to 4 as per the WA Oiled Wildlife Response Plan (AMOSC, AMOSC activated OWR contractors, Industry Mutual Aid, DBCA, OSRL activated OWR contractors - "Sea Alarm"). Level of escalation of the OWR is under authority of the DoT incident controller with technical input from the DBCA – Oiled Wildlife Adviser.	The nature of the hydrocarbon released in a worst-case scenario (MDO/MGO) predicts the spatial extent of floating oil above the impact threshold of 10 g/m^2 may extend up to 250 km from the release location. Therefore, widespread physical oiling to wildlife may occur. Additionally, OWR may be undertaken onshore in the event of a spill, the Pilbara Region OWRP provides contact details for local trade personnel, vets and wildlife specialists that could be employed for manning/maintenance of forward response wildlife response facilities. The equipment and personnel arrangements are consistent with the equipment and personnel requirements as specified in the WA Oiled Wildlife Response Plan and are consistent with the activities covered by this plan. All OWR efforts would be undertaken in consultation with DBCA, and Santos would undertake the response following the outcome of an	Pre-positioning of staging areas and responders has been considered for this spill scenario given worst case timeframe for oil on shorelines may be as soon as 2 days from the occurrence of the release. As Santos has access to OWR kits through third party agreements that can be mobilised in a timely manner, it is not considered to be necessary to increase resources. The available OWR kits are strategically positioned within WA enabling flexibility on locations for staging areas to be established. The ability to increase the OWR effort relies on having adequate numbers of trained personnel available to undertake the response	The cost of personnel (Level 1 responders) on standby is $1,500 per person per day as per existing arrangements through recruiting agencies. This is a guaranteed cost regardless of whether a spill occurs or not. Given that personnel on this level can be arranged within relatively short timeframes there is not considered sufficient environmental value in having dedicated OWR responders on standby. This is further supported by OWR being undertaken in consultation with relevant agencies (e.g. DBCA and DoEE) which is expected to be more of a limiting factor with regards to time than	Based on the timeframe for oil contact (approx. 2 days) and the nature and thickness of MDO/MGO (worst-case) released, resourcing required for OWR is considered to be within the capacity of Santos and contracted service providers and the response arrangements are considered ALARP.

Strategy	Resourcing	Justification	Environmental benefit of additional resources	Cost of additional resources	ALARP assessment
		operational NEBA that would direct efforts for maximum effectiveness.	rather than having access to extra OWR kits. Purchasing of an OWR kit by Santos has been discounted as any OWR would be in consultation with DBCA upon completion of a NEBA. The timeframe for this to occur would exceed the time to mobilise an OWR from one of the locations on the WA mainland.	mobilising additional resources.	

7.1.9 Acceptability Evaluation

Is the risk ranked between Low to Medium?	Yes – maximum hydrocarbon spill – MDO/MGO residual risk is ranked Low
Is further information required to support or validate the consequence assessment?	Yes – hydrocarbon spill modelling results were used to determine consequence and risk
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with *International Convention of the Safety of Life at Sea* (SOLAS) 1974, *Navigation Act 2012, MARPOL Annex III-Prevention of Pollution by Harmful Substances,* and relevant recovery plans for threatened species. Management is also consistent with the zoning of the AMPs, in that risks have been reduced to ALARP, e.g. implementation of spill response activities will limit impacts, thereby conserving the marine park values.
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above)

Given the control measures in place to prevent a vessel collision and the low frequency of significant volume spills that occur in the industry, the risk of the event occurring is considered acceptable.

Deteriorating water quality is identified as a potential threat to turtles in the marine turtle recovery plan, and in recovery plans for some bird and shark species (**Table 3-7**). Oil spills are also identified as a potential threat to habitats of the Eighty Mile Beach Marine Park (State Waters) in the park's Management Plan. Habitat modification/degradation/disruption, pollution and/or loss of habitat are also identified as threats to sharks, birds, cetaceans and turtles in conservation management and recovery plans. However, the potential hydrocarbon releases as a result of vessel collision are not expected to significantly impact the receiving environment with the implementation of the management controls proposed. Additionally, long term impacts resulting in complete habitat loss or degradation are not considered likely given the controls proposed to prevent releases and therefore the Activity will be conducted in a manner that is considered acceptable.

In accordance with Santos' risk assessment process, the residual risk is considered to be low and is therefore acceptable.

7.2 Minor Hydrocarbon Release

7.2.1 Description of Event

Hydrocarbon release at sea surface	
Event	A minor spill (~37.5 m^3) of MDO/MGO could occur during vessel refuelling resulting in a loss of hydrocarbons to the marine environment at sea surface. Spills of MDO/MGO during refuelling events have the potential to cause impacts to the marine environment through a reduction in water quality and marine fauna exposure. Spills during refuelling can occur through several pathways, including fuel hose breaks, coupling failure or tank overfilling. Spills resulting from overfilling will be contained within the vessel drains and slops tank system. In the event that the refuelling hose is ruptured, the fuel bunkering activity will cease by turning off the pump; the fuel remaining in the transfer line will escape to the environment as well as fuel released prior to the transfer operation being stopped. The AMSA (2015) *Technical Guidelines for Preparing Contingency Plans for Marine and Coastal Facilities* provides guidance for calculating a maximum credible spill volume for a refuelling spill. The guidance provided by AMSA (2015) for a refuelling spill under continuous supervision is considered appropriate given refuelling will be constantly supervised. The maximum credible spill volume during refuelling is calculated as: transfer rate (150 m^3/ hr) x 15 minutes of flow. The detection time of 15 minutes is seen as conservative but applicable following failure of multiple barriers, followed by manual detection and isolation of the fuel supply. Minor accidental loss of other hydrocarbon-based liquids (e.g. used lubricating oils, cooking oil, and hydraulic oil) to the marine environment could also occur via tank pipework failure or rupture, hydraulic hose failure, inadequate bunding and/or storage, insufficient fastening or inadequate handling. Seal oil could potentially leak from the vessel thruster/propeller stern tube directly to sea as a result of leaking seals or mechanical damage. The header tank for stern tube oil is approximately 1 m^3 and is equipped with limit switches in the event of a leak, thus preventing complete loss (the release of <1 m^3 of stern tube oil (non-hydrocarbon based lube oil) event is discussed further in **Section 7.4**). There will be no need to refuel helicopters on the seismic survey vessel.
Extent	Refer to **Section 7.1** for the hydrocarbon characteristics of the MDO/MGO refuelling release. A surface spill of MDO/MGO during refuelling is considered relatively small in comparison to a surface spill of MDO/MGO during a vessel collision. It is therefore assumed that the extent of a hydrocarbon spill during refuelling would remain within the extent of the worst case spill trajectory of MDO/MGO from a vessel collision as detailed in **Section 7.1**.
Duration	MDO/MGO fuel at the sea surface would spread rapidly in the direction of the prevailing wind and surface currents. Evaporation is the dominant process that would to the fate of spilled MDO/MGO from the sea surface during calm conditions while entrainment of droplets within the water column would increasingly contribute to removal of surface oil as wind speed increases.

7.2.2 Nature and Scale of Environmental Impacts

The nature and scale of a 37.5 m^3 MDO/MGO release during refuelling fits well within the expected impact and extent for the MGO/MDO release associated with a vessel collision detailed in **Section 7.1.** Therefore, no further modelling of the 37.5 m^3 is required.

7.2.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- No physical injury to marine fauna during the Activity (EPO-7);
- No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (EPO-3); and
- No unplanned objects, emissions or discharges to sea or air (EPO-6).

The control measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

CM reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-22	General chemical management procedures.	Potential impacts to the environment are reduced through following correct procedures for the safe handling and storage of chemicals.	Personnel costs associated with ensuring procedures are in place and implemented during inspections.	**Adopted** - benefits of ensuring procedures are followed and measures implemented outweigh the costs.
CM-23	Hazardous chemical management procedures.	Reduces the risk of spills and leaks (discharges) of hazardous chemicals to the sea by controlling the storage, handling and clean up.	Cost associated with permanent or temporary storage areas.	**Adopted** - benefits of ensuring procedures are followed and measures implemented outweigh the costs.
CM-30	MARPOL-compliant fuel oil (MDO/MGO) will be used during the Activity.	Use of MDO/MGO reduces the potential impacts to marine environment in the event of unplanned hydrocarbon spills or leaks during bunkering.	Additional personnel costs of ensuring vessels are using the required fuel.	**Adopted** – benefits of ensuring procedures are followed outweighs the minimal costs of personnel time.
CM-35	Oil pollution emergency plan (OPEP).	Implements response plans to deal with an unplanned hydrocarbon release quickly and efficiently in order to reduce impacts to the marine environment.	Administrative costs of preparing documents and large costs of implementing response strategies.	**Adopted** - benefits of ensuring procedures are followed and measures implemented and that the vessel is compliant outweighs the costs.
CM-36	Vessel spill response plans (SOPEP/SMPEP).			
CM-38	Maritime dangerous goods code.	Dangerous goods managed in accordance with International Maritime Dangerous Goods Code (IMDG Code) to reduce the risk of an environmental incident, such as an accidental release to sea or unintended chemical reaction.	Cost associated with implementation of code/procedure.	**Adopted** - benefits of ensuring procedures are followed and measures implemented outweighs the costs.
CM-39	Deck drainage control measures (such as scupper plugs) in areas where chemicals and hydrocarbons are stored and frequently handled.	Reduces potential for hydrocarbon release to the marine environment.	Additional personnel costs of ensuring deck drainage procedures are followed.	**Adopted** - benefits of ensuring vessel is compliant outweighs the minimal costs.
CM-40	Bulk refuelling transfer procedures.	Prevents probability of unplanned hydrocarbon spills or leaks occurring during bunkering leading to negative	Additional personnel costs of ensuring procedures	**Adopted** - benefits of ensuring procedures are followed outweighs the minimal

CM reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		impacts to the marine environment.	in place and followed.	costs of personnel time.
Additional control measures				
N/A	No bunkering in the operational area.	Eliminates the probability of a hydrocarbon spill or leak occurring during bunkering in the operational area.	Cost associated with vessel transits and risk transfer to Health and Safety issues with additional trips to port instead. Would significantly increase the schedule to include multiple trips.	**Not Adopted** – Cost outweighs the environmental benefit.
CM-41	Bunkering drill requirements.	Ensures the controls can be implemented and there is familiarity with the process.	Associated cost with the time spent conducting the drill during mobilisation.	**Adopted** – Benefit of conducting the drill prior to mobilisation outweighs the cost in lost time.

7.2.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Marine fauna – plankton, fish and sharks, marine mammals, marine reptiles
Consequence	A – Negligible

In the event of a minor hydrocarbon spill, the quantities would be limited to approximately 37.5 m^3. The small volumes and dilution and dispersion from natural weathering processes such as ocean currents indicate that the extent of exposure will be limited in area and duration (i.e. 5 km over 6 hours). The number of receptors present at the Activity location is expected to be limited to a small number of transient individuals. No shoreline receptors are expected to be impacted as the nearest shoreline (Bedout Island) is 45 km from the operational area.

The susceptibility of marine fauna to hydrocarbons is dependent on hydrocarbon type and exposure duration however given that exposures would be limited in extent and duration, exposure to marine fauna from this hazard is considered to be low. As the MDO/MGO is a moderately volatile substance, the impacts to receptors will decline rapidly with time and distance at the sea surface. Rapid dilution would also result in the impacts to receptors declining with time and distance.

Deteriorating water quality and marine pollution are identified as potential threats to a number of marine fauna species in relevant Recovery Plans and Approved Conservation Advice (**Table 3-7**).

For marine mammals that may be exposed to the more toxic aromatic components of the MDO/MGO, chemical effects are considered unlikely since these species are mobile and therefore will not be exposed for extended durations that would be required to cause any major toxic effects. Although humpback and pygmy blue whales may be exposed, this event is not expected to interfere with their migration activity.

Toxic impacts are not expected to the benthic community due to the water depths of the operational area (40 m – 250 m).

Near the sea surface, fish are able to detect and avoid contact with surface slicks and as a result, fish mortalities rarely occur in open waters from surface spills (Kennish, 1997; Scholz *et al*., 1992). Pelagic fish species are therefore generally not highly susceptible to impacts from hydrocarbon spills. In offshore waters near to the release point, pelagic fish are at risk of exposure to the more toxic aromatic components of the MDO/MGO. Pelagic fish in offshore waters are highly mobile and comprise species such as tunas, sharks and mackerel. Due to their mobility, it is unlikely that pelagic fish would be exposed to toxic components for long periods in this spill scenario. The more toxic components would also

Description	
rapidly evaporate, and concentrations would significantly diminish with distance from the spill site, limiting the potential area of impact. Adult marine turtles exhibit no avoidance behaviour when they encounter hydrocarbon slicks (Odell and MacMurray 1986). Contact with surface slicks, or entrained hydrocarbons, can therefore result in hydrocarbon adherence to body surfaces (Gagnon and Rawson 2010) causing irritation of mucous membranes in the nose, throat and eyes leading to inflammation and infection (NOAA 2010). Hydrocarbons in surface waters may also impact turtles when they surface to breathe and inhale toxic aromatic components of the MFO/MGO, resulting in damage to their respiratory systems. Impacts to sea snakes from direct contact with surface hydrocarbons are likely to result in similar physical effects to those recorded for marine turtles (ITOPF 2011). It is unlikely that marine reptiles would be exposed to toxic components for long periods, given the more toxic components of MDO/MGO would rapidly evaporate and concentrations would significantly diminish from the spill site, limiting the potential for impact. Given that a small hydrocarbon spill would not result in a decreased population size at a local or regional scale, it is expected that a spill of this nature would result in a **negligible** consequence.	
Likelihood	3 - Unlikely
The likelihood of a small hydrocarbon release occurring is limited given the set of management controls in place for this Activity. The likelihood of a refuelling incident with subsequent release to the marine environment is considered to be unlikely.	
Residual Risk	The residual risk associated with this hazard is Low

7.2.5 ALARP Evaluation

Offshore refuelling is standard industry practice and oil pollution legislation (*Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and MARPOL Annex I) has been developed to safeguard against the risk of a hydrocarbon spill occurring during refuelling. Other hydrocarbon types such as heavy fuel oil (HFO) or intermediate fuel oil (IFO) have specifically not been selected for this Activity (only MDO/MGO will be used in the operational area) to ensure that potential environmental impacts are reduced to ALARP. Alternative and additional controls were considered but not adopted as detailed in **Section 7.2.3.** The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. The proposed control measures are considered appropriate to manage the risk to ALARP.

7.2.6 Acceptability Evaluation

Is the risk ranked between Low to Medium?	Yes – residual risk is ranked Low.
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with *International Convention of the Safety of Life at Sea* (SOLAS) 1974 and *Navigation Act 2012, MARPOL Annex I - Prevention of Pollution from Ships,* and relevant recovery plans (**Table 3-7**).
Are control measures and performance standards consistent with Santos' Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

With the controls in place to prevent refuelling incidents and the minor impacts predicted from a release of MDO/MGO, the risk to the marine environment is considered low.

As described in **Section 3** deteriorating water quality is identified as a potential threat to turtles in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a), and some bird and shark species (**Table 3-7**). Habitat modification/degradation/disruption, pollution and/or loss of habitat are also identified as threats to sharks, birds, cetaceans and turtles in Approved Conservation Advice management and Recovery Plans. However, the volume of MDO/MGO that could occur is not expected to significantly impact the receiving environment and long-term impacts resulting in complete habitat loss or degradation are not considered likely given the controls proposed to prevent releases. The Activity will therefore be conducted in a manner that is considered acceptable.

In accordance with Santos' risk assessment process, the residual risk is considered to be tolerable and therefore acceptable.

7.3 Spill Response Operations

7.3.1 Description of Event

<table>
<tr><th colspan="2">Spill Response Operations</th></tr>
<tr><td>Aspect</td><td>In the event of a hydrocarbon spill, response strategies will be implemented where possible to reduce environmental impacts to ALARP. The selection of strategies will be undertaken through the Net Environmental Benefit Analysis (NEBA) process, outlined in Section 6.1 of the OPEP. Spill response will be under the direction of the relevant Control Agency, as defined within the OPEP (Section 2.2). The response strategies and supporting activities deemed appropriate for the worst-case oil spill scenarios identified for the Activity are detailed in Table 3-5 and Sections 7 to 13 of the OPEP, and comprise:
• Source control;
• Operational monitoring;
• Mechanical dispersion;
• Shoreline protection and deflection;
• Shoreline clean-up;
• Oiled wildlife response;
• Scientific monitoring; and
• Waste management.
While response strategies are intended to reduce the environmental consequences of a hydrocarbon spill, poorly planned and coordinated response activities can result in a lack of, or inadequate, information being available upon which poor decisions can be made, exacerbating or causing further environmental harm. An inadequate level of training and guidance during the implementation of spill response strategies can also result in environmental harm over and above that already caused by the spill.
Hydrocarbon response operations will be within offshore and inshore waters using vessels, aircraft, and personnel. Offshore impacts are consistent with vessel and aircraft operations described within this EP for the routine operations. The greatest potential for impacts additional to those described for routine operations are from oiled wildlife response, nearshore protection and deflection and shoreline clean-up operations where disturbance to the environment may occur through intentional response strategy implementation.</td></tr>
<tr><td>Extent</td><td>Extent of the hydrocarbon release.</td></tr>
<tr><td>Duration</td><td>As required.</td></tr>
</table>

7.3.2 Details of the Environmental Impacts and Risks for the Activities

<table>
<tr><th colspan="2">Light emissions</th></tr>
<tr><td colspan="2">Spill response activities will involve the use of vessels which are required at a minimum, to display navigational lighting. Vessels may operate in close proximity to shoreline areas during spill response activities.
Onshore operations are only expected for the worst-case scenario and only under specific metocean conditions. The onshore response if required is expected to be confined to isolated areas/beaches and a shoreline response will only occur during daylight hours A significant onshore response is not envisaged to clean up these volumes. However, spill response activities may involve onshore operations including the use of vehicles and temporary camps which may require lighting.</td></tr>
<tr><td>Potential receptors:</td><td>Fauna (including Threatened/ Migratory/ Local Fauna)
Protected Areas
Socio-Economic Receptors</td></tr>
<tr><td colspan="2">Lighting may cause behavioural changes to fish (including sharks), birds and marine turtles which can have a heightened consequence during key life-cycle activities, for example turtle nesting and hatching. Turtles and birds, which includes threatened and migratory fauna, have been identified as key fauna susceptible to lighting impacts. Refer to Section 6.4 for further detail on the impacts of light to fish, birds and marine turtles.
Spill response activities which require lighting may take place in protected areas in open ocean and shorelines through response strategy implementation. Environmental values and sensitivities potentially impacted by light from response strategy implementation, including BIA's for turtles and birds have been identified in Section 3.2.
However, given the scale of the response any impacts are expected to be short term, geographically confined and minor. Given that shoreline operations will only be conducted in daytime hours and light impacts would be considered when sighting any shoreline camps. Additionally, light impacts would be considered in the operational NEBA process.</td></tr>
<tr><th colspan="2">Noise emissions</th></tr>
<tr><td colspan="2">Spill response activities will involve the use of aircraft and vessels which will generate noise both offshore and in proximity to sensitive receptors in coastal areas.
Spill response activities will also involve the use of equipment on coastal areas during clean-up of shorelines (e.g. pumps and vehicles), for accessing shoreline areas (e.g. vehicles) and for supporting temporary camps (e.g. diesel generators).</td></tr>
<tr><td>Potential receptors:</td><td>Fauna (including Threatened/ Migratory/ Local Fauna)
Protected Areas
Socio-Economic Receptors</td></tr>
<tr><td colspan="2">Underwater noise from the use of vessels may impact marine fauna, such as fish (including commercial species), marine reptiles and marine mammals, in the worst instance causing physical injury to hearing organs, but more likely causing short term behavioural changes, e.g. temporary avoidance of the area, which may impact key life-cycle process (e.g. spawning, breeding, calving). Underwater noise can also mask communication or echolocation used by cetaceans. Refer to Section 6.2.3 for further detail on the environmental impact of noise attributed to vessel operations.
Cetaceans have been identified as the key concern for vessel noise associated with response strategy implementation, with the humpback and pygmy blue whale migration and distribution BIAs within the spill EMBA. Spill response activities using vessels have the potential to impact fauna in protected areas further described in Section 7.6.
Noise and vibration from terrestrial activities on shorelines has the potential to cause behavioural disturbance to coastal fauna including protected seabirds and turtles. Shoreline activities involving the use of noise generating equipment may take place in important nesting areas for turtles and/or roosting/feeding areas for shorebirds.
As a consequence of impacts to fauna (including shorebirds, marine mammals and fish), noise has the potential to impact supported industries such as tourism and commercial fishing.</td></tr>
<tr><th colspan="2">Atmospheric emissions</th></tr>
</table>

The use of fuels to power vessel engines, generators and mobile equipment used during spill response activities will result in emissions of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), along with non-GHG such as sulphur oxides (SO_x) and nitrous nitrogen oxides (NO_x). Emissions will result in localised decrease in air quality.	
Potential receptors:	Physical Environment/habitat Fauna (including Threatened/ Migratory/ Local Fauna) Protected Areas
Atmospheric emissions from spill response equipment will be localised and while there is potential for fauna and flora impacts, the use of mobile equipment, vessels and vehicles is not considered to create emissions on a scale where noticeable impacts would be predicted. Emissions may occur in protected areas, however, the scale of the impact relative to potential oil spill impacts is not considered great.	
Operational discharges and waste	
Operational discharges include those routine discharges from vessels used during spill response which may include: • Bilge water; • Deck drainage; • Putrescible waste and sewage; • Cooling water from operation of engines; and • Desalination plant effluent (brine) and backwash water discharge. In addition, there are specific spill response discharges and waste creation that may occur, including: • Cleaning of oily equipment/vessels and vehicles; • Flushing water for the cleaning of shoreline habitats; • Sewage/putrescible and municipal waste at camp areas; and • Creation, storage and transport of oily waste and contaminated organics.	
Potential receptors:	Fauna (including Threatened/ Migratory/ Local Fauna) Physical Environment/habitat Protected Areas Socio-Economic Receptors
Operational discharges from vessels may create a localised and temporary reduction in marine water quality. Effects include nutrient enrichment, toxicity, turbidity, temperature and salinity increases, as detailed in **Section 6.5**. Sensitive receptors potentially impacted are likely to be different to those described in **Section 6.5** given vessel use is likely to occur in shallower coastal waters during spill response activities. Discharge could potentially occur adjacent to marine habitats such as corals, seagrass, macroalgae, and in protected areas (i.e. receptors anywhere within the EMBA), which support a more diverse faunal community. Discharges are expected to be very localised and temporary. Cleaning of oil contaminated equipment, vehicles and vessels, has the potential to spread oil from contaminated areas to those areas not impacted by a spill, potentially spreading the impact area and moving oil into a more sensitive environment. Flushing of oil from shoreline habitats is a clean-up technique designed to remove oil from the receptor that has been oiled and remobilise back into the marine environment and result in further dispersion of the oil. The process of flushing has the potential to physically damage shoreline receptors such as mangroves and rocky shoreline communities, increase levels of erosion, and create an additional, and potentially higher, level of impact than if the habitat was left to bio-remediate. Sewage, putrescible and municipal waste will be generated from onshore activities at temporary camps which may include toilet and washing facilities. These wastes have the potential to attract fauna, impact habitats, flora and fauna and reduce the aesthetic value of the environment, which may be within protected areas. The creation, storage and transport of oily waste and contaminated organics has the potential to spread impacts of oil to areas, habitats and fauna not previously contaminated.	
Physical presence and disturbance	

The movement and operation of vessels, including anchoring and operating in the nearshore environment has potential to cause disturbance to the marine environment. Vehicles, personnel and equipment associated with response strategy implementation, have the potential to disturb the physical environment and marine/coastal habitats and fauna, which may include those habitats and fauna within protected areas. Disturbance may also impact cultural values of an area. The movement of vessels could potentially introduce invasive marine species attached as biofouling to nearshore areas, while vehicle and equipment movement could spread non-indigenous flora and fauna. Oiled wildlife response activities may involve deliberate disturbance (hazing), capture, handling, cleaning, rehabilitation and release of wildlife which could lead to additional impacts to wildlife.	
Potential receptors:	Fauna (including Threatened/ Migratory/ Local Fauna) Physical Environment/habitat Protected Areas Socio-Economic Receptors
The use of vessels may disturb benthic habitats in coastal waters including corals, seagrass, macroalgae and mangroves. Impacts to habitats from vessels include damage through the deployment of anchor/chain, nearshore booms and grounding. Vessel use in shallow coastal waters also increases the chance of contact or physical disturbance with marine megafauna such as turtles and dugongs. Booms create a physical barrier on the surface waters that has the potential to injure or entangle passing marine fauna that are either surface breathing or feeding. Vehicles, equipment, personnel used and cleaning activities during shoreline response activities have the potential to damage coastal habitats such as dune vegetation, mangroves and habitats important to threatened and migratory fauna including nests of turtles and birds and bird roosting/feeding areas. Shoreline clean-up may involve the physical removal of substrates that could cause impact to habitats and coastal hydrodynamics and alter erosion/accretion rates. The presence of camp areas, although relatively short-term, may disrupt normal behaviour of coastal species such as shorebirds and turtles, and could potentially interfere with nesting and feeding behaviours. Oiled wildlife response may include the hazing, capture, handling, transportation, cleaning and release of wildlife susceptible to oiling such as birds and marine turtles. While oiled wildlife response is aimed at having a net benefit, poor responses can potentially create additional stress and exacerbate impacts from oiling, interfering with life-cycle processes, hampering recovery and in the worst instance increasing levels of mortality. Impacts from invasive marine species released from vessel biofouling include out-competition, predation and interference with other ecosystem processes. The ability for a non-native species to establish is generally mitigated in deeper offshore waters where the depth, temperature, light availability and habitat diversity is not generally conducive to supporting reproduction and persistence of the invasive species. However, in shallow coastal areas, such as areas where vessel-based spill response activities may take place, conditions are likely to be more favourable. Impacts from invasive terrestrial species are similar in that the invasive species can out-compete local species (e.g. weeds) and interfere with ecosystem processes. Non-native species may be transported attached to equipment, vehicles and clothing. Such an introduction would be especially detrimental to wilderness areas or protected terrestrial reserves which may have a relatively undisturbed flora and fauna community. The disturbance to marine and coastal natural habitat, as well as the potential for disruption to culturally sensitive areas, which may occur in specially protected areas, may have flow on impacts to socio-economic values and industry (e.g. tourism, fisheries).	
Disruption to other users of marine and coastal areas and townships	
Spill response activities may involve the use of vessels, equipment and vehicles, and the establishment of temporary camps, in areas used by the general public or industry. The mobilisation of spill response personnel into an affected area may also place increased demands on local accommodation and other businesses.	
Potential receptors:	Socio-Economic Receptors
The use of vessels in the nearshore and offshore environment and the undertaking of spill response activities at shoreline locations may exclude the general public and industry use of the affected environment. As well as impacting leisure activities of the general public, this may impact on revenue with respect to industries such as	

tourism and commercial fishing. The mobilisation of personnel to small communities has the potential to affect the local community through demands on local accommodation and business, reducing the availability of services to members of the public.

7.3.3 Environmental Performance and Control Measures – Spill Response Operations

For EPOs, EPS and Measurement Criteria relating to spill response in the event of a spill during this Activity, refer to Section 16 of the OPEP.

Control measures considered for this Activity are provided below.

Control measure	Environmental benefit	Evaluation
Competent Incident Management Team (IMT) and Oil Spill Responder personnel	Ensures that spill response strategy selection and operational activities consider the potential for additional environmental impacts	**Adopt -** Considered a standard spill response control
Use of competent vessel crew/personnel	Reduces potential for environmental impacts from vessel usage	**Adopt -** Considered a standard spill response control
Spill response activities selected on basis of a Net Environmental Benefit Analysis (NEBA)	Provides a systematic and repeatable process for evaluating strategies with net least environmental impact	**Adopt -** Considered a standard spill response control
Noise and atmospheric emissions		
Vessels and aircraft compliant with Santos' *Protected Marine Fauna Interaction and Sighting Procedure* (EA-91-11-00003)	Reduces potential for behavioural disturbance to cetaceans	**Adopt -** Considered a standard spill response control (regulatory requirement)
If required under MARPOL, vessels will maintain a current International Air Pollution Prevention (IAPP) Certificate.	Reduces level of air quality impacts	**Adopt -** Considered a standard spill response control (regulatory requirement)
Operational discharges and waste		
Vessels meet applicable MARPOL sewage disposal requirements as appropriate for vessel class	Reduces potential for water quality impacts	**Adopt -** Considered a standard spill response control (regulatory requirement)
Vessels meet applicable MARPOL requirements for oily water (bilge) discharges as appropriate for vessel class	Reduces potential for water quality impacts	**Adopt-** Considered a standard spill response control (regulatory requirement)
Ballast water management plan for international vessels	Improves water quality discharge to marine environment to ALARP Reduces risk of introduced marine species	**Adopt -** Considered a standard spill response control (regulatory requirement)
Compliance with controlled waste, unauthorised discharge and landfill regulations	Ensures correct handling and disposal of oily wastes	**Adopt -** Considered a standard control (regulatory requirement)
Physical presence and disturbance		
Vessels and aircraft compliant with Santos' *Protected Marine Fauna Interaction and Sighting Procedure* (EA-91-11-00003)	Reduces potential for behavioural disturbance to cetaceans	**Adopt -** Considered a standard spill response control (regulatory requirement)

Control measure	Environmental benefit	Evaluation
DPIRD vessel check tool applied to all spill response vessels on basis of the outcome of a Net Environmental Benefit Analysis (NEBA)	Reduces risk for introduction of invasive marine species as part of vessel biofouling	**Adopt -** Adopting this control meets industry standards and provides a tool to identify and manage the potential risk
Use of shallow draft vessels for shoreline and nearshore operations	Reduces seabed and shoreline disturbance	**Adopt -** Considered a standard control
Oil Spill Response Team (OSRT) Team Leader assessment/selection of vehicle appropriate to shoreline conditions	Reduces coastal habitat and fauna disturbance	**Adopt -** Considered a standard control
Conduct shoreline/nearshore habitat/bathymetry assessment	Reduces shoreline habitat disturbance	**Adopt -** Considered a standard control
Establish demarcation zones for vehicle and personnel movement considering sensitive vegetation, bird nesting/roosting areas and turtle nesting habitat	Reduces coastal habitat and fauna disturbance	**Adopt -** Considered a standard control
Operational restriction of vehicle and personnel movement to limit erosion and compaction	Reduces coastal habitat erosion and compactions	**Adopt -** Considered a standard control
Prioritise use of existing roads and tracks	Reduces coastal habitat and fauna disturbance	**Adopt -** Considered a standard control
Soil profile assessment prior to earthworks	Reduce habitat disruption and erosion	**Adopt -** Considered a standard control
Pre-cleaning and inspection of equipment (quarantine)	Prevent introduction of invasive species	**Adopt -** Considered a standard control
Use of Heritage Adviser if spill response activities overlap with potential areas of cultural significance	Reduces disturbance to culturally significant sites	**Adopt -** Considered a standard control to be adopted by the relevant Controlling Agency
Adhere to WA Oiled Wildlife Response Plan (WAOWRP) and Pilbara Regional Oiled Wildlife Response Plan (PROWRP)	Oiled wildlife hazing, capture, handling and rehabilitation meet minimum standards as outlined within the WA Oiled Wildlife Response Plan	**Adopt -** Considered a standard control to be adopted by the relevant Controlling Agency

Control measure	Environmental benefit	Evaluation
Use existing moorings or anchor locations where possible or available	Reduces seabed disturbance from anchoring operations	**Adopt -** Considered a standard control
Boom will be monitored and maintained to ensure trapped fauna are released as early as possible	Reduces fauna disturbance from nearshore protection and deflection activities	**Adopt -** Considered a standard control
Disruption to other users of marine and coastal area and townships		
Stakeholder consultation	Early awareness of spill response activities which reduces potential disruption	**Adopt -** Considered a standard control
Accommodation assessment	Reduces strain on accommodation	**Adopt -** Considered a standard control
Security Management Plan	Reduces potential for security threat causing disruptions in the response activities	**Adopt -** Considered a standard control for large scale deployment in areas with potential security risk
Transport Management Plan	Reduces potential for traffic disruptions	**Adopt -** Considered a standard control for large scale deployment in highly populated areas

7.3.4 Impact and Consequence Ranking

Light emissions	
Potential receptors	Fauna (including Threatened/ Migratory/ Local Fauna): Seabirds, shorebirds and turtles Protected Areas Socio-Economic Receptors.
Consequence ranking	Fauna (including Threatened/ Migratory/ Local Fauna): *A (Negligible) – Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of Habitat Critical / disruption to the breeding cycle / introduction of disease.* Protected areas: *A (Negligible) – No or negligible impact on protected area values. No decline of species population within a protected area. No or negligible alteration, modification, obscuring or diminishing of protected area values.* Socio-economic receptors*: A (Negligible) – no or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the Activity*
The receptors considered most sensitive to lighting from vessel and shoreline operations (in event of shoreline clean-up operations) are seabirds and marine turtles, particularly over spring/summer months with respect to marine turtles where emerging hatchlings are sensitive to light spill onto beaches. Following restrictions on night-time operations by spill response vessels, which will demobilise to mooring areas offshore with safety lighting only, impacts from vessels are considered to be *Negligible*. The positioning of temporary camps will be done at the direction of Town of Port Hedland/DoT/ DBCA and following control measures on lighting colour and direction the consequence of shoreline lighting is considered *Negligible*. These species are likely to be values of the protected areas in which they occur (e.g. Eighty Mile Beach), and the impact to the protected area from light is also considered *Negligible.* As a consequence of impacts to fauna, lighting has the potential to impact supported industries such as tourism however as impacts to fauna are considered negligible any indirect impacts on tourism will also be *Negligible*.	
Noise	
Potential receptors	Fauna (including Threatened/ Migratory Fauna): Marine mammals (particularly humpback whales), seabirds and shorebirds Protected Areas Socio-Economic Receptors
Consequence ranking	Fauna (including Threatened/ Migratory/ Local Fauna): *A (Negligible) – Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of Habitat Critical / disruption to the breeding cycle / introduction of disease.* Protected areas: *A (Negligible) – No or negligible impact on protected area values. No decline of species population within a protected area. No or negligible alteration, modification, obscuring or diminishing of protected area values.* Socio-economic receptors*: A (Negligible) – no or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the Activity.*
Receptors considered most sensitive to vessel noise disturbance are populations of humpback whales and pygmy blue whales during migration season. A temporary behavioural disturbance is expected only with a consequence of *Negligible.* With respect to noise from onshore operations (mobile equipment and vehicles), nesting, roosting or feeding birds are considered to be the most sensitive to noise. The equipment used is not considered to have excessive sound levels and following direction by DoT and DBCA on the location of temporary camp areas, the consequence to birds from noise is expected to be *Negligible*. As a consequence of impacts to fauna, noise has the potential to impact supported industries such as tourism and commercial fishing however as impacts to fauna are considered negligible any indirect impacts on socio-economic receptors will also be *Negligible*.	

Atmospheric emissions	
Potential receptors	Physical environment/habitat: Air quality Fauna (including Threatened/ Migratory Fauna): seabirds and shorebirds Protected Areas
Consequence ranking	Physical environment/habitat: *A (Negligible) – No or negligible reduction in habitat area/function.* Fauna (including Threatened/ Migratory/ Local Fauna): *A (Negligible) – Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of Habitat Critical / disruption to the breeding cycle / introduction of disease.* Protected areas: *A (Negligible) – No or negligible impact on protected area values. No decline of species population within a protected area. No or negligible alteration, modification, obscuring or diminishing of protected area values.*
Atmospheric emissions from spill response equipment will be localised and impacts to even the most sensitive fauna, such as birds, are expected to be *Negligible*. Because of the localised and low level of emissions, impacts to protected area values and the physical environment are predicted to be *Negligible.*	
Operational discharges and waste	
Potential receptors	Physical environment/habitat: Coastal vegetation, intertidal and shallow habitats (corals, mangroves, seagrass, macroalgae) Fauna (including Threatened/ Migratory/ Local Fauna): Fish, marine reptiles, marine mammals, seabirds and shorebirds Protected areas Socio-Economic Receptors
Consequence ranking (planned operational discharges)	Physical environment/habitat: *A (Negligible) – No or negligible reduction in habitat area/function.* Fauna (including Threatened/ Migratory/ Local Fauna): *1 (Negligible) – Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of Habitat Critical / disruption to the breeding cycle / introduction of disease.* Protected areas: *A (Negligible) – No or negligible impact on protected area values. No decline of species population within a protected area. No or negligible alteration, modification, obscuring or diminishing of protected area values.* Socio-economic receptors*: A (Negligible) – no or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the Activity.*
Operational discharges from vessels may create a localised and temporary reduction in marine water quality, which has the potential to impact shallow coastal habitats in particular, however, following the adoption of regulatory requirements for vessel discharges, which prevent discharges close to shorelines, discharges will have a *Negligible* impact to habitats, fauna or protected area values. Furthermore, washing of vessels and equipment will take place only in defined offshore hot zones preventing impacts to shallow coastal habitats. As a consequence of impacts to fauna, operational discharges from vessels has the potential to impact supported industries such as tourism and commercial fishing however as impacts to fauna are considered negligible any indirect impacts on socio-economic receptors will also be *Negligible*. Onshore, the use of flushing water has the potential to damage sensitive shoreline and intertidal habitats, e.g. mangroves, however, low pressure flushing only will be used, preventing further damage to habitats or erosion of sediments. For sensitive habitats the deployment of booms will be considered to retain flushed hydrocarbons, if this presents a net benefit. Following these control measures the use of flushing to clean shorelines and intertidal habitats is seen to have a *Negligible* additional impact to habitats, fauna or protected area values. The cleaning of contaminated vehicles and equipment onshore has the potential to spread oily waste and damage habitats if not contained. Decontamination units will be in use during the spill response thus containing waste and preventing any secondary contamination. The consequence of cleaning discharges is therefore ranked as *Negligible* in terms of impacts to habitats, fauna or protected area values. Sewage, putrescible and municipal waste generated onshore will be stored and disposed of at approved locations.	

<table>
<tr><th colspan="2">Physical presence and disturbance</th></tr>
<tr><td>Potential receptors</td><td>Fauna (including Threatened/ Migratory/ Local Fauna): Nesting and hatching turtles, nesting, roosting and feeding shorebirds/seabirds
Protected Areas
Physical environment/habitat: coastal vegetation, turtle nesting beaches, shorebird/seabird nesting, roosting and feeding areas, intertidal and shallow habitats (corals, mangroves, seagrass, macroalgae)
Socio-Economic Receptors</td></tr>
<tr><td>Consequence ranking (physical presence and disturbance)</td><td>Fauna (including Threatened/ Migratory Fauna): B (Minor) – Detectable, but insignificant, decrease in local population size. Insignificant reduction in area of occupancy of species. Insignificant loss/disruption of Habitat Critical to survival of a species. Insignificant disruption to the breeding cycle of local population
Protected Areas: B (Minor) – Detectable but insignificant impact to on one or more of protected areas values.
Physical environment/habitat: B (Minor) – Detectable but localised and insignificant loss of area/function of habitat. Rapid recovery evident within ~1 year (seasonal recovery).
Socio-economic receptors: B (Minor) – Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.</td></tr>
<tr><td colspan="2">The use of vessels and nearshore booms has the potential to disturb benthic habitats including sensitive habitats in coastal waters such as corals, seagrass, macroalgae and mangroves. A review of shoreline and shallow water habitats, and bathymetry, utilising existing moorings and the establishment of demarcated areas for access and anchoring will reduce the level of impact to Negligible.
The use and movement of vehicles, equipment and personnel during shoreline response activities has the potential to disturb coastal habitats such as dune vegetation, samphire and mangroves, and important habitats of threatened and migratory fauna including nests of turtles and birds and bird roosting areas. Furthermore, clean-up can involve physical removal of substrates that could cause impact habitats, fauna and alter coastal hydrodynamics.
As with vessel use, an assessment of appropriate vehicles and equipment to reduce habitat damage, along with the establishment of access routes/demarcation zones, and operational restrictions on equipment/vehicles use will limit sensitive habitat damage and damage to important fauna areas. The establishment of temporary camp areas will be done under direction of Town of Port Hedland, DoT and DBCA with suitable advice sought if access is needed to culturally significant areas. Following these and other control measures the resultant consequence to the physical environment and habitat is assessed as Minor, indicating that there may be a detectable reduction in habitat area from response activities (as separate from spill impacts), but recovery will be relatively rapid, once spill response activities cease. As with all spill response activities, this disturbance will only occur if there is a net benefit to accessing and cleaning shoreline areas.
The main direct disturbance to fauna would be the hazing, capture, handling, transportation, cleaning and release of wildlife susceptible to oiling impacts, such as birds and marine turtles. This would only be done if this intervention were to deliver a net benefit to the species but may result in a Minor consequence following compliance with the WA Oiled Wildlife Response Plan and the Pilbara Region Oiled Wildlife Response Plan.
These habitats/environments are likely to be values of the protected area they occur in, and the impact to the protected area from physical disturbance is also considered Minor.
The disturbance to marine and coastal natural habitat, as well as the potential for disruption to culturally sensitive areas, which may occur in specially protected areas, may have flow on impacts to socio-economic values and industry (e.g. tourism, fisheries). This impact is considered Minor.</td></tr>
<tr><th colspan="2">Disruption to other users of marine and coastal areas and townships:</th></tr>
<tr><td>Potential receptors</td><td>Socio-Economic Receptors: Fisheries, Fisheries and Aquaculture, Tourism</td></tr>
<tr><td>Consequence ranking</td><td>B (Minor) - Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.</td></tr>
</table>

The use of vessels in the nearshore and offshore environment and spill response activities at shoreline locations/close to townships, may exclude general public and industry use. It should be noted that this is distinct from the socio-economic impact of a spill itself which would have a far greater detrimental impact to industry and recreation. Following the application of control measures, it is considered that the additional impact of spill response activities on affected industries would be *Minor*.	
Likelihood	3 - Unlikely
The likelihood of spill response being required is limited given the set of management controls in place for this Activity. The likelihood of spill response being required is considered to be unlikely.	
Residual Risk	The residual risk associated with this hazard is Low

7.3.5 ALARP Evaluation

A Net Environmental Benefit Analysis (NEBA) is the primary tool used during spill response to evaluate response strategies with the goal of selecting strategies that results in the least net impact to key environmental sensitivities. The NEBA process will identify and compare net environmental benefits of alternative spill response options. The NEBA will effectively determine whether an environmental benefit will be achieved through implementing a response strategy compared to undertaking no response. NEBA will be undertaken by the relevant Control Agency for the Activity. For those activities under the control of Santos, the Incident Management Team (IMT) Environmental Team Leader will be responsible for reviewing the priority receptors and selected response strategies identified within this EP and coordinating the NEBA for each operational period. This will ensure that at the strategy level, the response operations reduce additional environmental impacts to ALARP.

Spill response activities will be conducted in offshore and coastal waters using vessels and aircraft. The greatest potential for additional impacts from implementing spill response is considered to be to wildlife in offshore waters from oiled wildlife response activities, and shoreline habitats and fauna receptors within shallow waters or on shorelines from nearshore booming and shoreline clean-up activities.

Given the types of activities considered appropriate to responding to a worse-case spill and the scale of operations, standard control measures adopted by Santos for spill response to reduce the level of additional impacts are considered to reduce these impacts to ALARP. This includes working with the relevant Control Agency for spill response and applying the process and standards e.g. for oiled wildlife response as included within the WA Oiled Wildlife Response Plan and Pilbara Regional Oiled Wildlife Response Plan.

Santos considers the actions prescribed in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) and Approved Conservation Advice for other threatened fauna (**Table 3-7**) relevant to spill responses for the activities to minimise noise and light impacts on marine cetaceans, fish and marine turtles. The proposed Activity will not result in significant impacts on these species and implementation of identified control measures is in line with the relevant Conservation Advice and Recovery Plans. Pollution events (such as hydrocarbon spills) could impact on fauna (as described in **Section 7.1**), and the use of vessels and equipment during the spill response could result in potential impacts as described within this EP. Control measures in place for vessel and helicopter use will reduce potential impacts to marine fauna and these are consistent with current conservation advice. The assessed residual consequence for this impact is minor and cannot be reduced further without disproportionate costs. It is considered therefore that the impact of the activities conducted are ALARP.

7.3.6 Acceptability Evaluation

Is the consequence ranked as A (Negligible) or B (Minor)?	Yes – Maximum consequence is a B (Minor) from planned events and maximum risk is Medium.
Is further information required to support or validate the consequence assessment?	No – Potential impacts and risks are well understood through the information available.

Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – management is consistent with industry standards and regulatory requirements
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised. During any spill response, a close working relationship with relevant regulatory bodies (e.g. DoT, DBCA, and AMSA) will occur and thus there will be ongoing consultation with relevant stakeholders on the acceptability of response operations. Wildlife response will be conducted in accordance with the WA Oiled Wildlife Response Plan (WA OWRP) and Pilbara Regional Oiled Wildlife Response Plan.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes – see ALARP evaluation above.

7.4 Hazardous and Non-Hazardous Unplanned Discharges – Liquid

7.4.1 Description of Event

Hazardous and non-hazardous (liquid) release to the marine environment	
Event	Hazardous liquids, including miscellaneous chemicals and waste streams (cleaning and cooling agents, stored or spent chemicals and leftover paint materials), are used or stored on board the vessel during the Activity. The main engines and equipment such as pumps, cranes, winches, power packs and generators require MDO/MGO for fuel and a variety of hydraulic fluids and lubricating oils for efficient operation and maintenance of moving parts. These products are present within the equipment and also held in storage containers and tanks on the vessels. Small hydrocarbon leaks could occur, and potential impacts are covered under **Section 7.2**, chemical leaks are discussed further in this section. Outside the vessel, the largest credible spill would be a release of <1 m^3 of stern tube oil (non-hydrocarbon-based lube oil) from the vessel thruster/propeller stern tube. Accidental loss of liquid wastes to the marine environment could occur via tank pipework failure or rupture, inadequate bunding and/or storage, insufficient fastening or inadequate handling leading to dropped objects, which may result in impacts to water quality and hence sensitive environmental receptors. The seismic streamers that will be used for the survey are gel-filled, which has the characteristics of a ‘flexible’ solid and will not flow into the marine environment if the streamer skin is punctured. Therefore, there is no possibility of a loss of liquid from the in-water seismic equipment.
Extent	The maximum volume of hazardous chemical that could be released during routine operations is likely to be small and limited to the volume of individual containers (e.g. drums etc.) stored on-deck. The most credible worst-case spill scenario on-board is considered to be release from an on-deck hydraulic hose (loss of ~200 L), however the worst case overall is <1 m^3 of stern tube oil. In the event that the spill is not contained on deck, there would be a release to the marine environment, which would be likely to rapidly disperse and evaporate.
Duration	Instantaneous release during the Activity.

7.4.2 Nature and Scale of Environmental Impacts

Potential receptors: Fish, Sharks, Marine Mammals, Marine Reptiles and Seabirds

Environmentally hazardous chemicals and liquid wastes (hazardous/ non-hazardous liquids) lost to the marine environment from a vessel may lead to contamination of the water column in the vicinity of the vessel.

The potential impacts would be highly localised and restricted to the immediate area surrounding the spill, with rapid dispersal to concentrations below impact thresholds likely to occur in the open area of ocean (high energy environment that facilitates rapid dispersion and dilution to non-toxic concentrations). This is unlikely to lead to widespread ecological effects.

The changes to water quality that may result could potentially lead to short-term impacts on marine fauna (e.g. pelagic/benthic fish, epifauna, marine mammals, marine reptiles and seabirds), with chronic impacts not expected due to the short exposure times likely.

There are no emergent or inter-tidal habitats within the operational area that could be impacted by the release of hazardous and non-hazardous liquids. Impacts from the release of hazardous and non-hazardous liquids are unlikely to reach any of the demersal species or benthic habitats at the seabed. Sub-lethal or lethal effects from toxic hazardous/ non-hazardous liquids on marine fauna, is considered unlikely given the expected low concentrations and short exposure times.

7.4.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- No physical injury to marine fauna during the Activity (EPO-7);
- No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (EPO-3); and
- No unplanned objects, emissions or discharges to sea or air (EPO-6).

The control measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-22	General chemical management procedures.	Potential impacts to the environment are reduced through following correct procedures for the safe handling and storage of chemicals, including requirements of MARPOL Annex III and Marine Orders 94 as appropriate for vessel class.	Personnel costs associated with ensuring procedures are in place and implemented during inspections.	**Adopted -** benefits of ensuring procedures are followed and measures implemented outweigh the costs.
CM-23	Hazardous chemical management procedures.	Reduces the risk of spills and leaks (discharges) to the sea by controlling the storage, handling and clean-up of hazardous chemicals.	Cost associated with permanent or temporary storage areas.	**Adopted -** benefits of ensuring procedures are followed and measures implemented outweighs the costs.
CM-36	Vessel spill response plans (SOPEP/ Shipboard Marine Pollution Emergency Plan (SMPEP)).	Implements response plans to deal with an unplanned release quickly and efficiently in order to reduce impacts to the marine environment.	Administrative costs of preparing documents and large costs of implementing response strategies.	**Adopted -** benefits of ensuring procedures are followed and measures implemented and that the vessel is compliant outweighs the costs.
CM-38	Maritime dangerous goods code.	Dangerous goods managed in accordance with International Maritime Dangerous Goods Code (IMDG Code) to reduce the risk of an environmental incident, such as an accidental release to sea or unintended chemical reaction	Cost associated with implementation of code/procedure.	**Adopted -** benefits of ensuring procedures are followed and measures implemented outweighs the costs.
CM-42	Dropped object prevention procedure.	Minimises dropped object risk during vessel lifting operations that may cause secondary spill (discharges) resulting in reduction in water quality.	Cost to maintain lifting equipment and implement procedure.	**Adopted -** benefits of ensuring procedures are followed and measures implemented outweighs the costs.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-43	Equipment maintenance in accordance with PMS.	Ensures that lifting equipment is maintained and certified, and that lifting procedures are followed reducing probability of dropped objects occurring with the potential to result in hazardous/ non-hazardous liquids release.	Additional personnel costs of ensuring equipment is maintained and certified as appropriate and that procedures in place and followed.	**Adopted -** benefits of ensuring procedures are followed and equipment is compliant outweighs the minimal costs of personnel time.

7.4.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Marine fauna – Fish, sharks, marine mammals, marine reptiles, seabirds.
Consequence	A - Negligible
In the event of a hazardous/ non-hazardous liquid spill, the worst-case quantity would be limited to <1 m^3 of stern tube oil. The small volumes, dilution and dispersion from natural weathering processes such as ocean currents indicate that the extent of exposure will be limited in area and duration. The susceptibility of marine fauna to hazardous/ non-hazardous liquids is dependent on the type and exposure duration. Given that exposures would be limited in extent and duration, exposure to marine fauna from this hazard is not expected to result in a fatality. Potential impacts from small volumes (<1 m^3) of hazardous/non-hazardous liquids on water quality would be short-term and localised, due to the nature and behaviour of the hazardous/ non-hazardous liquids. Pelagic fauna present in the immediate vicinity of the spill would most likely be at risk. Deteriorating water quality and marine pollution are identified as potential threats to a number of marine fauna species in relevant Recovery Plans and Conservation Advice (**Table 3-7**). However, the potential release of hazardous/ non-hazardous liquids is not expected to significantly impact the receiving environment. Through the management controls proposed to prevent releases, the Activity will be conducted in a manner that is considered acceptable. Given that a small spill (<1m^3) of hazardous/ non-hazardous liquids would not result in a decreased population size at a local or regional scale, it is expected that a spill of this nature would result in a **negligible** consequence.	
Likelihood	2 – Very Unlikely
A small liquid release is unlikely to have widespread ecological effects given the nature of the chemicals on-board, the small volumes that could be released, the water depth, transient nature of marine fauna in this area and the prevention and management procedures in place to clean up a spill. Santos records indicate that although spills and leaks from equipment and machinery (due to split hoses, small leaks, or handling errors) have occurred, most of the spills and leaks reported occurred within bunded areas, were all less than 100 L and cleaned up immediately and therefore did not reach the marine environment. The likelihood of a small hazardous/ non-hazardous liquid release occurring is limited given the mitigation and management controls in place for this Activity. Consequently, the likelihood of releasing hazardous/ non-hazardous liquids to the environment which results in a negligible consequence is considered to be **unlikely**.	
Residual Risk	The residual risk associated with this hazard is **Low**

7.4.5 ALARP Evaluation

Hazardous/ non-hazardous liquids are required to operate the vessels and carry out the Activity or may be a resultant waste of the Activity/ vessel operation, so their removal is not viable. No beneficial additional controls were identified to further reduce the risk of this hazard. The management and mitigation controls outlined reduce the risk to a level considered ALARP by Santos.

7.4.6 Acceptability Evaluation

Is the risk ranked between Low to Medium?	Yes – maximum hazardous/ non-hazardous liquid release residual risk is ranked Low.
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with *MARPOL Annex III - Prevention of Pollution by Harmful Substances, International Maritime Dangerous Goods Code,* and relevant Recovery Plans and Approved Conservation Advice (**Table 3-7**).

Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

With the controls in place to prevent an accidental release of small volumes (<1m^3) of hazardous/ non-hazardous liquids and the negligible impacts predicted from a release, the risk to the marine environment is considered low and the environmental risk of using and handling the required chemicals is considered acceptable. Preventative and mitigative controls reduce the potential for pollution, deteriorating water quality and/or habitat loss/degradation meaning the Activity will be conducted in a manner consistent with identified recovery plans and advice (**Table 3-7**).

7.5 Hazardous and Non-Hazardous Unplanned Discharges – Solid

7.5.1 Description of Event

Hazardous and non-hazardous (solid) release to the marine environment	
Aspect	Non-hazardous solid wastes (including paper, plastics and packaging) and hazardous solid wastes (such as batteries, fluorescent tubes, medical wastes, and aerosol cans) may be dropped unintentionally to the marine environment, potentially impacting on sensitive receptors. Release of these waste streams may occur as a result of overfull and/or uncovered bins, incorrectly disposed items or spills during transfers of waste. Dropped objects/lost equipment such as a streamer could also result in seabed disturbance or floating obstacles. The largest potential dropped object would be a crate of supplies being transferred from a support vessel to a seismic survey vessel. A number of seismic streamers (of 9,100 m length) will be used during the Activity. The streamers are gel-filled, which has the characteristics of a 'flexible' solid and will not flow into the marine environment if the streamer skin is punctured, however if the streamer is lost, it will remain buoyant (due to floatation devices) and potentially be a floating obstacle. Other potential dropped objects could include the fenders that are on vessels, should this detach, it will remain buoyant, and potentially be a floating obstacle.
Extent	Localised as all non-buoyant waste material or dropped objects are expected to remain within the operational area. Buoyant waste material or dropped objects could potentially move beyond the operational area under wave action.
Duration	Temporary (duration of the Activity) or until the solid waste degrades or is retrieved.

7.5.2 Nature and Scale of Environmental Impacts

<u>Potential Receptors: Benthic habitats, fish, sharks, marine mammals, marine reptiles, seabirds and socioeconomic</u>

Non-hazardous solids such as plastics have the potential to smother benthic environments and harm marine fauna through entanglement or ingestion. Marine turtles and seabirds are particularly at risk from entanglement. Marine turtles may mistake plastics for food; once ingested, plastics can damage internal tissues and inhibit physiological processes, which can both potentially result in fatality. Marine debris has been highlighted as a threat to marine turtles, humpback whales and whale sharks in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017a), Conservation Management Plan for the Blue Whale (Recovery Plan) (DotE, 2015), Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) and Approved Conservation Advice for *Rhincodon typus* (whale shark). The Recovery Plans and Approved Conservation Advices have specified a number of recovery actions to help combat this threat. Of relevance to this Activity is the legislation for the prevention of garbage disposal from vessels, which Santos implements through adherence to MARPOL.

Release of hazardous solids (e.g. wastes such as batteries) may result in the pollution of the immediate receiving environment, which may lead to impacts to marine flora and fauna. Physiological damage, through ingestion or absorption may occur to individual fish, sharks, cetaceans, marine reptiles or seabirds.

Impacts to socioeconomic receptors could occur should hazardous/ non-hazardous solids cause a safety hazard to other marine users or potentially damage their equipment (e.g. fishing nets).

The area of potential disturbance due to a non-buoyant dropped object would be restricted to the operational area. The seabed within the operational area is primarily soft sediments with little epifauna; this habitat type is widely distributed and well represented in the NWS region. The operational area overlaps with the ancient coastline at the 125 m depth contour KEF, which may comprise harder substrate and associated fauna. Damage to hard substrates, and associated fauna, may occur, however such impact is expected to be restricted to the size of the dropped object, and when compared to the size of the KEF, overall impacts will be negligible. While soft sediment benthic habits will not be destroyed, disturbance of the communities on and within them (i.e. the epifauna) may occur in the event of a dropped object and depressions may remain on the seabed for some time after removal of the dropped object as it gradually infills over time.

In the unlikely event of damage to or loss of a seismic streamer, potential environmental effects could be limited to physical impacts on benthic communities arising from the streamer and associated equipment sinking to the seabed. Seismic streamers are fitted with floatation devices (pressure-activated, self-inflating buoys) that are designed to bring the equipment to the surface if lost accidentally during a seismic survey. As the equipment sinks it passes a certain water depth at which point the buoys inflate (compressed CO_2 gas cartridge) and bring the equipment back to the surface where it can be retrieved by the seismic or support vessel. Given the water depths of the operational area, benthic impacts from the loss of a streamer are not considered credible. Buoyant objects may cause interference with other marine users depending on the size of the object(s). Loss of a streamer (or part of) could create marine debris potentially interfering with other marine users by snagging equipment.

7.5.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (EPO-3);
- No unplanned objects, emissions or discharges to sea or air (EPO-6);
- No physical injury to marine fauna during the Activity (EPO-7); and
- No unplanned seabed disturbance (EPO-8).

The control measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-25	Waste (garbage) management plan.	Reduces probability of waste being discharged to sea, reducing potential impacts to marine fauna. Ensures food waste is discharged in manner that does not pose risk to the environment. Ensures compliance with Marine Orders (94 and 95) and MARPOL (Annex III and V) requirements as appropriate for vessel class.	Personnel cost of vessel audits and inspections, and in recording and reporting waste management.	**Adopted** - benefits of ensuring vessel is compliant outweighs the costs.
CM-42	Dropped object prevention procedure.	Impacts to environment are reduced by preventing dropped object and by retrieving dropped objects where possible.	Personnel costs involved in implementing procedures and in incident reporting.	**Adopted** - benefits of ensuring procedures are followed and measures implemented outweighs the costs of personnel time.
CM-43	Equipment maintenance in accordance with PMS.	Ensures that lifting equipment is maintained and certified, and that lifting procedures are followed reducing probability of dropped objects occurring.	Additional personnel costs of ensuring equipment is maintained and certified as appropriate and that procedures in place and followed.	**Adopted** - benefits of ensuring procedures are followed and equipment is compliant outweighs the minimal costs of personnel time.
CM-44	Streamers are fitted with floatation devices.	Reduced potential impacts to the marine environment due to streamer loss or damage.	Costs to fit with floatation devices, adds to weight of streamers so vessel uses more fuel.	**Adopted** – benefits outweigh the costs of personnel time, and increased fuel usage.
CM-45	Streamer deployment / retrieval procedure.	Reduced potential impacts to the marine environment due to streamer loss or damage.	Personnel costs involved in implementing procedures, maintaining logs / reporting and undertaking training.	**Adopted** – benefits of ensuring procedures are followed and measures implemented outweighs the costs of personnel time.
Additional control measures				
CM-46	Streamers towing depth.	Reduced risk of interaction with the seabed and seabed disturbance.	Limitations on the minimum water depth for acquisition that the survey can be undertaken.	**Adopted** – benefits outweigh operational constraints.
CM-47	Streamers have locating devices fitted.	Enables location and retrieval of streamers if they are lost.	None identified.	**Adopted** – benefits outweigh operational constraints.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	No lifting operations over ancient coastline at the 125 m depth contour KEF.	Reduce potential for disturbance of seafloor features and associated communities potentially found along the KEF.	Would require vessels to mobilise out of KEF for resupply. Seismic survey vessel may need to stop acquisition and therefore would lead to costly delays, prolonging the length of the survey.	**Not Adopted –** Additional costs associated with prolonged survey duration are disproportionate to the minimal environmental benefit given the area potentially impacted in context of the entire KEF.

7.5.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Benthic habitats. Marine fauna – cetaceans, marine turtles, seabirds, sharks and fish. Socio-economic receptors – other marine users (fisheries, shipping, oil and gas operators).
Consequence	A – Negligible
	Physical Environment – Seabed disturbance In the event of lost equipment/ dropped object, it is expected that it may result in localised damage to the seabed. The extent of the impact is limited to the size of the dropped object and given the size of standard materials transferred, any impact is expected to be very small. Surveys of previous seabed disturbances following drilling activities indicate that recovery of benthic fauna in soft sediment substrates occurs between 6-12 months after the Activity ceases (URS, 2001), suggesting any impacts are short term in duration, and result in a negligible reduction in habitat area/function.
	Marine Fauna- cetaceans, marine turtles, seabirds, sharks and fish. In the event of a hazardous/ non-hazardous solid release, the quantities would be limited. This unplanned release could cause localised impacts to water quality and the benthic environment if the solid can degrade, which may lead to impacts on marine flora and fauna species. Solid wastes have the potential to result in fauna mortality or injury through ingestion or entanglement. Any impacts would be restricted to a small number of individuals in close proximity to the unplanned release. Small volumes of the solid waste stream would be generated during the Activity and with the management measures in place, any accidental loss to the environment would be small in size. Marine debris is identified as a potential threat to a number of marine fauna species in relevant Recovery Plans and Conservation Advice (**Table 3-7**). The controls implemented demonstrate that the Activity will be conducted in a manner that reduces marine debris and therefore potential impacts are reduced to ALARP and of an acceptable level. The limited quantities of accidental hazardous/ non-hazardous solid release associated with this event indicate that, in a worst-case release, fatalities would be limited to individuals and is not expected to result in a decrease of the local population size and the consequence level is therefore, negligible.
	Socio-economic – Interference from a buoyant object In the event of a release of a buoyant object that cannot be recovered, it could present an obstacle to other marine users. Eventually the buoyant object may become non-buoyant and sink to the seabed where it may degrade over time. The time taken for this is dependent on the material released and any impacts to marine fauna and the seabed are described above. This may present a risk to commercial trawling activities and damage their equipment, so fishers may be required to avoid a highly localised area to avoid interaction. Given the likely size of buoyant equipment (i.e. seismic streamers), it will drift with the currents. It is considered unlikely to present a significant hazard to other marine users and the consequence level is therefore negligible.
Likelihood	2 – Very Unlikely
	A set of control measures and checks have been proposed to ensure that the risks of dropped objects, lost equipment or release of hazardous/ non-hazardous solid waste to the environment has been minimised. The likelihood of transient marine fauna occurring in the operational area is limited and given the controls in place, the likelihood of releasing hazardous and non-hazardous solids to the environment resulting in a negligible consequence is considered very unlikely (assumes potential for a single loss of solid waste incident during the Activity).
Residual Risk	The residual risk associated with this hazard is Low

7.5.5 ALARP Evaluation

Hazardous/ non-hazardous solid waste will be generated during the Activity and managed through the proposed control measures. Equipment loss and dropped objects, which might occur during vessel to vessel transfers in the field will be managed through transfer procedures and equipment management. The control measures proposed are considered sufficient to reduce the risk of hazardous/ non-hazardous solid releases to a level that is ALARP. Additional controls were considered but not adopted as detailed in **Section 7.5.3.** The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. The proposed control measures are considered appropriate to manage the risk to ALARP.

7.5.6 Acceptability Evaluation

Is the risk ranked between Low to Medium?	Yes – hazardous/ non-hazardous solid release residual risk is ranked Low.
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with MARPOL Annex V. Controls implemented will minimise the potential impacts from the Activity to species identified in relevant Recovery Plans and Approved Conservation Advice (**Table 3-7**) as having the potential to be impacted by marine debris (solid hazardous/ non-hazardous releases).
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

With the controls in place to prevent accidental release of hazardous/ non-hazardous solid waste or a dropped object, and the negligible impacts predicted, the risk to the marine environment is considered low and reduced to a level that is considered acceptable. The Activity undertaken with the controls, will be conducted in a manner that is acceptable under the relevant Recovery Plans and Approved Conservation Advice to prevent accidental release of hazardous/ non-hazardous solid (marine debris) (**Table 3-7**).

7.6 Marine Fauna Collisions

7.6.1 Description of Event

Vessels and/or equipment colliding with marine fauna	
Aspect	There is the potential for vessels and/or equipment involved in the Activity to collide with marine fauna including cetaceans, fish, sharks, marine reptiles and seabirds. The main collision risk associated with the Activity is through vessel collision or equipment collision with large, slow moving cetaceans; or turtle entrapment in tail buoys, potentially resulting in severe injury or mortality.
Extent	Within the operational area, in the immediate vicinity of the seismic and support vessel(s).
Duration	For the duration of the Activity (162 days).

7.6.2 Nature and Scale of Environmental Impacts

Potential receptors: Fish, Sharks, Rays, Marine Mammals, Marine Reptiles and Seabirds

Cetaceans are naturally inquisitive marine mammals that are often attracted to vessels underway; for example, dolphins commonly 'bow ride' with vessels.

Marine fauna in surface waters that would be most at risk from vessel collision include marine mammals, marine turtles and whale sharks. As summarised in **Section 3.2.3**, the operational area overlaps with a range of BIAs: flatback turtle internesting BIA, whale shark foraging BIA, humpback whale migration BIA and pygmy blue whale distribution BIA. The worst potential impact from vessel collision would be mortality or serious injury of an individual.

Collisions between vessels and cetaceans are most frequent on continental shelf areas where high vessel traffic and cetacean habitat occur simultaneously (WDCS, 2006). There has been recorded instances of cetacean deaths as a result of vessel collisions in Australian waters (e.g. a Bryde's whale in the Bass Strait in 1992) (WDCS, 2006), though the data indicates this is likely to be associated with container ships and fast ferries. Whale and Dolphin Conservation Society (WDCS) (2006) also indicates that some cetacean species, such as humpback whales, can detect and change course in order to avoid a vessel. A recent review of vessel whale strike data identified up to 109 potential strikes in Australian waters from 1840 to 2015 (Peel *et al*. 2016).

The most commonly sighted whale in continental shelf waters of the region is the humpback whale. Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) indicates that humpback whales are one of the most frequently reported whale species involved in vessel strikes worldwide (Laist *et al*., 2001). The increase in vessel numbers (Silber & and Bettridge 2012) is not only a threat to humpback whales in relation to vessel strikes but also in disturbance and displacement from key habitats. Similarly, boat strike is also recognised by the Approved Conservation Advice for whale sharks as one of the threats to their recovery, as well as the Conservation Management Plan (Recovery Plan) for the blue whale (DotE, 2015).

As described in *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**), the humpback whale migrates between calving grounds in the Kimberley region of WA to feeding grounds in Antarctica; with the northbound migration from early June to early August (BHPB, 2005), and the peak of the northbound migration between Exmouth Gulf and the Dampier Archipelago occurring around July, concentrated inshore of the 200 m depth contour (Jenner *et al.*, 2001). The southern migration, which peaks around early September, with pods travelling in shallower waters, typically at 30 - 100 m and passing to the west of Barrow Island and north of the Montebello islands. Given the timing of the survey (February to July) occurring before the peak northbound migration, large numbers of humpback whale encounters are not expected. Migrating individuals may traverse the operational Area, however, the timing will avoid humpback whale migration season, as described in **Section 6.2**.

Pygmy blue whales may also be encountered in the operational area. The National Conservation Values Atlas has identified the pygmy whale migration pathway on the continental shelf edge at depth of 500 to 1,000 m (McCauley & Jenner 2010) deeper than the water depths of the operational area. Migrating individuals are not expected to traverse the operational area in large numbers. Breeding areas have not yet been identified; however, it is likely that pygmy blue whales calve in tropical areas of high localised production such as deep offshore waters of the Banda and Molucca seas in Indonesia (Double *et al*. 2014). There are no known breeding areas of significance to pygmy blue whales in waters from Busselton to the Northern Territory border.

Whilst the control measures outlined in **Section 6.2** will prevent the Activity occurring in the peak humpback whale migration season, individual humpback and pygmy blue whales may pass through the operational area. The reaction of whales to the approach of a vessel is quite variable. Some species remain motionless when in the vicinity of a vessel while others are known to be curious and often approach vessels that have stopped or are slow moving, although they generally do not approach, and sometimes avoid, faster moving ships (Richardson *et al*., 1995).

Given the operational area overlaps with whale shark foraging BIA (**Section 3.2.3**), individuals may be encountered during the activities following peak aggregation (May-June) at Ningaloo Reef. However, given the distance from the operational area to Ningaloo Reef (500 km), post aggregating individuals are likely to have widely dispersed reducing the expectation of large numbers of whale shark encounters in the operational area.

Dugongs are prone to vessel collision since they spend a large proportion of time at the sea surface. However, dugong distribution is correlated with presence of seagrass habitat, which is highly unlikely to occur in the operational area due to the water depths. As such, dugong-vessel encounters are expected to be a rare occurrence.

Marine turtle mortality due to boat strike has been identified as an issue in Queensland waters in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017a). However, turtles appear to be more vulnerable to boat strike in areas of high urban population where incidents of pleasure crafts are higher. WA turtle populations have not been highlighted as those most affected by boat strike, possibly due to the relatively low human population density of the NWS Pilbara coastline. It is possible that individual flatback turtles may be encountered in the operational area. However, given the timing of the survey at the tail end of flatback internesting, the depth of water, lack of suitable habitat and distance to the shorelines, large numbers of turtle encounters are not expected.

Vessels will be moving at slow speeds in the operational area, reducing the likelihood that a collision between a seismic or support vessel and marine fauna will occur, and, should a collision occur, that it would result in serious injury.

7.6.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- No physical injury to marine fauna during the Activity (EPO-7).

The Control Measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-10	EPBC Regulations (Part 8) for interacting with cetaceans.	Reduces risk of physical and behavioural impacts to cetaceans from support vessels, helicopters and seismic survey vessel (when not operating).	Potential additional costs in not being able to recommence activity (if not acquiring the seismic survey) increasing survey duration and costs to Santos. Personnel costs involved in reporting sightings to authorities.	**Adopted** – benefits in reducing impacts to cetaceans and other marine fauna outweigh the costs incurred by Santos implementing EPBC Regulations (Part 8).
Additional control measures				
CM-6	Constant bridge watch.	Crew of support vessels and the seismic survey vessel will maintain constant bridge watch, including for third party vessels which may enter the exclusion zone.	No additional costs.	**Adopted –** no additional costs.
CM-12	Marine fauna observations undertaken to minimise the disturbance to fauna caused by the Activity.	Eliminate / reduce impact potential for collision or unwanted interactions.	Increased activity cost.	**Adopted** – benefit outweighs cost. Support vessels will already be in place as a safety requirement to manage interactions with third party vessels.
CM-13	Implementation of some control options consistent with EPBC Policy Statement 2.1 Part B: • Use of 2 MFOs (MMOs) on board the seismic survey vessel. At least one MFO will have >12 months experience in Australian waters (Part B.1)	Reduce likelihood of collision occurring through identification of megafauna at sea surface.	Activity cost of MFOs on board survey. vessels	**Adopted**– observations to assist in avoidance and compliance with regulations outweighs minor activity cost.
CM-16	No acquisition during peak humpback migration.	Avoidance of humpback whale migration periods	Reduces the timeframe available for seismic acquisition. This may result in	**Adopted** – Activity termination is based on whale instigated

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		would minimise impacts to this species.	the survey objectives not being met should start date be delayed.	shutdowns indicating peak migration.
N/A	No night-time / low visibility operations.	Eliminate / reduce likelihood and consequence of impact.	Lengthens time (doubles) of survey as operations only occur for ~ 10 hours/day. Increase cost due to increased survey time (more than double cost).	**Not Adopted** – Cost outweighs the environmental benefit given the low numbers of marine fauna which may be in the area (due to survey shutdown for peak whale migration). A control adopted will prevent night-time and low visibility operations if > 3 whales instigated shutdowns per day for 3 consecutive days occurs. Low visibility/ night-time seismic operations will not resume until there has been a 24-hour period with no whale shut downs.
N/A	Spotter planes / vessels sent ahead to planned night-time operational area.	Eliminate / reduce likelihood and consequence of impact.	Marine fauna may have moved away from the area by the time the operating seismic survey vessel arrives, or other marine fauna entered the area rendering the pre survey check invalid. Diving cetaceans may not be observed during pre-survey check. Cost of specialist aircraft with good downward visibility, or cost of an additional spotter vessel additional MFO's required on aboard aircraft/vessels. Additional risks to environment through use of vessels/airplanes, increased safety risks to personnel on board additional vessels.	**Not Adopted** – based on cost outweighing benefits.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-48	Use of a 'turtle friendly' tail buoy with a single tow point, undercarriage with a sloped front and no gap, thus no turtle entrapment sites. Or if a twin fin design tail buoy is to be used as a result of operational logistics a turtle guard (exclusion and/or deflection) will be implemented.	Reduce likelihood of entanglement of marine turtles.	May increase activity costs or limit number of potential contractors available leading to survey delays.	**Adopted** – based on risk outweighing cost. Turtle guards are commonplace equipment and therefore contractor selection will not be significantly impacted.

7.6.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Marine fauna – Fish and sharks, cetaceans, marine reptiles
Consequence	A –Negligible
	In the event of a collision with marine fauna, there is the potential for injury or death to an individual. The receptors present in the operational area are expected to be limited to a small number of transient individuals. Boat strike and vessel disturbance are identified as potential threats to a number of marine fauna species in relevant Recovery Plans and Approved Conservation Advice (**Table 3-7**). The above information above demonstrates that the Activity will be conducted in a manner that reduces potential impacts to ALARP and of acceptable level. In addition, all vessel strikes will be reported by Santos in the National Ship Strike Database. There is the potential for death or injury of EPBC listed individual species, however as they would represent a small proportion of the local population it is not expected that it would result in a decreased population size over what would usually occur due to natural variation, at a local or regional scale. In addition, given the vessels will be moving slowly during the Activity, it is expected that a collision with an individual would result in a minor injury only. Overall, the consequence of a striking an individual marine fauna is not expected to decrease the local population size and therefore is assessed as negligible.
Likelihood	2 – Very Unlikely
	The Australian National Marine Safety Committee (NMSC) reports that during 2009, there was one report of a vessel collision with a marine animal (species not defined) (NMSC, 2010). Water depths of within the operational area are shallower than known pygmy blue whale migration routes, reducing the likelihood of migrating blue whales occurring during the Activity. The operational area overlaps the humpback whale migration route, the Activity will not occur during peak migration season (**Section 3.2.5**) reducing the likelihood that significant interactions with humpback whales during the Activity will occur. Whale sharks may be encountered in the operational area given the overlap with the foraging BIA. However, large numbers of whale shark encounters are not expected given the distance between the operational area and key aggregation sites at Ningaloo Reef. Given that the timing of the Activity (i.e. end of nesting/ internesting) the nearest nesting beaches for flatback turtles are located 56 km (Eighty Mile Beach) from the operational area it is unlikely that large numbers of aggregating turtles will be encountered during the Activity. Vessels will be moving slowly whilst inside the operational area, posing a low risk of collision with marine fauna. Consequently, the likelihood of a collision with marine fauna resulting in a minor consequence is considered to be rare.
Residual Risk	The residual risk associated with this hazard is Low

7.6.5 ALARP Evaluation

No alternative options to the use of vessels and streamers for the Activity are possible in order to undertake the Activity. If the control measures are adhered to then the risk of marine fauna collisions will have been reduced to ALARP.

The assessed residual risk for this impact is low. Additional controls were identified and some have been adopted, as detailed in **Section 7.6.5**. The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. The proposed control measures are considered appropriate to manage the risk to ALARP.

7.6.6 Acceptability Evaluation

Is the risk ranked between Low to Medium?	Yes – maximum marine fauna collisions residual risk ranking is Low.
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with Part 8 of the EPBC Regulations. Controls implemented will minimise the potential impacts from the Activity to species identified in relevant Recovery Plans and Approved Conservation Advice as having the potential to be impacted by vessel strike.
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

Application of the proposed management and adherence to Commonwealth regulations are in line with relevant actions prescribed in the Recovery Plan and Approved Conservation Advice and reduces the likelihood of vessel interactions with marine fauna. While the potential exists for a collision with marine fauna to occur, it is considered a very unlikely scenario. Vessels will be moving slowly within the operational area, also reducing the likelihood of fauna strike. In the unlikely event that an impact did occur, it would be highly probable that only a single individual would be contacted. Given the rare likelihood of a collision occurring coupled with the potential impact limited to a single individual the risk is considered acceptable.

7.7 Introduction of Invasive Marine Species

7.7.1 Description of Event

Introduction of Invasive Marine Species	
Aspect	Invasive marine species (IMS) have been introduced and translocated around Australia by a variety of natural and human means including biofouling and ballast water. IMS could be introduced into the operational area and surrounds by vessels carrying IMS on external biological fouling, internal systems (sea chests, seawater systems etc.), on marine equipment such as seismic streamers, or through ballast water exchange.
Extent	Localised (seabed and water column near the operational area) to widespread, if successfully translocated to new areas via ocean currents or survey equipment transit.
Duration	Temporary (duration of the Activity) to long-term (in the event of successful translocation).

7.7.2 Nature and Scale of Environmental Impacts

<u>Potential Receptors: Marine ecosystem as a whole and Commercial / Recreational Users of the Marine Environment</u>

IMS are marine plants, animals and algae that have been introduced into a region that is beyond their natural range but have the ability to survive, and possibly thrive (DAFF, 2011). The majority of IMS that are climatically compatible with conditions in NWS waters are found in south-east Asian countries.

Some IMS pose a significant risk to environmental values, biodiversity, ecosystem health, human health, fisheries, aquaculture, shipping, ports and tourism (Wells *et al*. 2009). IMSs can cause a variety of adverse effects in a receiving environment, including:

- over-predation of native flora and fauna;
- out-competing of native flora and fauna for food;
- human illness through released toxins;
- depletion of viable fishing areas and aquaculture stock;
- reduction of coastal aesthetics; and
- damage to marine and industrial equipment and infrastructure.

Species of concern are those that are not native to the region; are likely to survive and establish in the region; and are able to spread by human mediated or natural means. Species of concern vary from one region to another depending on various environmental factors such as water temperature, salinity, nutrient levels and habitat type. These factors dictate their survival and invasive capabilities.

It is recognised that artificial, disturbed and/or polluted habitats in tropical regions are susceptible to introductions which is why ports are often areas of higher IMS risk (Neil *et al*. 2005).

Following their establishment, eradication of IMS populations is difficult, limiting management options to ongoing control or impact minimisation. Eradication is dependent on the environmental conditions and species. For this reason, increased management requirements have been implemented in recent years by Commonwealth and State regulatory agencies.

Ballast water exchange and biofouling on vessel hulls and other external niche areas, internal niches, and on equipment routinely immersed in water all pose a potential risk of introducing IMS into Australia. The potential biofouling risk presented by the vessels will relate to the length of time that the vessel has already been operating in Australian waters or, if they have been operating outside of Australian waters, the location/s of the operations it has been undertaking, the length of time spent at these location/s, and whether the vessel has undergone hull inspections, cleaning and application of new anti-foulant coating prior to returning to operate in Australia.

7.7.3 Environmental Performance and Control Measures

Environmental Performance Outcomes relating to this hazard include:

- No introduction of marine pest species (EPO-2).

The control measures considered for this Activity are shown below; Environmental Performance Standards and Measurement Criteria for the EPOs are described in **Table 8-3**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-49	DPIRD vessel check tool (applied to vessels), and immersible equipment clean.	The risk of introducing IMS is reduced through implementation of the vessel check tool and requirement for immersible equipment to be cleaned.	Personnel costs involved in demonstrating vessel(s) are of 'low risk' of introducing IMS through completion of DPIRD Vessel Check tool as well as the requirement for equipment to be cleaned could lead to potential delays in Activity schedule should remediation activities (e.g. additional cleaning and inspections) be required, potentially affecting vessel contracting process.	**Adopted** – Personnel costs and potential delays or costs to Activity are considered outweighed by the benefits of reducing the risk of IMS.
CM-50	Anti-foulant system.	The risk of introducing IMS is reduced due to anti-foulant systems.	Could lead to potential delays and therefore costs, in vessel contracting process due to availability of vessel with appropriate anti-foulant systems.	**Adopted** – Potential delays or costs to Activity are considered to outweigh the benefits of reducing the risk of IMS.
CM-51	Biosecurity risk management.	Reduces the level of biosecurity risk.	Personnel costs involved in demonstrating the seismic survey vessels level of biosecurity risk is assessed as 'low risk' prior to interacting with domestic support vessels and aircraft. Could lead to potential delays and costs.	**Adopted** – Personnel costs and potential delays to the Activity are considered outweighed by the benefits of reducing the level of biosecurity risk.
CM-52	Ballast water management plan.	Reduces the risk of introducing IMS through procedures managing ballast water exchange and identifying high risk ballast water.	Personnel costs in producing and implementing ballast water management plan and in maintaining record books and logs.	**Adopted** – Potential costs are considered outweighed by the benefits of reducing the risk of IMS.
Additional control measures				
N/A	Contract vessels only operating in local, state or National waters to reduce potential for IMS.	Eliminate likelihood of invasive marine species.	Appropriate seismic survey vessels required for the Activity are not currently working in Australian waters only. The survey objectives would not be met if vessel selection was restricted to those operating in only Australian waters.	**Not Adopted** – not feasible to restrict vessels due to availability.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	Mandatory dry docking prior to entering field to clean vessel and/or equipment and remove biofouling.	Eliminate invasive marine species.	Significant cost for this to occur and would lead to scheduling delays.	**Not Adopted -** Given other controls in place already reducing the risk, cost outweighs risk.
N/A	Mandatory independent IMS survey.	Eliminate invasive marine species.	Cost is high compared to existing risk.	**Not Adopted** – Based on cost outweighing risk.
N/A	Pre-mobilisation chemical dosage of ballast water to eliminate IMS.	Would reduce potential for IMS to establish by eliminating individuals present in ballast water.	High cost compared to existing risk; introduction of additional chemical to the marine environment which would likely be toxic to native marine species.	**Not Adopted** – Based on risk to marine environment from release of chemicals and high cost considered disproportionate compared to base case risk.
N/A	Heat treatment of ballast water to eliminate IMS.	Would reduce potential for IMS to establish by eliminating individuals present in ballast water.	High cost compared to existing risk; introduction of water at much higher temperature than surrounding marine environment would likely result in death of native marine species.	**Not Adopted** – based on increased risk to marine environment compared to base case risk.
N/A	Utilise an alternative ballast system to avoid uptake/discharge of water.	Eliminate need for ballast water exchange therefore decreasing risk of introducing IMS through ballast water.	Vessels suitable for the Activity may not have options for alternative ballast therefore would require modification at significant cost.	**Not Adopted** – Cost outweighs benefit.

7.7.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Threatened, migratory, and local fauna; Physical environment and habitats; Socio-economic receptors.
Consequence	C - Moderate
	Ballast water is responsible for up to 30% of all IMS incursions into Australian waters, however, research indicates that biofouling (the accumulation of aquatic micro-organisms, algae, plants and animals on vessel hulls and submerged surfaces) has been responsible for more foreign marine introductions than ballast water (DAWR 2017). IMS, if they successfully establish, can out-compete native species for food or space, preying on native species or changing the nature of the environment and can subsequently impact on fisheries or aquaculture. If an IMS is introduced, they have been known to colonise areas outside of the areas they are introduced to. In the event that an IMS is introduced into the operational area, given the lack of diversity and extensiveness of similar benthic habitat in the region, there would only be a minor reduction in the physical environment. The overall consequence level was assessed as moderate.
Likelihood	1 - Rare
	The pathways for IMS introductions are well known, and consequently standard preventative measures are proposed. The ability for invasive marine species to colonise a habitat is dependent on a number of environmental conditions. It has been found that highly disturbed environments (such as marinas) are more susceptible to colonisation than open water environments where the number of dilutions and the degree of dispersal are high (Paulay *et al.* 2002). Given the water depths of in the operational area (40 – 250 m), the likelihood that an IMS would be able to successfully translocate from the operational area to surrounding shallower habitats is reduced. With controls in place to reduce the risk of introduction of IMS the likelihood of introducing an IMS is considered rare.
Residual Risk	The residual risk associated with this hazard is Low

7.7.5 ALARP Evaluation

Ballast water will be managed through a Ballast Water Management Plan, and a vessel biosecurity risk assessment undertaken on all vessels planned for use for the Activity (using the DPIRD Vessel Check tool) to minimise the risk of introduction of a marine pest species.

Completion of the DPIRD Vessel Check Tool prior to movement/ transit into a Santos petroleum permit, demonstrating vessels are low risk of introducing IMS reduces the risk of IMS. Given the water depths in the operational area, the potential for IMS establishing is considered very low.

Immersible equipment will be cleaned to 'low risk' prior to submerging, this ensures the equipment operates efficiently and also reduces the risk of introducing IMS.

Accepted control measures will ensure the risk of IMS introduction is consistent with outcomes outlined in DPIRD's Aquatic Biosecurity Policy (2017).

Through the use of the DPIRD vessel check tool, and cleaning of immersible equipment, Santos is confident that the potential risk of introducing IMS through biofouling will be ALARP.

Additional controls were identified and considered but not adopted as detailed in **Section 7.7.3.** The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk. The proposed control measures are considered appropriate to manage the risk to ALARP.

7.7.6 Acceptability Evaluation

Is the risk ranked between Low to Medium?	Yes – introduction of invasive marine species residual risk ranking is Medium.
Is further information required to support or validate the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?	Yes – Management consistent with *Biosecurity Act* (2015) and National Biofouling Guidance for the Petroleum Industry.
Are control measures and performance standards consistent with the Santos Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

The vessels will meet Australian biosecurity requirements and proposed management is consistent with National Biofouling Guidance for the Petroleum Industry.

Application of the proposed management and adherence to regulations reduces the likelihood of introducing IMS into the operational area. While the potential exists for IMS to be translocated to the area, the likelihood of them settling and colonizing is unlikely given the water depths. Due to the rare likelihood of an IMS entering the operational area coupled with the light-limited deep water, the risk is deemed acceptable.

8. Implementation Strategy

In accordance with Regulation 14(1) of the OPGGS 2009 Regulations, this section provides details on this EP's implementation strategy. The specific measures and arrangements that will be implemented in the event of an oil pollution emergency are detailed in the OPEP.

8.1 Environmental Management System

Santos' Management System (SMS) exists to support its moral, professional and legal obligations to undertake work in a manner that does not cause harm to people or the environment. The SMS is a framework of policies, standards, processes, procedures, tools and control measures that, when used together by a properly resourced and competent organisation, ensure that:

- A common HSE approach is followed across the organisation;
- HSE is proactively managed and maintained;
- The mandatory requirements of HSE management are implemented and are auditable;
- HSE management performance is measured and corrective actions are taken;
- Opportunities for improvement are recognised and implemented; and
- Workforce commitments are understood and demonstrated.

The structure of this implementation strategy is consistent with the SMS and is designed to ensure that:

- Environmental impacts and risks continue to be identified for the duration of the Activity and reduced to ALARP;
- Control measures are effective in reducing environmental impacts and risks to ALARP and acceptable levels;
- Environmental performance outcomes and standards set out in this EP are met; and
- Stakeholder consultation is maintained throughout the Activity as appropriate.

8.2 Environmental Management Policy

The Environmental Management Policy (**Figure 1-1**) clearly sets out Santos' strategic environmental objectives and the commitment of the management team to continuous environmental performance. This EP has been prepared in accordance with the fundamentals of this Policy. By accepting employment with Santos, each employee and contractor is made aware that he/she is responsible for the application of this Policy.

8.3 Leadership, Accountability and Responsibility

While Santos' Executive Vice President has the overall accountability for the implementation of the SMS, the General Manager for Offshore Exploration is responsible for ensuring implementation, management and review of this EP.

Effective implementation of this EP will require collaboration and cooperation amongst Santos and its contractors. This is reflected in **Table 8-1**, which sets out the roles and responsibilities of personnel in relation to the implementation, management and review of the EP.

Table 8-1: Chain of command, key leadership roles and responsibilities

Role	Responsibilities
General Manager, Offshore Exploration	• Ensures Santos policies and standards are adhered to and communicated to all employees and contractors; • Promotes HSE as a core value integral with how Santos does its business; • Empowers personnel to 'stop-the-job' due to HSE concerns; • Provides resources for HSE management; • Ensures a high level of HSE performance and drives improvement opportunities; • Ensures emergency response plans are in place; • Maintains communication with company personnel, government agencies and the media; • Approves Management of Change (MoC) documents, if acceptable and ALARP.
Geophysical Manager	• Ensures conformance with environmental performance outcomes and standards in the EP; • Delegates HSE responsibilities to ensure the EP is implemented; • Empowers personnel to 'stop-the-job' due to HSE concerns; • Ensures HSE incidents are reported, investigated, corrected and communicated; • Ensures HSE inspections and audits are completed and corrective actions implemented; • Reviews Management of Change (MoC) documents; and • Ensures personnel on the facility have the necessary qualifications, training and/or supervision.
Contractor Vessel Manager	• Ensures vessel meets quarantine requirements to operate in Australian waters. • Ensures subcontractors are communicated the EP requirements. • Ensures the Activity risks are assessed and HSE Plan is created including the requirements of this EP.
MFOs	In addition to the requirements of vessel crew, the MFOs will • Undertake visual observations for marine fauna as per this EP. • Record all sightings of marine fauna. • Advise vessel master to delay or shut down seismic source if required. • Provide additional training to crew in fauna observations as required.
Vessel Masters	• Overall authority for the safety of vessel and crew. • Ensures compliance with applicable local and international regulations. • Responsible for ensuring implementation of the following documents: Vessel SOPEP/SMPEP, Waste Management Procedure, Bunkering Procedure, Emergency Response Plan and communication with authorities (AMSA). • Ensures vessel equipment is kept according to the preventative maintenance schedule. • Responsible for training all crew to ensure they are competent to perform their duties during an Emergency Response situation. • Ensures implementation of MoC documents and distribution to relevant personnel. • Investigates all incidents and near misses and reports these to Santos representative. • Comply with operating procedures and this EP.

Role	Responsibilities
On board Representatives	• Ensures compliance with operating procedures and this EP. • Ensures conformance with environmental performance outcomes and standards in the EP. • Ensures Vessels crew comply with environmental performance standards. • Facilitates communication between Santos onshore management and Vessel Master. • Carries out induction with offshore crew and with any new personnel joining the Vessel. • Maintains records of compliance with this EP. • Reviews Management of Change (MoC) documents and ensures compliance with any MoC. • Responsible for compliance with the standard management procedures, as outlined in the EPBC Policy Statement 2.1 – interactions between offshore seismic exploration and whales, including adequate fauna monitoring and operational response. • Provides daily reports, incident reports and any Marine Fauna reports to Santos. • Ensures HSE incidents are reported, investigated, corrected and communicated. • Ensures HSE inspections and audits are completed and corrective actions implemented. • Ensures personnel on the vessels have the necessary qualifications, training and/or supervision.
Vessel Party Manager	• Communicates operating Policies and procedures to all vessel personnel ensuring their compliance. • Communicates all relevant MoC requirements to appropriate personnel. • Monitors crew compliance with the EP and relevant environmental legislative requirements. • Facilitates communication between the Santos Representative on board and the crew. • Maintains records of daily logs and environmental events and HSE key performance indicators.
Vessel Crew	• Adhere to HSE obligations. • Comply with operating procedures and this EP. • Follow good housekeeping procedures and work practices. • Report immediately any HSE events to the Vessel Master. • Carry out duties in according with defined work systems and procedures. • Report sightings of marine fauna and incidents of marine pollution. • Identify HSE improvement opportunities wherever possible. • Report HSE incidents, hazards or non-conformances to supervisors in a timely manner. • Obligation to 'stop-the-job' due to HSE concerns. • Adhere to any MoC requirements.
Senior Advisor - Oil Spill Response	• Ensures that personnel with OPEP responsibilities are aware of their obligations; • Monitors and guides oil spill responses to ensure obligations as stated in OPEP are implemented; • Maintains a state of preparedness by: – Managing oil spill response equipment and personnel; – Managing contracts with response equipment and personnel suppliers; and – Managing agreements with national regulatory agencies for support in oil spill response. • Ensuring Santos' oil spill response exercise and training schedule is implemented.

Role	Responsibilities
HSE Manager and Team Leads	• Ensures EP is managed and reviewed: monitors conformance with environmental performance outcomes and standards, and the implementation strategy in the EP; • Prepares, maintains and distributes the environmental compliance register; • Completes regular HSE reports, inspections and audits; • Completes HSE inductions and promotes general awareness; • Collates HSE data and records; • Contributes to HSE incident management and investigations; • Provides operational HSE oversight and advice; • Facilitates the development and implementation of MoC documents; • Provides incident reports, compliance reports and notifications to NOPSEMA; • Ensures stakeholder consultation and communication requirements have been fulfilled; • Ensure vessel meets quarantine requirements to operate in Australian waters; • Ensure subcontractors are communicated the EP requirements; • Ensure the Activity risks are assessed and HSE Plan is created including the requirements of this EP; and • Responsible for notifying the Geophysical Manager of any known or potential non-compliance issues.

8.4 Workforce Training and Competency

8.4.1 Activity Inductions

All offshore personnel on the vessels will complete an induction that addresses their EP responsibilities. Induction attendance records for all personnel will be maintained. Inductions will include information on:

- Operating environment (e.g. nearby marine protected areas, KEFs, BIAs, etc.);
- Regulatory regime (NOPSEMA);
- Interactions with other marine users;
- Highest risk activities;
- EP commitments;
- Key environmental management requirements; and
- HSE expectations, including reporting.

8.4.2 Training and Competency

All members of the workforce on the vessels will complete relevant training and hold qualifications and certificates for their role (e.g. rigging and crane operator certificates, etc.).

Santos and its contractors are individually responsible for ensuring that their personnel are qualified and trained. The systems, procedures and/or responsible persons necessary to ensure that this commitment is met will vary (e.g. online databases, desktop matrix, staff on-boarding processes, training departments, etc.).

Personnel qualification and training records will be sampled before and/or during an activity. Such checks will be performed during the procurement process, inductions, crew change, and/or operational inspections and audits.

MFOs will be suitably qualified with the lead MFO having >12 months experience on a seismic survey vessel as an MFO in Australian waters.

8.5 Hazard Identification, Risk and Impact Assessment and Controls

Hazards and associated environmental risks and impacts for the proposed activities have been systematically identified and assessed in this EP (refer to **Sections 6** and **7**). The control measures and environmental performance standards that will be implemented to manage the identified risks and impacts, and the environmental performance outcomes that will be achieved, are detailed below.

To ensure that environmental risks and impacts remain ALARP and of an acceptable level during the Activity and for the duration of this EP, hazards will continue to be identified, assessed and controlled as described in Operations Management (**Section 8.9**) and Reviews, Audits and Inspections (**Section 8.16**).

Any new, or proposed amendment to a control measure or environmental performance standard or outcome will be managed in accordance with the MoC procedure (**Section 8.10**).

Oil spill response control measures and environmental performance standards and outcomes are listed in the OPEP.

8.6 Environmental Performance Outcomes

To ensure environmental risks and impacts will be of an acceptable level, environmental performance outcomes have been defined and are listed in **Table 8-2**. These outcomes will be achieved by implementing the identified control measures to the defined performance standards.

Table 8-2: Environmental performance outcomes

Reference	Environmental Performance Outcomes
EPO-1	Information available to regulatory authorities and marine users directly affected by planned activities
EPO-2	No introduction of marine pest species
EPO-3	No long-term environmental impact in the event of an unplanned hydrocarbon release to sea
EPO-4	Discharges to sea meet legislated permissible discharge requirements
EPO-5	Emissions to air meet legislated requirements
EPO-6	No unplanned objects, emissions or discharges to sea or air
EPO-7	No physical injury to marine fauna during the Activity
EPO-8	No unplanned seabed disturbance
EPO-9	No serious or irreversible impacts to the values of the KEF (ancient coastline at 125 m depth contour KEF).
EPO-10	No mortality or permanent injury to cetaceans due to noise associated with the operation of seismic sources.
EPO-11	No disturbance to humpback whales during the peak migration period.
EPO-12	No mortality or permanent injury to turtles due to noise associated with the operation of seismic sources.
EPO-13	Undertake seismic acquisition in a manner consistent with the Recovery Plan for Marine Turtles in Australia 2017-2027.
EPO-14	No serious or irreversible impacts to listed marine fish (including sharks) due to noise associated with the operation of seismic sources, consistent with the MNES Significant Impact Guideline 1.1.
EPO-15	Undertake seismic acquisition in a manner that prevents serious or irreversible impacts to marine invertebrate populations within the operational area due to noise associated with the operation of seismic sources.
EPO-16	Undertake seismic acquisition in a manner that prevents serious or irreversible impacts to plankton or fauna dependent on plankton as a food source within the operational area.
EPO-17	No serious or irreversible impact on the following fisheries due to noise associated with the operation of seismic sources: • Pilbara Trap Managed Fishery; • Pilbara Fish Trawl Interim Managed Fishery (Area 4 or 5); • Pilbara Line Fishery; • Mackerel Managed Fishery (Area 2) ; and • Pearl Oyster Managed Fisher (Zone 2)
EPO-18	No unplanned interactions with commercial fishers.
EPO-19	Commercial fishing licence holders are no worse off as a result of the seismic survey.
EPO-20	Seismic acquisition is undertaken in a manner that prevents impacts to divers.
EPO-21	Far-field source levels for the selected seismic source for the Keraudren Extension 3D MSS are consistent with levels assessed in this EP.
EPO-22	Seismic acquisition is undertaken in a manner that prevents impact to subsea cables.
EPO-23	Potential additive impacts from concurrent seismic survey operations are identified and reduced as far as reasonably practicable.

8.6.1 Control Measures and Performance Standards

The control measures that will be used to manage identified environmental impacts and risks, and the associated statements of performance required of the control measure (i.e. environmental performance standards) are listed in **Table 8-3.** Criteria outlining how compliance with the control measure, and the expected environmental performance, could be evidenced are also listed. A separate set of performance standards based on the oil spill response operational control measures are included in the OPEP.

In the event of any discrepancies between the control measures listed in **Table 8-3** and the remainder of this EP, the control measures in **Table 8-3** shall prevail.

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Table 8-3: Control measures and environmental performance standards for the Activity

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-1	Maritime Notices - Notices to Mariners (NTM) and AUSCOAST warnings	A notification will be provided prior to vessel arrival in the operational area to AMSA's RCC (minimum two days prior), AHO (minimum four weeks prior) and Pilbara Port Authority (minimum one week prior), and following vessel departure (within one week), so the maritime industry is aware of petroleum activities.	CM-1-EPS-1	Notice to stakeholder	EPO-1
CM-2	Stakeholder consultation	Relevant persons for the survey operations identified in **Table 4-2** are provided a commencement notification at least two weeks prior to the Activity commencing.	CM-2-EPS-1	Santos correspondence to relevant stakeholders	EPO-1
		All correspondence with external stakeholders is recorded by Santos.	CM-2-EPS-2	Stakeholder database	
		Santos Consultation Coordinator remains available before, during and after the Activity to ensure stakeholder feedback is evaluated and considered during the operational activity stages.	CM-2-EPS-3	Consultation Coordinator contact details provided to relevant persons in all correspondence	
CM-3	Exclusion zone established to reduce potential for collision or interference with other marine user activities	A 3 nautical mile exclusion zone is defined around the seismic survey vessel (towing source array and streamers).	CM-3-EPS-1	Stakeholder consultation	EPO-1 EPO-18
CM-4	Navigation equipment and procedures	Vessels undergo an International Marine Contractors Association (IMCA), Common Marine Inspection Audit (CMID) or Offshore Vessel Inspection Document (OVID) inspections within 12 months of the Activity commencing to confirm that they meet international HSE and maintenance standards.	CM-4-EPS-1	All vessels have a current (<12 months) IMCA or CMID or OVID certificate prior to mobilisation.	EPO-1 EPO-3 EPO-18
		Seismic survey vessel equipped with an automatic radar plotting aid (ARPA) system.	CM-4-EPS-2	Completed Inspection report or vessel statement of conformance	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-5	Support vessel in place during Activity to reduce potential for collision or interference with other marine users	At least one support vessel on standby at all times to monitor the seismic survey vessel exclusion zone to identify approaching third-party vessels and communicate with the vessels. During times when the support vessel's radar is not operational, the seismic survey vessel will monitor at all times for approaching third-party vessels using an Automatic Identification System.	CM-5-EPS-1	Daily vessel report	EPO-3 EPO-18
CM-6	Constant bridge watch	Competent crew shall maintain constant bridge-watch.	CM-6-EPS-1	Vessel log of times and persons on watch. Crew training records. Completed vessel statement of conformance.	EPO-3 EPO-7 EPO-18
CM-7	Vessels fitted with AIS systems and radars	Support vessels and the seismic survey vessel will be equipped with an automatic identification system (AIS) and radar.	CM-7-EPS-1	Written confirmation from vessel contractor that the correct equipment is on-board	EPO-1 EPO-3 EPO-18
CM-8	Concurrent operations planning with relevant commercial fishers	If requested by a commercial fishing licence holder Santos will provide operational survey plans, commencement and cessation notifications, and daily operational reports.	CM-8-EPS-1	Documented correspondence with commercial fishing licence holders.	EPO-18 EPO-19
		At a minimum the daily operational reports will include: • Current seismic survey vessel position. • Look ahead seismic survey activities and vessel positions. • Support vessel activities and positions. • Vessel contact details. • Santos management contact details.	CM-8-EPS-2	Completed daily reports, if requested by commercial fishing licence holders	
		Santos support vessels will avoid commercial fishing vessels that are actively fishing and avoid schooling fish as identified and communicated by active commercial fishing vessels.	CM-8-EPS-3	Documented correspondence with commercial fishing licence holders.	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		Santos will change survey vessel sail lines to accommodate commercial fishers' requests wherever possible, providing there is open and advanced communication between the seismic survey and commercial fishing vessel.	CM-8-EPS-4	Seismic survey vessel log detailed radio communications between vessels	
CM-9	Commercial fishery payment claims (further details are provided in Section **8.6.2**)	All evidence-based payment claims made by a commercial fishing licence holder that a survey stage[7] caused a temporary loss of fish catch from within the operational area will be assessed for merit by Santos.	CM-9-EPS-1	Santos' merit assessment of commercial fishing licence holder claim. Documented correspondence with commercial fishing licence holders.	EPO-19
		All evidence-based payment claims made by a commercial fishing licence holder that a survey stage caused a fishing vessel to be temporarily displaced from the operational area at a cost to the licence holder will be assessed for merit by Santos.	CM-9-EPS-2	Santos' merit assessment of commercial fishing licence holder claim. Documented correspondence with commercial fishing licence holders.	
		All evidence-based payment claims made by a commercial fishing licence holder that a survey stage caused fishing equipment located within the operational area to be damaged or lost at a cost to the licence holder will be assessed for merit by Santos.	CM-9-EPS-3	Santos' merit assessment of commercial fishing licence holder claim. Documented correspondence with commercial fishing licence holders.	
		Payment claims substantiated and accepted by Santos will be paid to the claimant in accordance with Santos payment terms and conditions, and within 60 days from acceptance.	CM-9-EPS-04	Payment invoice	
CM-10		Vessels comply with Santos Protected Marine Fauna Interaction and Sighting Procedure (EA-91-11-00003) which ensures compliance with Part 8 of the	CM-10-EPS-1	Vessel contractor procedures align with Part 8 of EPBC Regulations	EPO-7 EPO-10

[7] Survey stage is defined as the proportion of 3D seismic survey acquired in any given calendar year.

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
	EPBC Regulations (Part 8) for interacting with cetaceans	Environment Protection and Biodiversity Conservation Regulations 2000 which includes controls for minimising the risk of collision with marine fauna including: all vessels must travel at less than 6 knots within the caution zone of a cetacean (150 m radius for dolphins, 300 m for whales) known to be in the area.		Records of breaches of the requirements outlined in Santos' Protected Marine Fauna Interaction and Sighting Procedure (EA-91-11-00003), reported via Monthly Recordable Incident Report and Environmental Performance Report. Vessel Statement of conformance	EPO-11
		Helicopters comply with Santos Protected Marine Fauna Interaction and Sighting Procedure (EA-91-11-00003) which ensures compliance with Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna: Contractor must not operate a helicopter lower than 1650 ft (502 m) or within a horizontal radius of 500 m of a cetacean), unless taking off or landing because they are taking reasonable actions necessary to reduce safety risk to humans.	CM-10-EPS-2	Helicopter contractor procedures align with Part 8 of EPBC Regulations Records of breaches of the requirements outlined in Santos' Protected Marine Fauna Interaction and Sighting Procedure (EA-91-11-00003), reported via Monthly Recordable Incident Report and Environmental Performance Report.	
		Any vessel strikes with cetaceans will be reported in the National Ship Strike Database.	CM-10-EPS-3	Conformance checked on receipt of incident report.	
CM-11	Implementation of EPBC Policy Statement 2.1 (Part A): • pre start-up visual observation • Soft start procedures • Start-up delay procedure • Operations procedure • Stop work procedure • Night-time and low visibility procedures	Implementation of Part A of the EPBC Policy Statement 2.1 with the below cautionary zones observed. Compliance with the following policy statement sections: • A1: Pre-survey planning (this EP) • A2: Trained crew • A3.1: Pre start-up visual observation • A3.2: Soft start procedures • A3.2: Start-up delay procedure • A3.4: Operations procedure • A3.5: Stop work procedure • A3.6: Night-time and low visibility procedures	CM-11-EPS-1	Completed marine fauna sighting datasheet Vessel logs with records of all soft starts, shut down procedures and timing of acquisition. MFO records/reports (daily, weekly) show that marine fauna interaction procedures are followed during survey including precaution zones, soft starts and recommencement procedures Completed report within 2 months of survey (refer **Section 8.14**).	EPO-7 EPO-10 EPO-11 EPO-12 EPO-13 EPO-14 EPO-15 EPO-16 EPO-17

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
	Apply these requirements to cetaceans, marine turtles and whale sharks.	• A4: Compliance and sighting report provided to DoE The following precaution zones will be implemented for cetaceans, turtles and whale sharks: • Observation zone: 3+ km horizontal radius from the acoustic source. • Power down (Low power) zone: 2 km horizontal radius from the acoustic source. • Shut-down zone: 500m horizontal radius from the acoustic source.			
CM-12	Marine fauna observations undertaken to minimise the disturbance to fauna caused by the Activity.	Binoculars and Marine Fauna Sighting Datasheet available on all vessels.	CM-12-EPS-1	Binoculars and Marine Fauna Sighting Datasheets present	EPO-7 EPO-10 EPO-11 EPO-12 EPO-13 EPO-14
		All vessels note any marine fauna observations on marine fauna sighting datasheets and communicates findings with the seismic survey vessel.	CM-12-EPS-2	Marine Fauna Sighting Database	
CM-13	Implementation of some control options consistent with EPBC Policy Statement 2.1 Part B: Use of 2 MFOs (MMOs) on board the seismic survey vessel. At least one MFO will have >12 months experience in Australian waters (Part B.1).	Two MFOs will be on the seismic survey vessel with one MFO on watch during daylight hours.	CM-13-EPS-1	Vessel POB lists. MFO training and competency records. MFO Report.	EPO-7 EPO-10 EPO-11 EPO-12 EPO-13 EPO-14
		At least one MFO will have >12 months experience on a seismic survey vessel as an MFO in Australian waters.	CM-13-EPS-2	Vessel POB lists. MFO training and competency records.	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-14	Implementation of EPBC Policy Statement 2.1 (partial part B.6 – adaptive management): • Ceasing seismic acquisition for 24 hours if there are 3 or more humpback whale induced shutdowns/ power downs within the previous 24-hour period. • Seismic acquisition may re-commence after 24 hours if there have been no further sightings of humpback whales and in accordance with CM-12, CM-13, CM-14. • The survey will be terminated if there are 3 consecutive days of no seismic acquisition due to the presence of migrating humpback whales.	If observed numbers of whales are higher than expected, as determined by there being three or more whales within the shutdown / power down zones in 24 hours then acquisition will cease for 24 hours, if no further sightings of humpback whales then the survey can recommence.	CM-14-EPS-1	Completed marine fauna sighting datasheet Vessel logs with records of all soft starts, shut down procedures and timing of acquisition. MFO records/reports (daily, weekly) show that marine fauna interaction procedures are followed during survey including precaution zones, soft starts and recommencement procedures Completed report within 2 months of survey	EPO-7 EPO-10 EPO-11 EPO-12 EPO-13 EPO-14

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-15	Seismic source validation	In the event a seismic source is selected for the Activity that is different to the modelled source options, acoustic source modelling will be undertaken to confirm that the far-field source level specifications of the seismic source selected for the 3D seismic survey are consistent with those assessed in this EP.	CM-15-EPS-1	Acoustic modelling report.	EPO-10 EPO-11 EPO-12 EPO-13 EPO-14 EPO-15 EPO-16 EPO-17 EPO-19 EPO-20 EPO-21
CM-16	No acquisition during peak humpback whale migration	No seismic survey acquisition after the 31 July each year. Survey operations will be suspended for 24 hours if there are 3 or more humpback whale sightings within the shutdown/ power down zones within 24 hours. The survey may commence following the 24 hours with no seismic acquisition. If the survey is required to shutdown/ power-down 3 or more times within 24 hours for 3 consecutive days as a result of sighting humpback whales, this is taken as peak migration and the survey will end for that year.	CM-17-EPS-1	No seismic survey activity recorded on or after 1 August. Seismic survey acquisition will cease for 24 hours if 3 or more humpback whale sightings within the shutdown/ power down zones within 24 hours. The survey will cease if there are 3 or more shutdown/ power-downs per day for 3 consecutive days as a result of sighting whales Vessel Logs with records of acquisition dates	EPO-10 EPO-11
CM-17	No seismic source emissions in Habitat Critical for flatback turtles	No seismic source emissions within 'Habitat Critical' for flatback turtles between October and March.	CM-16-EPS-1	Daily report detailing completed operational activities and vessel locations	EPO-13

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-18	*UK Diving Medical Advisory Committee (DMAC 12)* Identification of presence of divers, concurrent operations with divers.	Notify pearl farm operators of the proposed seismic survey that may undertake diving activities within 45 km of the seismic source.	CM-18-EPS-1	Consultation records	EPO-20
		Where diving and seismic activity occur within 30 km of each other, a joint risk assessment is conducted.	CM-18-EPS-2	Consultation records and record of joint risk assessment completed where relevant	
CM-19	Procedure for discharge the seismic source within close proximity to subsea communication cables	No discharge of the seismic source within 100 m of the North West Cable System.	CM-19-EPS-1	Daily operational reports	EPO-22
CM-20	Consultation with other seismic survey operators if concurrent seismic surveys with Keraudren Extension are expected within the Pilbara Demersal Scalefish Fishery (trawl, trap and line) or Mackerel Managed Fishery (Area 2).	If concurrent seismic surveys with Keraudren Extension are expected within the Pilbara Demersal Scalefish Fishery (trawl, trap and line) or Mackerel Managed Fishery (Area 2), Santos will: • Consult with the seismic survey operator on ways to minimise interference with relevant commercial fishers. • Provide the survey operator proposed survey plans and vessel contact details, and the details of any agreed on-water vessel interaction protocols with commercial fishers. • Provide the survey operator commencement and cessation notifications, and daily operational reports.	CM-20-EPS-1	Consultation records	EPO-23

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-21	Seismic source separation distance during concurrent surveys: minimum 20 km while operating.	During operation of the seismic sources, a minimum separation distance of 20 km shall be maintained between the Keraudren Extension seismic source and a third-party seismic source.	CM-21-EPS-1	Daily operational reports	EPO-23
CM-22	General chemical management procedures	Safety data sheet (SDS[8]) available for all chemicals to aid in the process of hazard identification and chemical management.	CM-22-EPS-1	Completed inspection checklist	EPO-3 EPO-4 EPO-6
		Chemicals managed in accordance with SDS in relation to safe handling and storage, spill-response and emergency procedures, and disposal considerations.	CM-22-EPS-2		
CM-23	Hazardous chemical management procedures	For hazardous chemicals including hydrocarbons, the following standards apply to reduce the risk of an accidental release to sea: • Storage containers closed when the product is not being used; • Storage containers managed in a manner that provides for secondary containment in the event of a spill or leak; • Storage containers labelled with the technical product name as per the safety data sheet (SDS); • Spills and leaks to deck, excluding storage bunds and drip trays, immediately cleaned up; • Storage bunds and drip trays do not contain free flowing volumes of liquid; and • Spill response equipment readily available.	CM-23-EPS-1	Completed inspection checklist	EPO-3 EPO-4 EPO-6
CM-24	Sewage treatment system	Pursuant to MARPOL Annex IV, vessel has a current International Sewage Pollution Prevention (ISPP) Certificate or equivalent which confirms that required	CM-24-EPS-1	Current ISPP certificate or equivalent	EPO-4 EPO-6

[8] SDS or MSDS.

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		measures to reduce impacts from sewage disposal are in place.			
		Sewage discharged in accordance with MARPOL Annex IV.	CM-24-EPS-2	Completed inspection checklist	
		Preventive maintenance on sewage treatment equipment is completed as scheduled.	CM-24-EPS-3	Maintenance records	
CM-25	Waste (garbage) management procedure	Waste management procedure implemented to reduce the risk of unplanned release of waste to sea. The procedure includes standards for: • Bin types; • Lids and covers; • Waste segregation; and • Bin storage.	CM-25-EPS-1	Completed inspection checklist	EPO-4 EPO-6
		Food waste is disposed in accordance with MARPOL Annex V.	CM-25-EPS-2	Completed garbage disposal record book or recording system	
		Vessel's garbage record book maintained to record quantities and types of waste in accordance with MARPOL.	CM-25-EPS-3	Up-to-date Garbage Record Book	
CM-26	Oily water treatment system	Oily mixtures only discharged to sea in accordance with MARPOL Annex I.	CM-26-EPS-1	Completed inspection checklist	EPO-4 EPO-6
			CM-26-EPS-2	Oil record book.	
		Preventative maintenance on oil filtering equipment completed as scheduled.	CM-26-EPS-3	Maintenance records or evidence of maintenance in operational reports	
		Pursuant to MAPROL Annex I, as relevant to class, vessel will have an International Oil Pollution Prevention (IOPP) Certificate which confirms that required measures to reduce impacts of planned oil discharges are in place.	CM-26-EPS-4	Current IOPP certificate or equivalent	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-27	Deck cleaning product selection procedure	Deck cleaning products planned to be released to sea meet the criteria for not being harmful to the marine environment according to MARPOL Annex V; or Gold/Silver/D or E rated through OCNS; or have a completed Santos ecotoxicological risk assessment so that only environmentally acceptable products are used.	CM-27-EPS-1	Safety data sheet (SDS) and product supplier supplementary data as required	EPO-4 EPO-6
CM-28	Clean up of oil/ lubricant spills to deck in accordance with vessel SOPEP	Reported spills to deck are cleaned up as per the vessel SOPEP.	CM-28-EPS-1	Incident report details spill clean up	EPO-4 EPO-6
CM-29	Waste incineration managed in accordance MARPOL and Marine Orders as appropriate	Waste incineration managed in accordance with MARPOL Annex VI.	CM-29-EPS-1	Completed waste record book or recording system	EPO-6
CM-30	MARPOL compliant fuel oil (MDO/MGO) will be used during the Activity.	MARPOL-compliant fuel oil (MDO/MGO) will be used during the Activity.	CM-30-EPS-1	Fuel bunkering records	EPO-6
CM-31	Air pollution prevention certification	Pursuant to MARPOL Annex VI, vessel will maintain a current International Air Pollution Prevention (IAPP) Certificate or equivalent which confirms that measures to prevent ozone-depleting substance (ODS) emissions, and reduce NOx, SOx and incineration emissions during the Activity are in place.	CM-31-EPS-1	Current IAPP certificate or equivalent	EPO-5 EPO-6
CM-32	Ozone-depleting substance handling procedures	Ozone-depleting substances (ODS) managed in accordance with MARPOL Annex VI to reduce the risk of an accidental release of ODS to air.	CM-32-EPS-1	Completed ODS record book or recording system	EPO-5 EPO-6
CM-33	All vessel engines to be maintained in accordance	Documented maintenance program is in place for equipment on vessels, that provides a status on the maintenance of equipment.	CM-33-EPS-1	Vessel maintenance records show that there are no outstanding maintenance activities for emission generating equipment.	EPO-5 EPO-6

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
	with manufacturers specifications				
CM-34	IFO and HFO use and storage restrictions	IFO and HFO will not be used as the fuel source during the survey.	CM-34-EPS-1	Vessel operational logs	EPO-6
		If IFO and/or HFO is proposed to be on board a vessel then a risk assessment shall be completed. For the vessel to store IFO and/or HFO then the risk assessment must conclude that the high cost of removing and disposing of the IFO and/or HFO onshore is grossly disproportionate to the low risk of a vessel collision and rupture of a fuel tank containing small volumes of the fuel.	CM-34-EPS-2	Completed risk assessment.	
		IFO and/or HFO stored on a vessel must not be stored in tanks that have direct exposure to the marine environment.	CM-34-EPS-2	Vessel operational logs	
CM-35	Oil pollution emergency plan (OPEP)	In the event of a hydrocarbon spill to sea, the Santos OPEP requirements are implemented to mitigate environmental impacts.	CM-35-EPS-1	Completed incident documentation	EPO-3 EPO-6
CM-36	Vessel spill response plans (SOPEP/SMPEP)	Vessels have, and implement, a Shipboard Marine Pollution Emergency Plan (SMPEP) or SOPEP pursuant to MARPOL Annex I, as appropriate for vessel class.	CM-36-EPS-1	Approved SMPEP or SOPEP	EPO-3 EPO-6
		SMPEP/SOPEP spill response exercises conducted not less often than every three months to ensure personnel are prepared.	CM-36-EPS-2	Spill exercise records or evidence of a spill exercise in an operational report	
CM- 37	Marine diesel volume restrictions	The maximum volume of MGO/MDO stored in a single tank shall not exceed 1,065 m^3.	CM-37-EPS-1	Written directive to vessel contractor	EPO-3
CM-38	Maritime dangerous goods code	Dangerous goods managed in accordance with International Maritime Dangerous Goods Code (IMDG	CM-38-EPS-1	Completed Multimodal Dangerous Goods Form	EPO-4

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		Code) to reduce the risk of an environmental incident, such as an accidental release to sea or unintended chemical reaction.		Completed inspection checklist	EPO-6
CM-39	Deck drainage control measures (such as scupper plugs) in areas where chemicals and hydrocarbons are stored and frequently handled	Scupper plugs or equivalent deck drainage control measures available where chemicals and hydrocarbons are stored and frequently handled.	CM-39-EPS-1	Weekly environmental inspection checklist	EPO-4 EPO-6
CM-40	Bulk refuelling transfer procedures	Bulk fuel transferred in accordance with the vessel contractor procedures to reduce the risk of a release to sea. The procedures will require: • Hose integrity: certified hoses inspected prior to use • Hose floatation: bulk hoses in the water fitted with floatation collars. • Hose connections: hoses used for hydrocarbons fitted with self-sealing (dry-break) connections and self-sealing break-away connections when two or more hoses are joined together. • Valve alignment: a vessel supervisor checks that all valves are lined up correctly. • Tank venting: air vents for hydrocarbon storage tanks bunded if there is a risk of spill to deck. • Supervision: dedicated hose watch person while pumping bulk fuel. • Communications: constant radio communications between two vessels. • Inventory control: a vessel supervisor monitors tank fill levels. • Emergency shutdown: vessel emergency pumping stop tested before each transfer operation.	CM-40-EPS-1	Completed procedural documents, for example work permits, job safety analysis forms, checklists, etc. Spill details contained in incident documentation.	EPO-3 EPO-4 EPO-6

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-41	Bunkering drill requirements.	Bunkering drill undertaken by seismic survey vessel prior to first bunker operations in operational area, unless bunkering drill completed within the previous three months in Australian waters.	CM-41-EPS-1	Vessel logs record bunker drill undertaken.	EPO-3 EPO-4 EPO-6
CM-42	Dropped object prevention procedure	Vessels lifting procedures include the following control measures to reduce the risk of objects entering the marine environment: • Lifting equipment certification and inspection. • Lifting crew competencies. • Preventative maintenance on cranes.	CM-42-EPS-1	Completed inspection checklist	EPO-6 EPO-8
		Objects dropped overboard are recovered (if possible) to mitigate the environmental consequences from objects remaining in the marine environment, unless the environmental consequences are negligible, or safety risks are disproportionate to the environmental consequences.	CM-42-EPS-2	Fate of dropped objects detailed in incident documents	
		Material handling and lifting equipment and remediation equipment maintained in accordance with the PMS.	CM-42-EPS-3	Vessel PMS schedule and maintenance records	
		Lifting equipment maintained and certified.	CM-42-EPS-4	Lifting equipment certification valid and current	
CM-43	Equipment maintenance in accordance with PMS	Documented maintenance program is in place for equipment on vessels, that provides a status on the maintenance of equipment.	CM-43-EPS-1	Vessel equipment maintenance records show that there are no outstanding maintenance activities for equipment.	EPO-6 EPO-8
CM-44	Streamers are fitted with floatation devices	Solid-filled seismic streamer contains buoyancy devices and is fitted with marker buoys.	CM-44-EPS-1	End of survey report provides diagrams and report of streamers	EPO-6 EPO-7 EPO-8

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-45	Streamer deployment / retrieval procedure	Seismic streamers undergo regular inspection and planned maintenance system checks on streamer towing systems for wear and damaged components. These components are replaced on an 'as required' basis.	CM-45-EPS-1	Seismic streamers maintenance log	EPO-6 EPO-7 EPO-8
		A secondary retaining/ attachment device is utilised.	CM-45-EPS-2	End of survey report provides diagrams and report of streamers	
		Relevant personnel are trained in requirements of the procedures for streamer deployment and retrieval.	CM-45-EPS-3	Training records	
CM-46	Streamer towing depth	Streamers are towed at least 10 m above the seabed to avoid seabed disturbance.	CM-46-EPS-1	Streamer deployment procedure includes streamers must be towed at a minimum of 10m above the seabed.	EPO-8
CM-47	Streamers have locating devices fitted	Deployed streamers will be fitted with locating devices and tracked on the seismic survey vessel.	CM-47-EPS-1	Vessel streamer specifications Streamer location tracking on boarding vessel.	EPO-8
CM-48	Use of a 'turtle friendly' tail buoy with a single tow point, undercarriage with a sloped front and no gap, thus no turtle entrapment sites. Or if a twin fin design tail buoy is to be used as a result of operational logistics a turtle guard (exclusion and/ or deflection) will be implemented.	Tail buoys on the streamers will be fitted with turtle guards to minimise the risk of entanglement of marine fauna.	CM-48-EPS-1	Vessel streamer specifications	EPO-7

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-49	DPIRD vessel check tool (applied to vessels), and immersible equipment clean.	Vessels to be risk assessed using the DPIRD vessel check tool demonstrating vessel is at 'low risk' of introducing invasive marine species.	CM-49-EPS-1	Completed DPIRD vessel check report demonstrating vessel are low risk.	EPO-2
		Immersible equipment to be cleaned to 'low risk' of introducing invasive marine species if being deployed to sea during the Activity.	CM-49-EPS-2	Verification that immersible equipment was cleaned to low risk (e.g. photos, inspection reports)	
		Santos will forward the most current Western Australian Prevention List for Introduced Marine Pests to all vessel operators prior to each survey stage to ensure they are aware of potential invasive marine pest species and the reporting requirements	CM-49-EPS-2	Verification that current Western Australian Prevention List has been provided to vessel operators.	
CM-50	Anti-foulant system	Anti-foulant systems are maintained in compliance with International Convention on the Control of Harmful Anti-Fouling Systems on Ships.	CM-50-EPS-1	Current International Anti-Fouling System Certificate.	EPO-2
CM -51	Biosecurity risk management	Pursuant to the Biosecurity Act 2015 and the Biosecurity (Exposed Conveyances – Exceptions from Biosecurity Control) Determination 2016 the seismic survey vessel level of biosecurity risk is assessed as 'low' by the vessel contractor or Commonwealth Department of Agriculture prior to interacting with domestic support vessels and aircraft.	CM-51-EPS-1	Written evidence that the seismic survey vessel meets the requirements set out in the Determination.	EPO-2
CM-52	Ballast water management plan	Pursuant to the *Biosecurity Act 2015* and *Australian Ballast Water Management Requirements 2017*, vessels carrying ballast water and engaged in international voyages shall manage ballast water in accordance with a Ballast Water Management Plan so that marine pest species are not introduced. The plan shall include: • Ballast water exchange; • Ballast water management systems; • Sediment management;	CM-52-EPS-1	Administrator-approved ballast water management plan.	EPO-2
			CM-52-EPS-2	Completed ballast water record book or log	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		• Duties of officers and crew; • Coordination with local authorities; and • Record keeping.			
CM-53	Recreational fishing restrictions	Seismic survey and support vessels within the operational area are prohibited from fishing.	CM-53-EPS-1	No recorded breaches Environment induction	EPO-7
CM-54	Regulatory notifications issued to NOPSEMA	NOPSEMA notified that the Activity is to commence at least 10 days before the Activity commences.	CM-54-EPS-1	Submitted Regulation 29(1)	EPO-1
		NOPSEMA notified that the Activity is completed within 10 days after finishing.	CM-56-EPS-2	Submitted Regulation 29(2) notification form	
CM-55	Activity assurance reviews	Prior to the seismic survey, Santos will conduct a Pre-activity Assurance Review following the review process outlined in **Section 8.16.1** to ensure that environmental impact and risk levels remain acceptance and ALARP for the duration of this EP.	CM-55-EPS-1	Completed assurance review	All

8.6.2 Commercial Fishers Payment Claim Protocol

Santos has made a commitment that commercial fishing licence holders are no worse off as a result of the seismic survey (refer to **Table 8-2**). Further, that Santos will assess the merit of all evidence-based payment claims made by commercial fishing licence holders relating to temporary loss of fish catch, displacement costs and equipment damage or loss (refer to **Table 8-3**). The purpose of the following section is to provide additional detail about these commitments:

Loss of Catch Costs

- All evidence-based payment claims made by commercial fishing licence holder that a survey stage caused a temporary loss of fish catch from within the operational area will be assessed for merit by Santos.
- Payment to a commercial fishing licence holder will be made for each month there is a loss of catch by the commercial fishing licence holder based on an assessment of what the commercial fishing licence holder would have caught in that month from within the operational area “but for” the survey stage.
- A loss of catch will be concluded if there is a reduction in the catch per unit of effort for each species calculated over a month, compared to the average historical catch per unit of effort for the same species and corresponding month.
- If a loss of catch is substantiated, payments will be calculated based on the reduced kilograms per species caught, multiplied by the market price per kilogram at the time the catch would have been sold.
- Loss of catch payments will be assessed for the months of each survey stage and for up to 6 months from the completion date of each survey stage.
- Where a commercial fishing licence holder wants to receive a loss of catch payment, they will need to provide Santos with monthly catch disposal records and multiple years of historical data to allow average monthly catch rates per species to be determined.
- For Santos to accept a payment claim for a temporary loss of catch the commercial fishing licence holder must provide evidence that their vessel(s) continued to fish over the claim period.

Displacement Costs

- All evidence-based payment claims made by commercial fishing licence holder that a survey stage caused a fishing vessel to be temporarily displaced from the operational area at a cost to the licence holder will be assessed for merit by Santos.
- Where a commercial fishing licence holder is displaced from the operational area such that it is required to relocate their operations to another area during the survey stage, Santos will make a one off payment to reimburse operational expenses which are in addition to those the commercial fishing licence holder would have borne “but for” the seismic survey stage.
- Where a commercial fishing licence holder intends to make an operational expense claim for relocation, they will need to notify Santos as soon as practicable and prior to relocating, and state why the seismic survey has caused them to relocate.
- Where a commercial fishing licence holder wants to be reimbursed for any relocation operational expenses, they will need to provide Santos with evidence of the operating costs of bait, fuel, wages and any other costs that are additional to the costs that would have been incurred to catch the fish “but for” the relocation.

Equipment Damage or Loss Costs

- All evidence-based payment claims made by commercial fishing licence holder that a survey stage caused fishing equipment located within the operational area to be damaged or lost at a cost to the licence holder will be assessed for merit by Santos.
- Where a commercial fishing licence holder intends to make an equipment damage or loss expenses claim, they will need to evidence that Santos was made aware of the specific equipment location and deployment dates.
- Where a commercial fishing licence holder intends to make an equipment damage or loss expenses claim, they will need to have notified Santos within 14 days of the equipment being damaged or lost and provide evidence of the damage.

General Provisions

- Survey stage is defined as the proportion of 3D seismic survey acquired in any given calendar year.
- Santos will assess requests for administrative support to help commercial fishing licence holders collate historical fishing data required for an evidence-based payment claim.
- Santos is offering a means for commercial fishers to claim for their time spent progressing a make good payment claim. The process for making a claim and the claim limitations will be discussed with individual commercial fishers. Santos expects the claim amount to be capped, to be for reasonable expenses not normally incurred by commercial fishers and be itemised with evidence to support any claim.
- Santos' preference is for 10 years of data to determine the average historical catch per unit of effort per species per month. However, this will be assessed on a case-by-case basis.
- Where a commercial fishing licence holder wants to receive any payment, they will need to lodge a claim with Santos within 8 months of the survey stage completion. The 8 months is intended to give fishers reasonable time to prepare a claim and to minimise overlap between subsequent survey stages.
- Santos will not accept a claim under this EP if the claim covers the same time, area, fishing activity and equipment made in another claim for a different seismic survey.
- If there are any issues with the required evidence, loss of catch determination or payment amount, Santos will, in consultation with the commercial fishing licence holder, engage an independent relevant expert to determine the issue.
- Payment claims substantiated and accepted by Santos will be paid to the claimant in accordance with Santos payment terms and conditions, and within 60 days.

The above arrangements will not apply if Santos enters into a commercial agreement with a commercial fishing licence holder relating to these matters.

A survey stage is defined as "the portion of the survey acquired within any given calendar year".

The loss of catch payments will be assessed for the months of each survey stage and for up to 6 months from the completion date of each survey stage. This is considered by Santos to be a reasonable time frame for commercial fishing licence holders to claim payments and is consistent with the impact assessment that post-survey fish catch levels are expected to return within a short period (days to weeks) to typical catch levels relative to fishing effort. Based on limited research and the anecdotal evidence Santos considers that 6 months following completion of the survey for fishers to lodge claims is appropriate. In addition, beyond 6 months there are other variables that could affect fish catch levels such as, but not limited to, other nearby seismic surveys, natural events and general fishery harvesting level and quotas. In addition, CSIRO (2017) could not find an example of compensation being offered for future risks to fisheries caused by seismic surveys.

Santos is committed to ensuring commercial fishing licence holders are no worse off as a result of the seismic survey.

8.7 Workforce Involvement and Stakeholder Communication

Daily operational meetings will be held offshore at which HSE will be a standing agenda item. It is a requirement that supervisors attend daily operational meetings and all personnel attend daily toolbox/ pre-shift meetings.

Toolbox meetings will be regularly held offshore to plan jobs and discuss work tasks, including HSE risks and controls.

HSE performance will be monitored and reported during the Activity, and performance metrics (such as the number of environmental incidents) will be regularly communicated to the workforce.

Workforce involvement and environmental awareness will also be promoted by encouraging offshore personnel to report marine fauna sightings and marine pollution (e.g. oil on water).

Ongoing stakeholder management strategies are discussed in **Section 3**.

8.8 Information Management and Document Control

This EP and OPEP, as well as approved MoC documents, are controlled documents and current versions will be available on Santos' intranet. Vessel contractors are also required to maintain current versions of HSE documents on their facilities (i.e. vessels).

Santos, and the vessel contractors, will maintain records so that emissions and discharges can be determined or estimated. The following types of records will be used in assessing whether environmental performance outcomes and standards have been met:

- Audit and inspection reports;
- Ballast-water log;
- Certificates;
- Daily operational reports;
- Emails;
- Fuel usage logs;
- Garbage record books;
- Incident records and reports;
- Inspection checklists;
- Maintenance records and work orders;
- MoC documents;
- Marine fauna sighting datasheets;
- Oil record books;
- ODS record books;
- Stakeholder consultation logs;
- Survey reports;
- Technical reports; and

- Waste manifests and receipts.

Such records will be maintained for a period of five years. Contractors are required to make these records available upon request.

8.9 Operations Management

Daily reports will be completed by the vessels as a means of monitoring completed and planned activities, and any HSE accidents or incidents.

All personnel are required to adhere to the contractor safety management systems and respective systems of work. Examples include, but are not limited to, preventative maintenance systems and work orders, permits to work, safe work procedures, work instructions, job hazard analysis, job checklists, behavioural observation programs, emergency response and record keeping. Compliance with vessel systems of work will be monitored through work supervision, inspections, audits and after action reviews (**Section 8.16**).

Collectively, these represent a comprehensive and integrated system through which operational control measures (e.g. refuelling) described in this EP will be implemented.

8.10 Management of Change

Proposed changes to this EP and OPEP will be managed in accordance with Santos' *Environment Management of Change Procedure* (EA-91-IQ-10001) – MoC process. The MoC process provides a systematic approach to initiate, assess, document, approve, communicate and implement changes to EPs and OPEPs.

The MoC process considers Regulation 7, 8 and 17 of the OPGGS(E) Regulations and determines if a proposed change can proceed and the manner in which it can proceed. The MoC procedure will determine whether a revision of the EP is required and whether that revision is to be submitted to NOPSEMA. For a change to proceed, the associated environmental impacts and risks must be demonstrated to be acceptable and ALARP. Additional stakeholder consultation may be required depending on the nature and scale of the change. Additional information on the MoC process is provided in **Figure 8-1.**

The MoC procedure also allows for the assessment of new information that may become available post EP acceptance (refer to **Section 8.16**). For example, new management plans or conservation advice. If new information is identified, this is treated as "Change that has an impact on Environment Plan" in **Figure 8-1** and the MoC process is followed accordingly.

Accepted MoCs become part of the in-force EP or OPEP, will be tracked on a register and made available on Santos' intranet. Where appropriate, Santos' environmental compliance register will be updated to ensure changes to control measures or environmental performance standards are communicated to the workforce and implemented. Any MoC will be distributed to the relevant persons, and the most relevant management position (e.g. geophysical manager, vessel masters) will ensure the MoC is communicated and implemented, which may include crew meetings/ briefings/ communications as appropriate for the change.

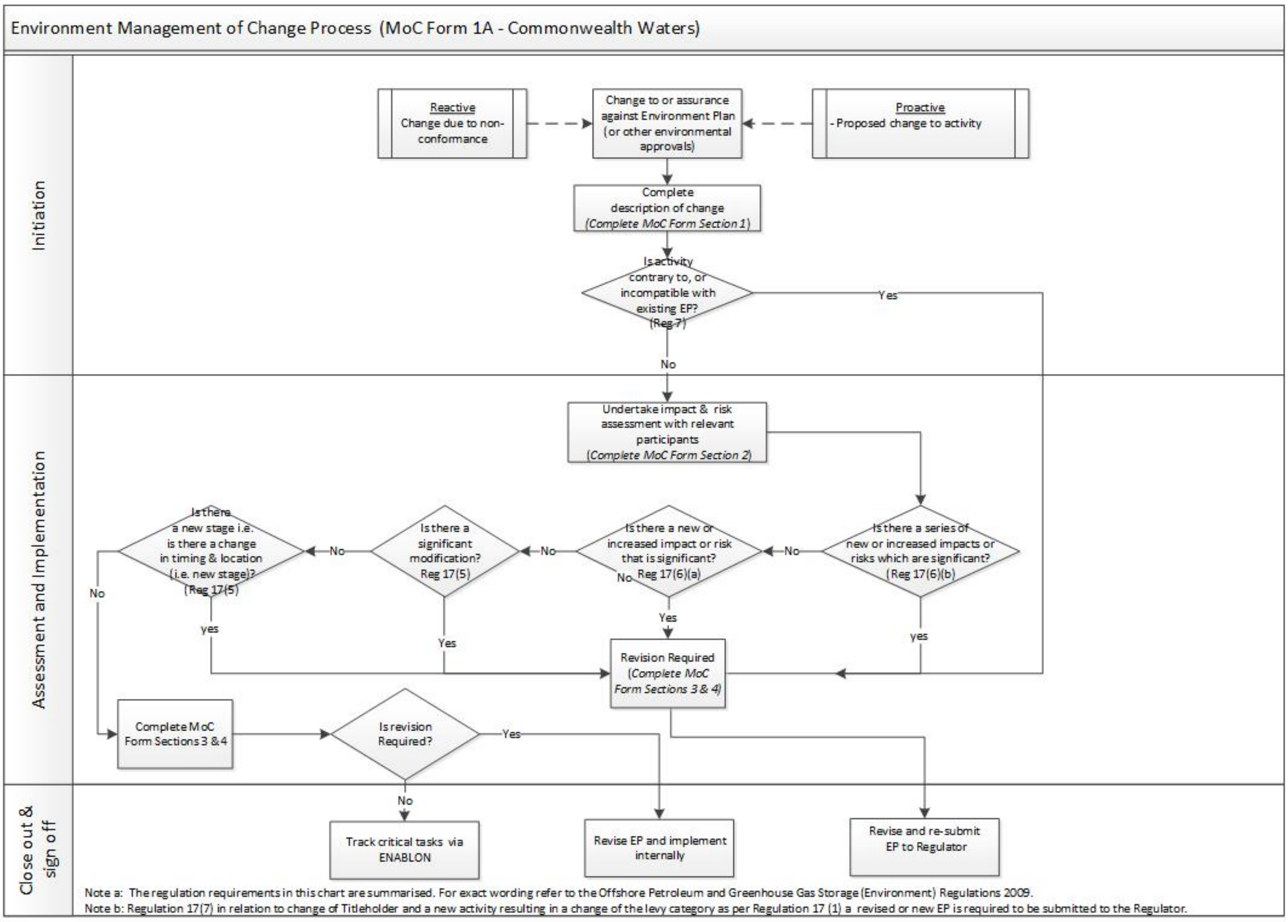

Figure 8-1: Environment Management of Change Process

8.11 Emergency Preparedness and Response

The vessels are required to have and implement incident response plans, such as an emergency response plan and SMPEP/ SOPEP. Regular incident response drills and exercises (e.g. as defined in emergency response plan, SMPEP/ SOPEP etc.) will be carried out on activity vessels to refresh the crew in using equipment and implementing incident response procedures.

Santos will implement the *Keraudren Extension 3D Marine Seismic Survey Oil Pollution Emergency Plan* (SO-91-BO-20006.02) in the event of a significant hydrocarbon spill (level 2 or 3). To maintain a state of oil spill preparedness, personnel with OPEP responsibilities will be made aware of their obligations, oil spill response equipment will be maintained, contracts with critical equipment and personnel suppliers will be managed, and agreements will be in place with national regulatory agencies for support in oil spill response. Santos will also implement its oil spill response exercise and training schedule. Further information on oil spill response is provided in the OPEP.

A communications test for the Activity is completed prior to commencement of the activities (refer to the OPEP).

8.12 Incident Reporting, Investigation and Follow-up

All personnel will be informed through inductions and daily operational meetings of their duty to report HSE incidents and hazards. Reported HSE incidents and hazards will be shared during daily operational meetings, and HSE incidents and hazards will be documented in the incident management systems as appropriate. Significant HSE incidents will be investigated using root cause analysis.

Environmental recordable and reportable environmental incidents will be reported to NOPSEMA, and other regulators as required, in accordance with **Table 8-4.** The incident reporting requirements from **Table 8-4.** will be provided to vessels with special attention to the reporting time frames to ensure accurate and timely reporting.

Santos will be responsible for reporting all reportable incidents under Regulation 26 of the OPGGS (E) Regulations within 2 hours. Recordable incidents will also be reported according to the requirements of Regulation 26B of the OPGGS (E) Regulations by Santos no later than 15 days after the end of the calendar month. For the purposes of this Activity, a reportable incident is defined as an incident relating to the Activity that has caused, or has the potential to cause, moderate to significant environmental damage (ranked a C, D or E in the Santos Environmental Consequence Matrix (**Appendix G**)).

Recordable incidents that are a breach of EPO or EPS could include:

- Uncontrolled release of hydrocarbon or hazardous chemical to the marine environment;
- Uncontrolled significant release of ozone depleting substance (ODS);
- Unrecovered container (e.g. 44-gallon drum) of hydrocarbon, chemical or waste to sea;
- Harm or mortality to marine fauna whether attributable to the vessel or not; and
- Large oil slick or sheen on the sea surface whether attributable to the vessel or not.

8.13 Regulatory Notifications

In accordance with Regulation 29 and 30, NOPSEMA will be notified at least 10 days before the commencement and within 10 days after finishing each seismic survey. As such, multiple commencement and cessation notifications will be submitted over the duration of the EP.

A Regulation 25A end-of-operation of EP notification will be submitted within 12 months of the final Regulation 29(2) notification, unless agreed otherwise with NOPSEMA.

These notification requirements are summarised in **Table 8-4.** Additional marine user and stakeholder notification requirements are detailed in **Table 8-3.**

8.14 Compliance Reporting

A detailed environmental performance report will be submitted within three months of submission of Regulation 29(2) end-of-activity notification to NOPSEMA. This report will meet the requirements of Regulation 26(C).

These compliance reporting requirements are summarised in **Table 8-4**.

8.15 Monitoring and Recording of Emissions and Discharges

Discharges associated with this Activity will limited to those allowed for under maritime law. Therefore, all discharges will be recorded and controlled in accordance with maritime monitoring and recording requirements. Any non-compliance with discharge requirements will be included in the monthly recordable incident report to NOPSEMA.

8.16 Reviews, Audits and Inspections

This part of the implementation strategy provides for monitoring, recording, audit, management of non-conformance and review of environmental performance including demonstration that the environmental performance outcomes and standards are being met.

8.16.1 Reviews

Given this is a three-year EP, it is recognised that the following parametres may change over time:

- Legislation;
- Regulator policy and guidance;
- Businesses conditions, systems, processes and people;
- Industry practices;
- Science and technology;
- Societal and stakeholder expectations;
- Petroleum industry survey, exploration and development activities;
- Knowledge about control measure effectiveness and environmental impacts and risks;
- Financial assurance requirements.

Through maintenance of up to date knowledge (**Section 8.16.2**), these changes will be identified. Should a change to the EP be required, then an assessment will be conducted and documented in accordance with Santos' *Environmental Management of Change Procedure* (EA-91-IQ-10001) (**Section 8.10**).

Additionally, Santos will conduct a Pre-Activity Assurance Review prior to the commencement of a seismic survey provided for in this EP. The review will assess changes to the abovementioned parameters, and ensure that systems, procedures and people are in place for the proposed seismic survey to comply with the requirements of this EP. Through this process, Santos will demonstrate for each seismic survey that:

- the environmental impacts and risks of the Activity continue to be identified and reduced to a level that is as low as reasonably practicable; and
- control measures detailed in the environment plan are effective in reducing the environmental impacts and risks of the Activity to as low as reasonably practicable and an acceptable level; and
- environmental performance outcomes and standards set out in the environment plan will be met.

8.16.2 Maintaining Up to Date Knowledge

To ensure that Santos maintains up to date knowledge of the parameters described in **Section 8.16.1** the following tasks are undertaken:

- Member of APPEA to ensure that potential changes in legislation, industry practice and other issues that may affect EP implementation are known;
- Stakeholder, including regulator, management in accordance with **Section 3**;
- Undertaking annual review of *Values and Sensitivities of the Western Australian Marine Environment* (EA-00-RI-10062, **Appendix B**) which includes completing a new EPBC Act Protected Matters Search; reviewing relevant legislation, government guidance material and conservation management plan updates; and reviewing new published, relevant scientific papers;
- Monitoring the AIMS North West Shoals to Shore Research Program, specifically the fish and pearl oyster impact studies;
- Undertaking annual spill response exercises to ensure spill response arrangements and capability are adequate;
- Reviewing the DPIRD Western Australian Prevention List for Introduced Marine Pests prior to each survey stage;
- Subscription to NOPSEMA's "The Regulator" issued quarterly;

- Subscriptions to various other regulator updates; and
- Regular liaison meetings with regulators, including NOPSEMA.

If new information is identified through these processes, this will be treated as "Change that has a potential to impact on Environment Plans" as described in **Figure 8-1**. Should a change to the EP be required, then an assessment will be conducted and documented in accordance with Santos' *Environmental Management of Change Procedure* (EA-91-IQ-10001) (**Section 8.10**).

8.16.3 Audits

Santos audit plans and schedules are reviewed and updated at the beginning of each calendar year and cover all Santos facilities and activities. Santos' audit schedule may be amended to accommodate operational priorities, activity risk, and personnel availability or should audit demands be high during certain periods (e.g. regulatory audits, contractor audits etc.). Seismic surveys conducted under this EP will be considered in the development of the audit schedule.

Audit criteria is typically a selection of control measures and environmental performance standards and outcomes; however, may also include parts of the activity description or stakeholder consultation and implementation strategies.

Audits may be onshore or offshore, and audit findings may include opportunities for improvement and non-conformances. Audit non-conformances are managed as described below. Audit reports will be given a document number and managed as a controlled document.

8.16.4 Inspections

During an activity, frequent (weekly/monthly) HSE inspections will be conducted to identify hazards, incidents and EP non-conformances. Santos representatives will conduct EP compliance inspections throughout the Activity to ensure compliance against all of the environmental performance outcomes and standards of this EP (**Table 8-3**). Any in-field opportunities for improvement or corrective actions will be discussed during the inspection with the work area supervisor and/or crew. Inspection reports will be distributed to Santos' relevant personnel (e.g. Santos on-board representatives), and HSE Department representatives, for review.

8.16.5 Non-Conformance Management

EP non-conformances will be addressed and resolved by a systematic corrective action process. Non-conformances will be entered into Santos' incident management system. Once entered, corrective actions, time frames and responsible persons (including action owners and event validators) will be assigned. Corrective action 'close out' will be monitored using a management escalation process.

8.17 Continuous Improvement

For this EP, continuous improvement will be achieved as a result of:

- Improvements identified from the review of Santos HSE key performance indicators (KPIs);
- Actions arising from Santos HSE improvement plans;
- Corrective actions and feedback from HSE audits and inspections, incident investigations and after-action reviews;
- Opportunities for improvement and changes identified during pre-activity reviews, MoC documents and environmental performance reviews;
- Actions taken to address concerns and issues raised during the ongoing stakeholder management process (**Section 3**); and

- Identified continuous improvement opportunities will be assessed in accordance with Santos' *Environmental Management of Change Procedure* (EA-91-IQ-10001) (refer to **Section 8.10**) to ensure any potential changes to this EP, or OPEP, are managed in accordance with the OPGGS(E) Regulations and in a controlled manner.

Table 8-4: Regulator Activity Notification and Reporting Requirements

Regulation	Requirement	Required Information	Timing	Type	Recipient
Before the Activity					
Regulation 29 & 30 - Notifications	NOPSEMA and DMIRS must be notified that the Activity is to commence.	Complete NOPSEMA's Regulation 29 and 30 Start or End of Activity Notification form for both notifications.	At least 10 days before the Activity commences.	Written	NOPSEMA and DMIRS
N/A	Australian Hydrographic Office (AHO)	Pre-start notification.	At least 21 days before the Activity commences.	Written	AHO
N/A	AMSA Joint Rescue Coordination Centre (JRCC) Notification		48 hrs. prior to Activity commencement.	Written	AMSA
Department of Agriculture, Compliance Division	Voluntary biosecurity risk assessment under the Biosecurity Act 2015	To have the biosecurity risk status assessed, offshore vessel contractors must apply to the department at least one month prior to project commencement.	At least one month before the survey.	Written	DoA
During the Activity					
Regulation 16(c), 26 & 26A – Reportable Incident	NOPSEMA must be notified of any reportable incidents. For the purposes of Regulation 16(c), a reportable incident is defined as: • An incident relating to the Activity that has caused, or has the potential to cause, moderate to significant environmental damage In the event of an incident impacting on State waters, this will also be reported to DMIRS.	The oral notification must contain: • All material facts and circumstances concerning the reportable incident known or by reasonable search or enquiry could be found out; • Any action taken to avoid or mitigate an adverse environmental impact of the reportable incident; and • The corrective action that has been taken, or is proposed to be taken, to sop, control or remedy the reportable incident.	As soon as practicable, and in any case not later than 2 hours after the first occurrence of a reportable incident, <u>or</u> if the incident was not detected at the time of the first occurrence, at the time of becoming aware of the reportable incident.	Oral	NOPSEMA
		A written record of the oral notification must be submitted. The written record is not required to include anything that was not included in the oral notification.	As soon as practicable after the oral notification.	Written	NOPSEMA NOPTA DMIRS National Ship Strike Database

Regulation	Requirement	Required Information	Timing	Type	Recipient
	Any ship strike incident will also be reported to the National Ship Strike database.	A written report must contain: • All material facts and circumstances concerning the reportable incident known or by reasonable search or enquiry could be found out; • Any action taken to avoid or mitigate an adverse environmental impact of the reportable incident; • The corrective action that has been taken, or is proposed to be taken, to sop, control or remedy the reportable incident; and • The action that has been taken, or is proposed to be taken, to prevent a similar incident occurring in the future. Consider reporting using NOPSEMA's Report of an Accident, Dangerous Occurrence or Environmental Incident form: https://www.nopsema.gov.au/assets/Forms/N-03000-FM0831-Report-of-an-Accident-Dangerous-Occurrence-or-Environmental-Incident-Rev-8-Jan-2015-MS-Word-2010.docx Ship strike report: **https://data.marinemammals.gov.au/report/shipstrike**	Must be submitted as soon as practicable, and in any case not later than 3 days after the first occurrence of the reportable incident unless NOPSEMA specifies otherwise. Same report to be submitted to NOPTA and DMIRS within 7 days after giving the written report to NOPSEMA.	Written	NOPSEMA NOPTA DMIRS
Director of National Parks Reporting	Notification of the event of an oil pollution incident which occurs within a marine park or is likely to impact on a marine park.	The notification should include: • titleholder details • time and location of the incident (including name of marine park likely to be affected) • proposed response arrangements as per the Oil Pollution Emergency Plan (e.g. dispersant, containment, etc.) • confirmation of providing access to relevant monitoring and evaluation reports when available; and	As soon as practicable.	Oral	Director of National Parks

Regulation	Requirement	Required Information	Timing	Type	Recipient
		• contact details for the response coordinator.			
AMSA Reporting	In consultation AMSA requests notification of reportable vessel incidents under Marine *Safety (Domestic Commercial Vessel) National Law Act 2012, Schedule 1* including: • the loss of a vessel; • a collision with another vessel or an object; • the grounding, sinking, flooding or capsizing of a vessel; • a fire; • a loss of stability that affects the safety of the vessel; • a close quarters situation; • the death or injury, or possible death or injury, of a person on board; and • the loss, or possible loss, of a person from a vessel.	A written report must contain: 1) Incident details (date and time); 2) Location; 3) Type of incident; 4) Incident description; 5) Vessels involved; 6) Persons involved; and 7) Details of assistance rendered/received at incident. Consider reporting using AMSA's Incident Report: http://www.amsa.gov.au/domestic/vessels-operations-surveys/domestic-incident-reporting/	Within 72 hours of the incident.	Written	AMSA
DPIRD Reporting	If marine pests or disease are suspected this must be reported to DPIRD.	Notification of any suspected marine pests or diseases including any organism listed in the Western Australian Prevention List for Introduced Marine Pests and any other non-endemic organism that demonstrates invasive characteristics.	Within 24 hours.	Oral	DPIRD FishWatch
DoEE Reporting	Any harm or mortality to EPBC Act-listed threatened marine fauna.	Notification of any harm or mortality to an EPBC listed species of marine fauna whether attributable to the Activity or not.	Within 48 hours to compliance@environment.gov.au.	Written	DoE
DBCA Reporting	Impacts to marine mammals or turtles in reserves.	Notification of any incidence of entanglement, boat collisions and stranding of marine mammals in the reserves' and any incident of turtle mortality and	Within 48 hours.	Written	DBCA

Regulation	Requirement	Required Information	Timing	Type	Recipient
		incidents of entanglement.			
Regulation 26B – Recordable Incidents	NOPSEMA must be notified of a breach of an environmental performance outcome or standard, in the environment plan that applies to the Activity that is not a reportable incident.	Complete NOPSEMA's Recordable Environmental Incident Monthly Report form.	The report must be submitted as soon as practicable after the end of the calendar month, and in any case, not later than 15 days after the end of the calendar month.	Written	NOPSEMA
Regulation 26C Environmental Performance	NOPSEMA must be notified of the environmental performance at the intervals provided for in the EP.	Report must contain sufficient information to determine whether or not environmental performance outcomes and standards in the EP have been met.	A detailed environmental performance report will be submitted within three months of submission of a Regulation 29(2).	Written	NOPSEMA
End of Activity					
Regulation 29 – Notifications	NOPSEMA must be notified that the Activity is completed.	Complete NOPSEMA's Regulation 29 Start or End of Activity Notification form.	Within 10 days after finishing.	Written	NOPSEMA
Regulation 14 (2) & 26C – Environmental Performance	NOPSEMA must be notified of the environmental performance of the Activity.	Report must contain sufficient information to determine whether or not environmental performance outcomes and standards in the EP have been met.	Environmental performance report submitted within 3 months of the end of the Activity.	Written	NOPSEMA
Regulation 25A Plan ends when titleholder notifies completion and the Regulator accepts the notification.	NOPSEMA must be notified that the Activity has ended, and all EP obligations have been completed.	Notification advising NOPSEMA of end of all activities to which the EP relates and that all obligations have been completed.	Within six months of the final Regulation 29 (2) notification.	Written	NOPSEMA

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Appendix A – Legislation

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	This Act provides for the preservation and protection from injury or desecration areas and objects that are of significance to Aboriginal people, under which the Minister may make a declaration to protect such areas and objects. The Act also requires the discovery of Aboriginal remains to be reported to the Minister.	Yes	Commonwealth – Department of Environment and Energy	No activity being undertaken on land or near shore. No known sites of Aboriginal Heritage Significance are within the operational area, but are present within the EMBA. May be relevant in the event of a hydrocarbon spill requiring shoreline access (e.g. shoreline clean-up)	**Section 7.3**– Spill response operations
Australian Heritage Council Act 2003	This Act identifies areas of heritage value listed on the Register of the National Estate and sets up the Australian Heritage Council and its functions.	No	Australian Heritage Council	There are no national heritage places found on the National Heritage List, within the EMBA. The Dampier Archipelago is the nearest site located approximately 12 km south of the EMBA.	N/A
Australian Maritime Safety Authority Act 1990 (AMSA Act)	This Act specifies that the Australian Maritime Safety Authority's (AMSA) role includes protection of the marine environment from pollution from ships and other environmental damage caused by shipping. AMSA is responsible for administering the Marine Orders in Commonwealth waters. Facilitates international cooperation and mutual assistance in preparing and responding to a major oil spill incident and encourages countries to develop and maintain an adequate capability to deal with oil pollution emergencies. Requirements are given effect through AMSA. AMSA is the lead agency for responding to oil spills in the marine environment and is	Yes	AMSA	Vessel movements Marine orders administration Spill control agency	**Section 7.1** – Hydrocarbon spill from a vessel collision

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
	responsible for the Australian National Plan for Maritime Environmental Emergencies (MEE).				
Maritime Powers Act 2013	Protects the heritage values of shipwrecks and relics for shipwrecks over 75 years. It is an offence to interfere with a shipwreck covered by this Act. Available historic shipwreck locations covered by international conventions enacted by this legislation have been identified and assessed (as applicable) within this EP.	No	The Department of Immigration and Border Protection	No planned interaction or interference. Potential impact could be due to a hydrocarbon spill but the credible spill is to surface, and therefore shipwrecks are highly unlikely to be impacted.	N/A
Biosecurity Act 2015 *Biosecurity Regulations 2016*	This Act provides the Commonwealth with powers to take measures of quarantine, and implement related programs as are necessary, to prevent the introduction of any plant, animal, organism or matter that could contain anything that could threaten Australia's native flora and fauna or natural environment. The Commonwealth's powers include powers of entry, seizure, detention and disposal. This Act includes mandatory controls on the use of seawater as ballast in ships and the declaration of sea vessels voyaging out of and into Commonwealth waters. The Regulations stipulate that all information regarding the voyage of the vessel and the ballast water is declared correctly to the quarantine officers.	Yes	Commonwealth – Department of Agriculture and Water Resources	Potential internationally sourced vessel operating in Australian Waters which could have the potential for introduction of Invasive Marine Species and potential ballast water exchange	**Section 7.7** Introduction of IMS
Environment Protection and Biodiversity Conservation Act 1999	A new streamlined approach for offshore petroleum and greenhouse gas activity environmental approvals came into effect on 28 February 2014. The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is now the sole assessor for offshore petroleum activities in	Yes	Commonwealth – Department of Environment and Energy	Undertaking the Activity involves: • Interaction with marine fauna (MNES which are threatened and migratory species,	**Section 6.3** - Light emissions **Section 6.2** – Noise emissions **Section 6.3** – Planned operational discharges

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
Environment Protection and Biodiversity Conservation Amendment Regulations 2006	Commonwealth waters. Under the new arrangements, environmental protection will be met through NOPSEMA's decision-making processes. Where activities have existing approvals under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), these will continue to apply.			• Light emissions • Underwater noise • Drilling and cement discharges • Operational discharges • Vessel movements • Unplanned hydrocarbon/chemical release	**Section 7.1** to **7.4** – for unplanned hydrocarbon and non-hydrocarbon/chemical releases **Section 7.6** Marine fauna collisions
Underwater Cultural Heritage Act 2018	This Act protects shipwrecks, sunken aircraft and other types of underwater heritage (including human remains) that have lain in territorial waters for 75 years or more. The Act replaced the *Historic Shipwreck Act 1976* on 1 July 2019. It also increases penalties applicable to damaged sites.	Yes	Commonwealth – Department of Environment and Energy	No planned interaction or interference. Potential impact could be due to a hydrocarbon spill but the credible spill is to surface, and therefore shipwrecks are highly unlikely to be impacted. Multiple shipwrecks (25) and one sunken aircraft identified within EMBA.	**Section 7.1** and **7.2** – for unplanned hydrocarbon spills
National Greenhouse and Energy Reporting Act 2007	Introduces a single national reporting framework for the reporting and dissemination of information about greenhouse gas emissions, greenhouse gas projects and energy use and production of corporations.	Yes	Commonwealth – Department of Environment and Energy And Climate Change Authority	Atmospheric emissions through combustion engine use to operate the DSV/ISV. To reduce impact of GHG emissions, Santos will comply with MARPOL Annex VI (Marine Orders Part 97: Marine Pollution Prevention – Air Pollution) And require the use of low sulphur fuel	**Section 6.6**– Atmospheric emissions
Maritime Legislation Amendment (Prevention of Air	This Act implements the requirements of MARPOL 73/78 Annex VI for shipping in Commonwealth waters.	Yes	Commonwealth, Department of Infrastructure	Atmospheric emissions through combustion engine use to operate the DSV/ISV. To reduce impact of GHG emissions, Santos will comply with MARPOL Annex	**Section 6.6** – Atmospheric emissions

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
Pollution from Ships) Act 2007			and Regional Development.	VI (Marine Orders Part 97: Marine Pollution Prevention – Air Pollution) And require the use of low sulphur fuel	
Navigation Act 2012	An act regulating navigation and shipping including Safety of Life at Sea (SOLAS). A number of Marine Orders enacted under this Act apply directly to offshore petroleum exploration and production activities: Marine Orders - Part 17: Liquefied gas carriers and chemical tankers Marine Orders - Part 21: Safety of navigation and emergency procedures Marine Orders - Part 30: Prevention of collisions Marine Orders - Part 47: Mobile Offshore Drilling Units Marine Orders - Part 50: Special purpose ships Marine Orders - Part 57: Helicopter Operations Marine Order - Part 59: Off-shore industry vessel operations Marine Orders - Part 60: Floating Offshore facilities	Yes	AMSA (operational) Department of Infrastructure and Regional Development Minister for Infrastructure and Regional Development	Vessel movements	**Section 6.1** – Interaction with other marine users
Offshore Petroleum and Greenhouse Gas Storage Act 2006 Offshore Petroleum and Greenhouse Gas Storage	Petroleum exploration and development activities in Australia's offshore areas are subject to the environmental requirements specified in the OPGGS Act and associated Regulations. The OPGGS Act contains a broad requirement for titleholders to operate in accordance with "good oil-field practice". Specific environmental provisions relating to work practices essentially	Yes	NOPSEMA	Undertaking Activity is a Petroleum Activity regulated by NOPSEMA.	**Section 6** and **7**

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
(Environment) Regulations 2009	require operators to control and prevent the escape of wastes and petroleum. The Act also requires that activities are carried out in a manner that does not unduly interfere with other rights or interests, including the conservation of the resources of the sea and sea-bed, such as fishing or shipping. In some cases, where there are particular environmental sensitivities or multiple use issues it may be necessary to apply special conditions to an exploration permit area. The holder of a petroleum title must maintain adequate insurance against expenses or liabilities arising from activities in the title, including expenses relating to clean-up or other remedying of the effects of the escape of petroleum. The OPGGS Environment Regulations provide an objective based regime for the management of environmental performance for Australian offshore petroleum exploration and production activities in areas of Commonwealth jurisdiction. Key objectives of the Environment Regulations include: • to ensure operations are carried out in a way that is consistent with the principles of ecologically sustainable development; • to adopt best practice to achieve agreed environment protection standards in industry operations; and • to encourage industry to continuously improve its environmental performance.				

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	Regulates the manufacture, importation and use of ozone depleting substances (typically used in fire-fighting equipment and refrigerants). Applicable to the handling of any ODS.	Yes	Commonwealth - Department of Environment and Energy	No import, export or manufacture activities of ODS. It is noted that ODS is rarely found on vessels' refrigeration system.	**Section 6.6**– Atmospheric emissions
Protection of the Sea (Powers of Intervention) Act 1981 Protection of the Sea (Powers of Intervention) Regulations 1983	The Act authorises the Commonwealth to take measures for the purpose of protecting the sea from pollution by oil and other noxious substances discharged from ships and provides legal immunity for persons acting under an AMSA direction.	Yes	Commonwealth – Department of Infrastructure and Regional Development (AMSA administers the act and is responsible for ensuring compliance)	Vessel discharges Vessel movements Only relevant to the extent that Santos will comply with MARPOL through the following relevant Marine Orders relating to marine pollution prevention have been put in place to give effect to relevant regulations of Annexes I, II, III, IV, V and VI of MARPOL 73/78: Marine Orders - Part 91: Marine Pollution Prevention - Oil Marine Orders - Part 93: Marine Pollution Prevention - Noxious Liquid Substances Marine Orders - Part 95: Marine Pollution Prevention – Garbage Marine Orders - Part 96: Marine Pollution Prevention – Sewage Marine Orders - Part 98: Marine Pollution - Anti-fouling Systems	**Section 6.1** – Interaction with other marine users **Section 6.3** – Planned operational discharges **Section 7.1** to **7.4** – for unplanned hydrocarbon and non-hydrocarbon/chemical spills **Section 7.7** – Introduction of IMS
Protection of the Sea (Prevention	This Act relates to the protection of the sea from pollution by oil and other harmful substances discharged from ships. This Act disallows any	Yes	Commonwealth – Department of Infrastructure	Vessel discharges Vessel movements	**Section 6.1** – Interaction with other marine users

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
of Pollution from Ships) Act 1983 Protection of the Sea (Prevention of Pollution from Ships) (Orders) Regulations 1994	harmful discharge of sewage, oil and noxious substances into the sea and sets the requirements for a shipboard waste management plan. The following Marine Orders relating to marine pollution prevention have been put in place to give effect to relevant regulations of Annexes I, II, III, IV, V and VI of MARPOL 73/78: Marine Orders - Part 91: Marine Pollution Prevention - Oil Marine Orders - Part 93: Marine Pollution Prevention - Noxious Liquid Substances Marine Orders - Part 94: Marine Pollution Prevention - Harmful Substances in Packaged Forms Marine Orders - Part 95: Marine Pollution Prevention – Garbage Marine Orders - Part 96: Marine Pollution Prevention – Sewage Marine Orders - Part 97: Marine Pollution Prevention - Air Pollution Marine Orders - Part 98: Marine Pollution - Anti-fouling Systems		and Regional Development (AMSA administers the act and is responsible for ensuring compliance)	Santos will comply with MARPOL through the following relevant Marine Orders relating to marine pollution prevention have been put in place to give effect to relevant regulations of Annexes I, II, III, IV, V and VI of MARPOL 73/78: Marine Orders - Part 91: Marine Pollution Prevention - Oil Marine Orders - Part 93: Marine Pollution Prevention - Noxious Liquid Substances Marine Orders - Part 95: Marine Pollution Prevention – Garbage Marine Orders - Part 96: Marine Pollution Prevention – Sewage Marine Orders - Part 98: Marine Pollution - Anti-fouling Systems	**Section 6.3** – Planned operational discharges **Section 7.1** to **7.4** – for unplanned hydrocarbon and non-hydrocarbon/chemical spills **Section 7.7** – Introduction of IMS
Protection of the Sea (Civil Liability of Bunker Oil Pollution Damage) Act 2008	This Act implements the requirements for the International Convention on Civil Liability for Bunker Oil Pollution Damage.	Yes	AMSA	Refuelling of spill response vessels may be undertaken at sea	**Section 7.1**– Hydrocarbon release (vessel collision)

Commonwealth Legislation	Summary	Relevant to activity?	Administering Authority	Relevant aspects of the Activity	EP Section
Protection of the Sea (Harmful Antifouling Systems) Act 2006	This Act relates to the protection of the sea from the effects of harmful anti-fouling systems. It prohibits the use of harmful organotins in ant-fouling paints used on ships.	Yes	Commonwealth, Department of Infrastructure and Regional Development and AMSA	Vessel movements in Australian Waters. Vessels are required to have biofouling systems in place to prevent introduction of Invasive Marine Species / Harmful Impact on Australian biodiversity	**Section 7.7** - Introduction of IMS

International Agreements and Conventions	Summary	Relevant to Activity?	Relevant Aspects	EP Section
1996 Protocol To The Convention On The Prevention Of Marine Pollution By Dumping Of Wastes And Other Matter, 1972.	Implemented in WA Marine (Sea Dumping) Act and *Environmental Protection (Sea Dumping) Act 1981.*	No	No wastes will be dumped as part of the Activity.	N/A
Agreement Between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and Their Environment 1974 (commonly referred to as the Japan Australia Migratory Bird Agreement or JAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan. Implemented in EPBC Act 1999.	Yes	Only relevant in so far as the credible spill scenario may result in impact to migratory seabirds foraging in area.	**Section 7.1** – Hydrocarbon release (vessel collision)
Agreement Between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and Their Environment 1986 (commonly referred to as the China Australia Migratory Bird Agreement or CAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China. Implemented in EPBC Act 1999.	Yes	Only relevant in so far as the credible spill scenario may result in impact to migratory seabirds foraging in area.	**Section 7.1** – Hydrocarbon release (vessel collision)
United Nations Convention on Biological Diversity -1992	An international treaty to sustain life on earth.	Yes	Relevant only insofar as the Activity may interact with MNES (threatened and migratory species) protected under the EPBC Act.	**Section 6.2** – Noise emissions **Section 7.1** – Hydrocarbon release (vessel collision) **Section 7.7** Introduction of IMS
Convention on Oil Pollution Preparedness, Response and Co-operation 1990 (OPRC 90)	This convention comprises national arrangements for responding to oil pollution incidents from ships, offshore oil facilities, sea ports and oil handling. The convention recognises that in the event of pollution incident, prompt and effective action is essential.	Yes	In the event that worse-case credible spill scenarios may enact a national arrangement for response.	**Section 7.1** – Hydrocarbon release (vessel collision)

International Agreements and Conventions	Summary	Relevant to Activity?	Relevant Aspects	EP Section
Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species.	Yes	A credible spill scenario may result in impacts to MNES protected migratory species. The Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessment for Marine Noise-generating Activities is also developed and maintained under the Convention.	**Section 7.1** – Hydrocarbon release (vessel collision) **Section 6.2** – Noise emissions
International Convention for the Prevention of Pollution from Ships 1973/1978 (MARPOL 73/78)	This Convention and Protocol (together known as MARPOL 73/78) build on earlier conventions in the same area. MARPOL is concerned with operational discharges of pollutants from ships. It contains five Annexes, dealing respectively with oil, noxious liquid substances, harmful packaged substances, sewage and garbage. Detailed rules are laid out as to the extent to which (if at all) such substances can be released in different sea areas. The legislation giving effect to MARPOL in Australia is the Protection of the Sea (Prevention of Pollution from Ships) Act 1983, the Navigation Act 2012 and several Parts of Marine Orders made under this legislation.	Yes	Santos will comply with MARPOL through the following relevant Marine Orders relating to marine pollution prevention have been put in place to give effect to relevant regulations of Annexes I, II, III, IV, V and VI of MARPOL 73/78: • Marine Orders - Part 91: Marine Pollution Prevention - Oil • Marine Orders - Part 93: Marine Pollution Prevention - Noxious Liquid Substances • Marine Orders - Part 95: Marine Pollution Prevention – Garbage • Marine Orders - Part 96: Marine Pollution Prevention – Sewage • Marine Orders - Part 97: Marine Pollution Prevention - Air Pollution • Marine Orders - Part 98: Marine Pollution - Anti-fouling Systems	**Section 7.1** to **7.4**– for unplanned hydrocarbon and non-hydrocarbon/chemical spills **Section 7.7** – Introduction of IMS
International Convention for the Safety of Life at Sea 1974	This convention is generally regarded as the most important of all international treaties concerning the safety of merchant ships.	Yes	Only relevant in so far as SOLAS relates to safety aspects of the Activity, such as navigation aids which reduce potential for vessel collision and hydrocarbon release	**Section 7.1** – Hydrocarbon release (vessel collision)

International Agreements and Conventions	Summary	Relevant to Activity?	Relevant Aspects	EP Section
	The legislation giving effect to the Safety Convention in Australia is the Protection of the Sea (Prevention of Pollution from Ships) Act 1983, the Navigation Act 2012 and several Parts of Marine Orders made under this legislation.		to the environment (refer to table above for Navigation Act 2012)	
United Nations Framework Convention on Climate Change (1992)	The objective of the convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. Australia ratified the convention in December 1992 and it came into force on 21 December 1993.	Yes	Only relevant in to the extent that to reduce impact of GHG emissions associated with vessel use, Santos will comply with MARPOL Annex VI (Marine Orders Part 97: Marine Pollution Prevention – Air Pollution) And require the use of low sulphur fuel.	**Section 6.6**– Atmospheric emissions

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Appendix B – Values and Sensitivities of the Marine and Coastal Environment

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Values and Sensitivites of the Marine and Coastal Environment

PROJECT / FACILITY	All
REVIEW INTERVAL (MONTHS)	12 Months
SAFETY CRITICAL DOCUMENT	NO

Rev	Owner	Reviewer/s *Managerial/Technical/Site*	Approver
	HSE Approvals Manager	Chief Environment Advisor	HSE Support Manager
5	Sonja Mavrick	Libby Howitt pp S.T. Mavrick.	Nick Phillips

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Appendices

Appendix A: EPBC Act Protected Matters Report

1. Introduction

Santos WA Energy Limited (Santos WA)) is the titleholder of multiple petroleum titles for exploration, development and operational activities located in marine waters off north-western Western Australia. This document describes the existing environment that may be affected (EMBA) by these petroleum activities and includes details of the particular relevant values and sensitivities of that environment as required by the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* and State *Western Australian Petroleum (Submerged Lands) (Environment) Regulations 2012.* This document is informed by a search of the protected matters search tool (PMST) provided by the Department of Environment and Energy (DoEE) dated 24/11/2018; provided in **Appendix A** as well as published scientific literature and studies where applicable. Descriptions of all fauna are provided, with a focus on protected species that are threatened and migratory.

1.1 Geographical Extent

The Australian 'area of interest', for the purposes of thisdocument, includes the coastal waters and shoreline habitats of Western Australia (WA), encompassing the south west of WA in the south and the Northern Territory (NT) border in the north (**Appendix A**). This area largely approximates the Commonwealth North-west Marine Region (NWMR), the South-west Marine Region (SWMR) and the North Marine Region (NMR) (DEWHA 2008, 2008a). Based on the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) Version 4.0, there are sixteen bioregions that occur which are based on fish, benthic habitat and oceanographic data (IMCRA v. 4.0). Where relevant, the physical, biological and social environments within the area of interest are discussed with reference to the IMCRA Provincial Bioregions. The provinces of most relevance (**Figure** 1-1) are:

North-west Marine Region

+ Northwest Shelf Transition;
+ Timor Province;
+ Northwest Transition;
+ Northwest Province;
+ Northwest Shelf Province;
+ Central Western Transition;
+ Central Western Shelf Transition; and
+ Central Western Shelf Province.

South-west Marine Region

+ Central Western Province;
+ Southwest Shelf Transition;
+ Southwest Transition; and
+ Southwest Shelf Province.

North Marine Region

+ Northwest Shelf Transition (as above).

Other IMCRA 4.0 bioregions of interest include: Christmas Island Province.

The international waters of south west Indonesia and Timor Leste (in part) are also an area of interest and described where relevant throughout thisdocument.

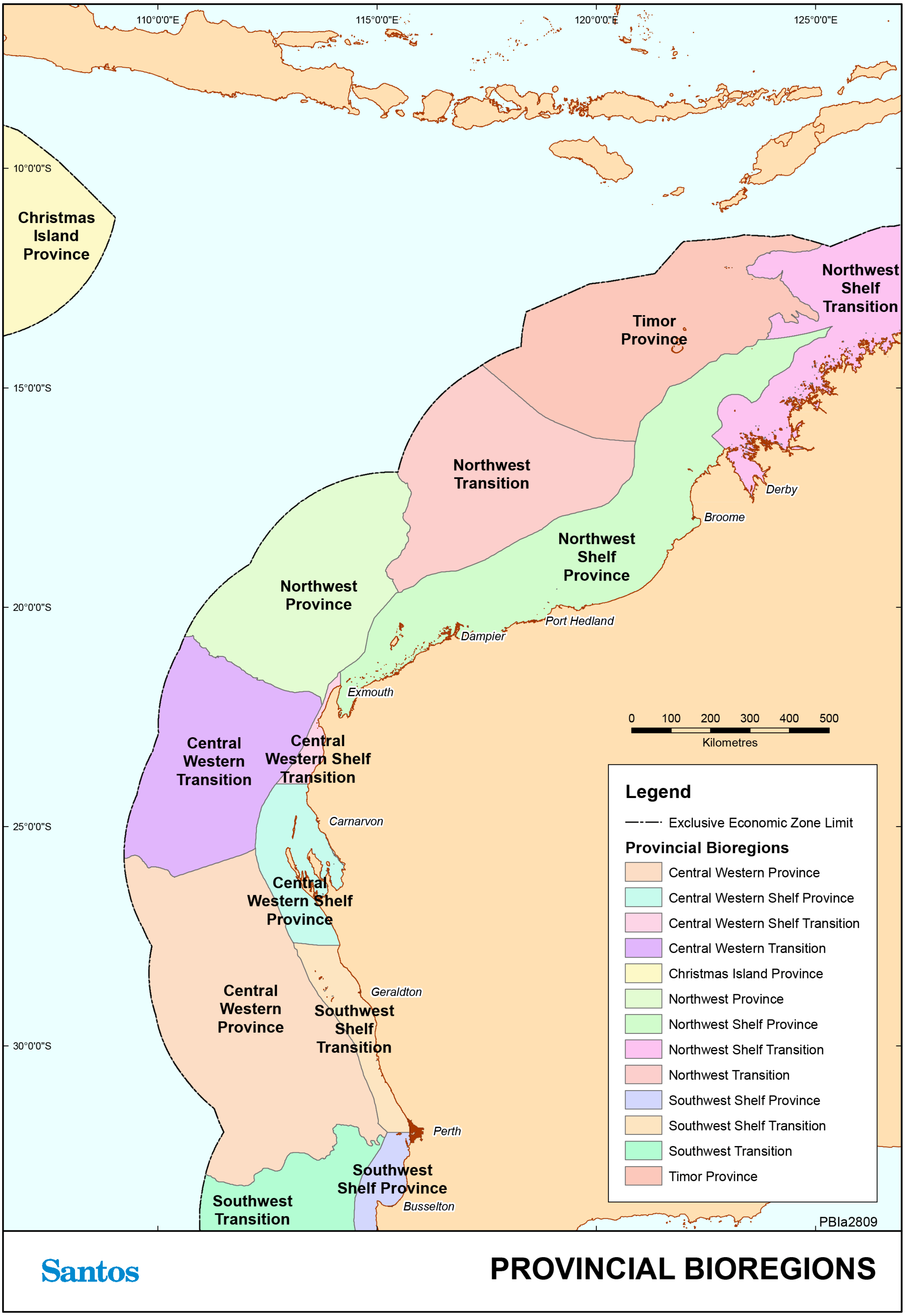


Figure 1-1: Area of interest within IMCRA 4.0 Provincial Bioregions

2. Physical Environment

2.1 Geomorphology

2.1.1 Formation History

Approximately 550–160 million years ago, the area of interest formed part of the northern margin of Gondwana. About 300 million years ago, crustal stretching, rifting and breakup initiated development of an extensive basin that became the site for deposition of sediments (Baker *et al*. 2008 in DEWHA 2008). Approximately 135 million years ago the continent broke up resulting in the separation of greater India and Australia. Ocean spreading associated with the continental break-up resulted in the creation of the Argo and Cuvier abyssal plains. Subsidence of the rifted margin resulted in the formation of the Exmouth and Scott plateaux and the Rowley Terrace. The narrow shelf south of North West Cape was formed approximately 130 million years ago as a result of the separation of India and seafloor spreading (Baker *et al*. 2008 in DEWHA 2008).

The South-west region has been relatively stable throughout its recent geological past. This has shaped a continental shelf that has high wave exposure and is punctuated with coastal features such as island groups and fringing coastal reefs providing sheltered habitats for marine communities (2008a).

2.1.2 Present Day Geological Features

The area of interest consists of four major landform features: continental shelf, continental slope, continental rise and abyssal plain. The majority of the area consists of either continental shelf or continental slope (DEWHA 2008).

Limited surveys have shown that the continental slope in the area of interest comprises diverse geological features such as canyons, plateaux, terraces, ridges, reefs, banks and shoals (Source: DEWHA (2008)) (**Figure** 2-1 and **Figure 2-2**). These features are significant in that over half of the total area of banks and shoals across Australia's entire marine jurisdiction occurs in the Commonwealth waters from the South Australian border to the Northern Territory border, as well as 39% of terraces and 56% of deeps, holes and valleys (DEWHA 2008).

An important characteristic of the area of interest is the significant narrowing of the continental shelf around North West Cape from the broad continental shelf in the north (Figure 2-3). For example, in the Joseph Bonaparte Gulf (at the Northern Territory boundary), the continental shelf is around 400 km wide, whereas at North West Cape the shelf is only 7 km wide – the narrowest of anywhere on the Australian continental margin (DEWHA 2008). Shelf width affects oceanography with flow on effects to productivity and ecosystem functioning.

The continental shelf north of Cape Leveque is characterised by a rimmed ramp where the waters over the outer margins of the shelf (approximately 50 to 100 m waters depth) are shallower than the middle portions (up to 150 m water depth). The rim at its outer edge is the site of a number of coral reefs including Ashmore, Cartier, Scott and Seringapatam (DEWHA 2008).

The Indonesian archipelago lies between the Pacific and Indian oceans, and bridges the continents of Asia and Australia. The archipelago is divided into several shallow shelves and deep-sea basins.

2.1.3 Southwest Shelf Province

The Southwest Shelf Province consists of an area of narrow continental shelf from Rottnest to Point Dempster. For the purposes of this document (area of interest) we are interested in the northern limits of the bioregion, which are an extension of the seafloor described in the Southwest Shelf Transition (below). It includes, features such as limestone ridges, depressions defining an inshore lagoon and a relatively smooth inner shelf plain that meets the South Bank Ridge on the outer shelf, and islands providing important habitat, such as Rottnest Island. The shelf progressively broadens to form the relatively sheltered waters of Geographe Bay before narrowing once again at Cape Mentelle.

2.1.4 The Southwest Shelf Transition

The Southwest Shelf Transition is a nearshore bioregion that covers the area of continental shelf from Perth to Busselton, and extends out to the edge of the shelf. This bioregion consists of a narrow continental shelf, ranging from approximately 40–80 km wide. It includes a series of complex nearshore ridges and depressions that form inshore lagoons, a smooth inner shelf plain, a series of offshore ridges and a steep, narrow outer shelf. The near-shore ridges are formed by eroded limestone reefs and pinnacles that stand 10–20 m above the seafloor. The edge of the inner shelf plain is marked by a series of broken offshore ridges that extend north to the northern limits of the bioregion, where they emerge to support the tropical carbonate reef growth of the Houtman Abrolhos Islands.

2.1.5 Southwest Transition

The Southwest Transition is an offshore deep-water bioregion with a submerged continental fragment as its dominant seafloor feature – the Naturaliste Plateau. The Plateau extends across an area of 90,000 km^2 of which only 29,825 km^2 is within Commonwealth waters. It is located west of Cape Leeuwin and Cape Naturaliste in water depths ranging from 2,000–5,000 m. It is relatively flat with a slight northward dip, and has steep southern and western sides and a more gently sloping northern side. The Plateau is separated from the Australian continent by the Naturaliste Trough and two offshore terraces on the continental slope (average depth 780 m). Submarine canyons incise the northern parts of the slope and parts of the Naturaliste Plateau.

2.1.6 Sediments

Terrestrial environments are not a major source of sediment in the area and terrigenous sediments tend to be confined to the inner shelf (generally less than 100 m water depth), particularly in areas adjacent to rivers. Sediments in the area generally become finer with increasing water depth, ranging from sand and gravels on the shelf to mud on the slope and abyssal plain. Joseph Bonaparte Gulf is an exception to this pattern, as sediments with high mud content extend across the inner and mid shelf within the Gulf, graduating to sands and gravels in the Bonaparte Depression.

The distribution and resuspension of sediments on the inner shelf is strongly influenced by the strength of tides across the continental shelf as well as episodic events such as cyclones. Further offshore, on the mid to outer shelf and on the slope itself, sediment movement is primarily influenced by ocean currents and internal tides. Internal tides describe the tidal movement across a slope of water stratified by marked differences in density. Internal tides cause resuspension and net down-slope deposition of sediments on the North West Shelf (DEWHA 2008).

Surveys conducted over the North West Shelf indicate that similar sediments occur extensively over this geographic region, but with spatial variation in the grain size and origin of the surface sediments.

The ecology of the southwest is also greatly influenced by the lack of river discharge into the Region. The few significant rivers adjacent to the Region flow intermittently and their overall discharge is low. The low discharge of rivers and the generally low rate of biological productivity also results in low turbidity (suspended sediments), making the waters of the Region relatively clear (McLoughlin & Young 1985). Surface sediments in the area are predominantly composed of skeletal remains of marine fauna, with lenses of weathered sands (McLoughlin & Young 1985).

Several geomorphic formations have been associated with Key Ecological Features (DEWHA 2008) and these are discussed in Section 10.

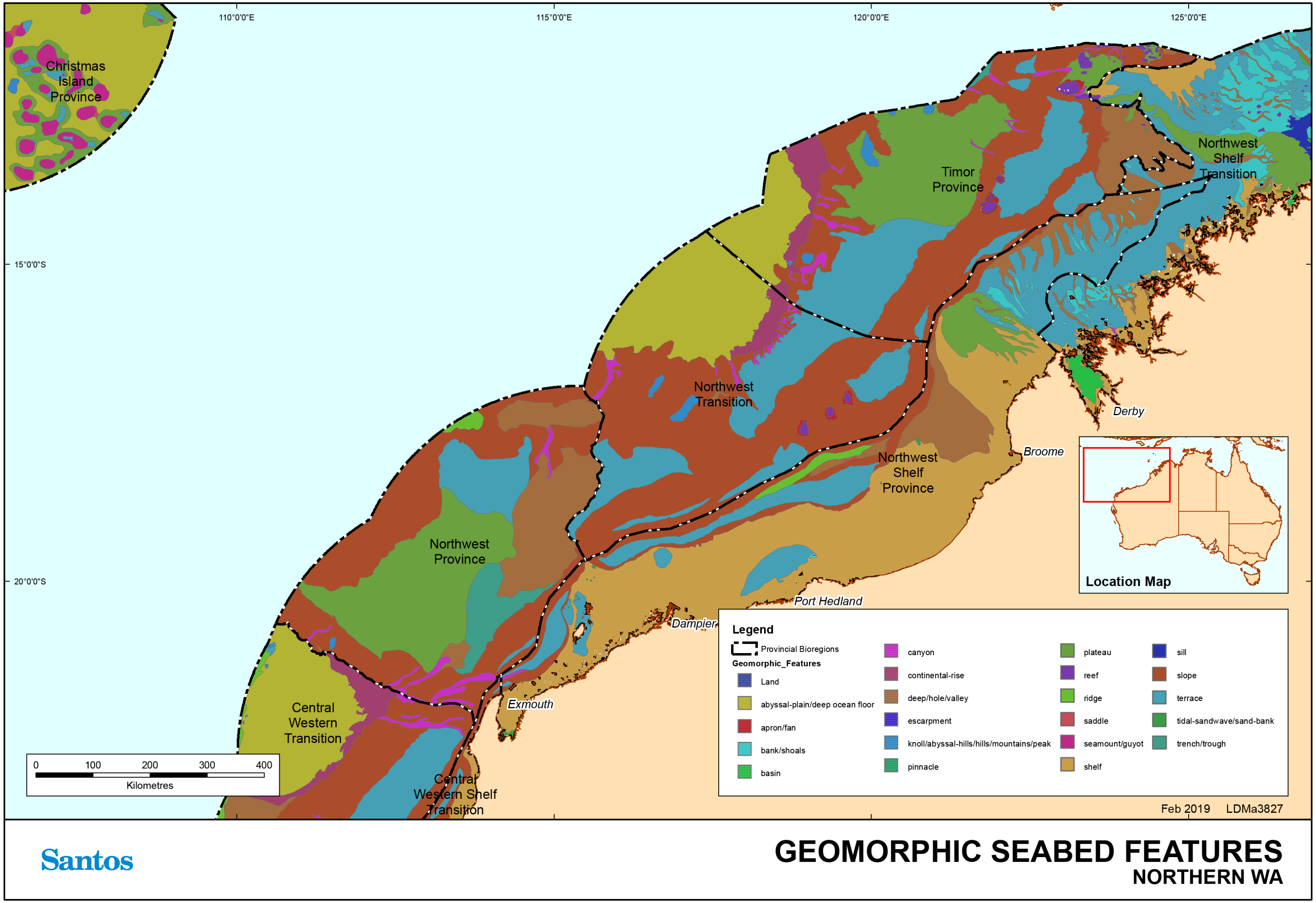


Figure 2-1: Geomorphic/seafloor features of Northern WA

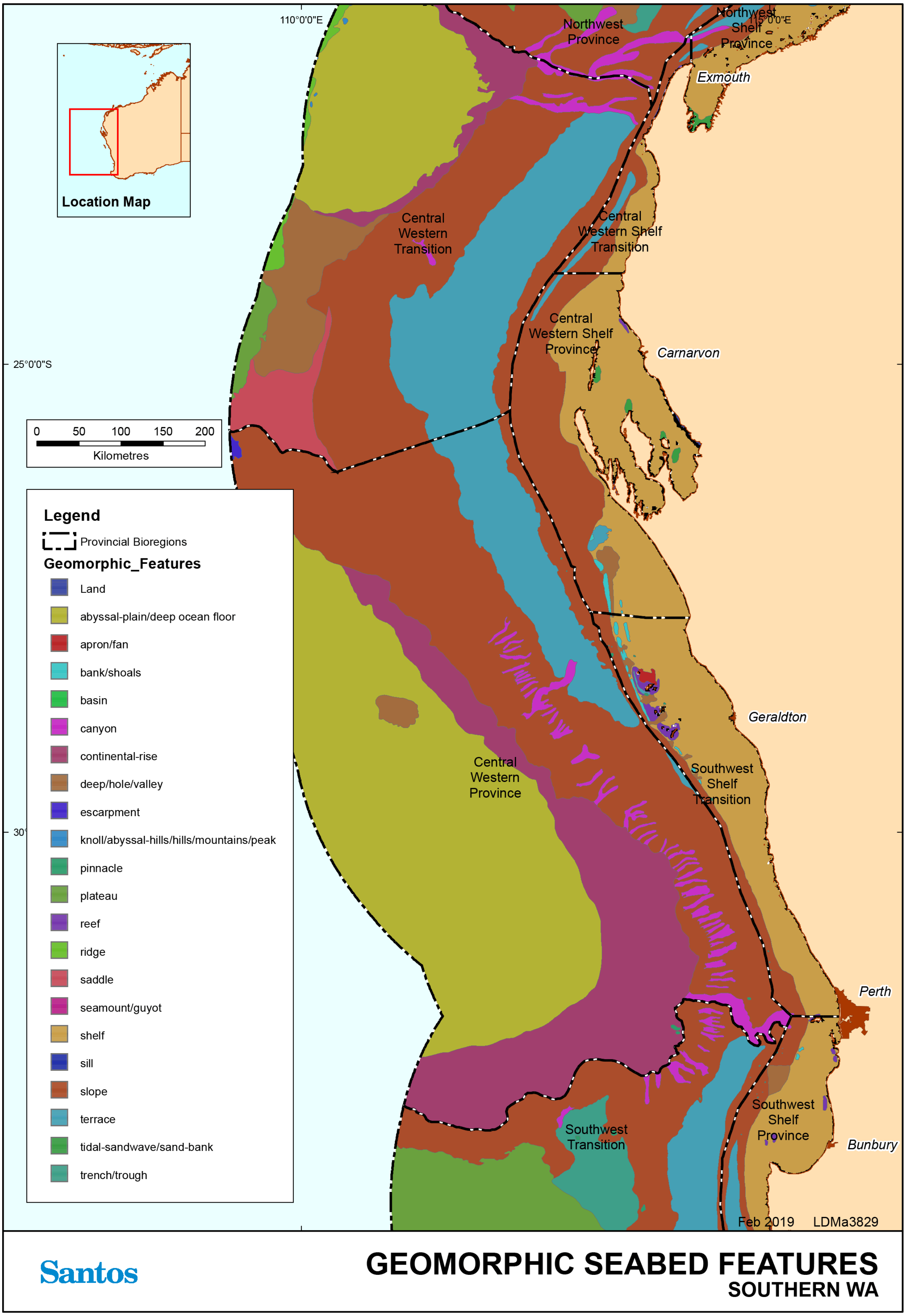


Figure 2-2: Geomorphic/seafloor features of Southern WA

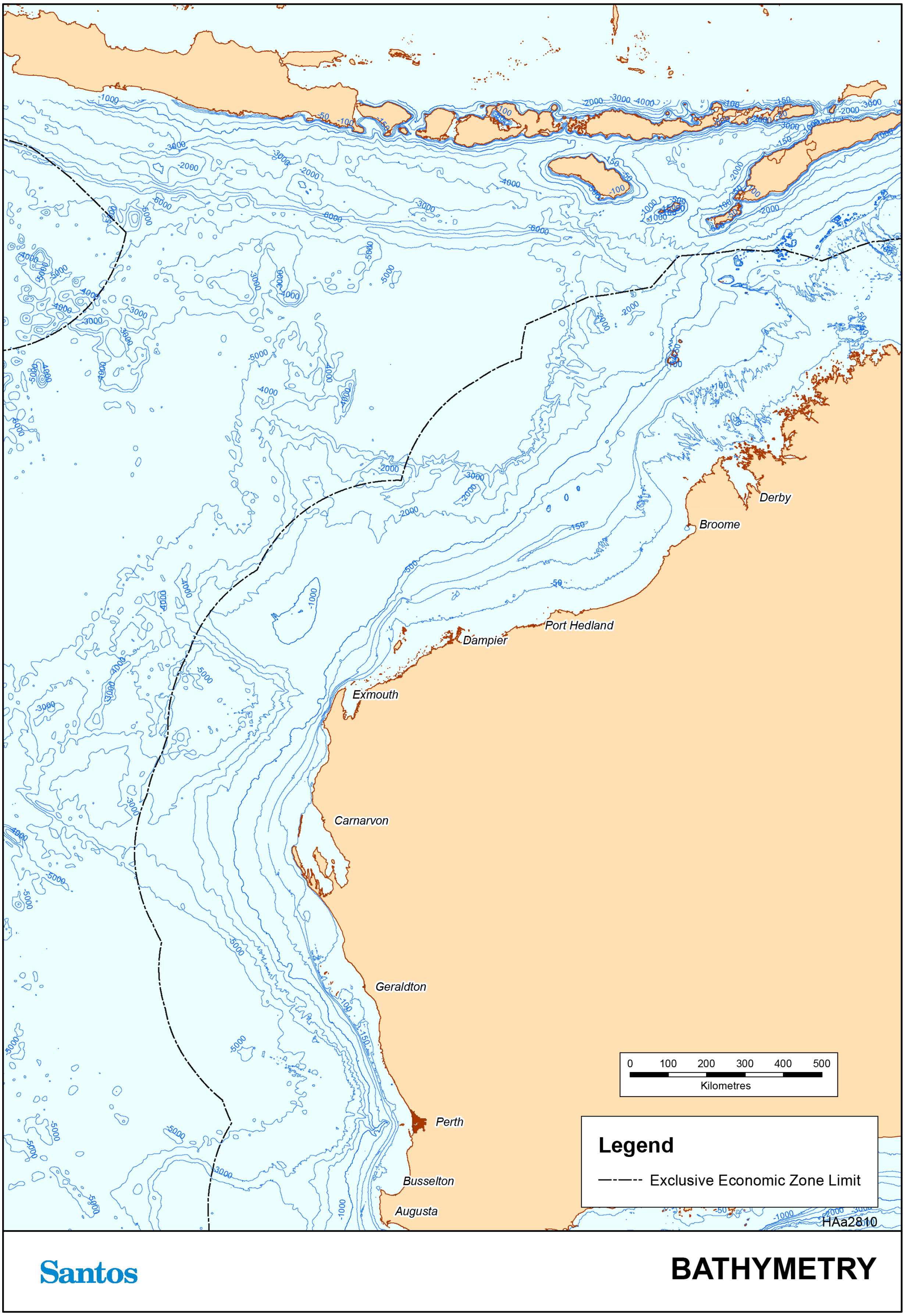


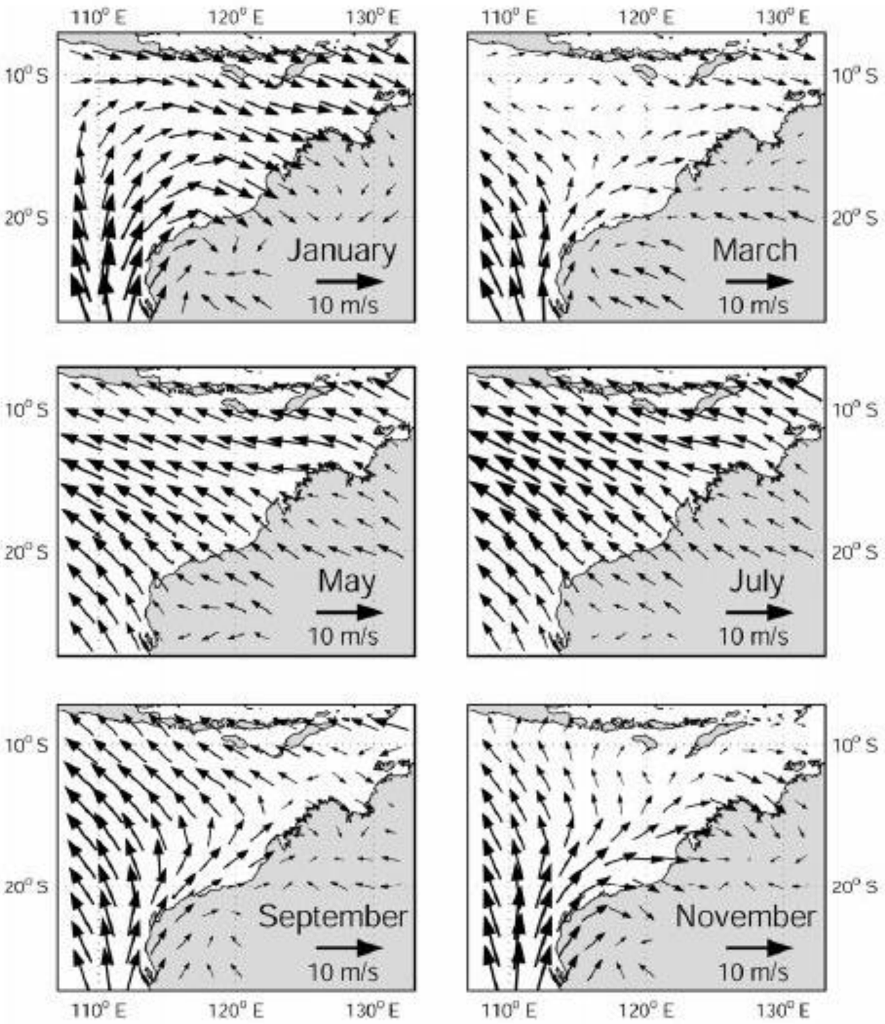
Figure 2-3: Bathymetry of area of interest

2.2 Climate

Waters in the northern extent of the area of interest predominantly lie in the arid tropics, experiencing high summer temperatures and periodic tropical cyclones in summer. Rainfall in the region is low, although intense rainfall may occur during the passage of summer tropical cyclones and thunderstorms (Condie et al. 2006). Mean air temperatures range from a minimum of 11°C in winter to a maximum of 36°C in summer (Condie et al. 2006). Due to the arid climate, daytime visibility in the area is generally greater than 5 nautical miles (SSE 1991).

The summer and winter seasons fall into the periods September–March and May–July, respectively. Winters are characterised by clear skies, fine weather, predominantly strong east to southeast winds and infrequent rain (calculated from NCEP-NCAR dataset measured from 1982 to1999; Condie et al. (2006); Figure 2-4).

Summer winds are more variable, with strong south-westerlies dominating. Transitional wind periods, during which either pattern may predominate, can be experienced in April–May and September of each year.



Calculated from NCEP-NCAR dataset measured from 1982 to 1999. Source: Condie *et al*. (2006)

Figure 2-4: Seasonally averaged winds at 10 m above mean sea level

Tropical cyclones generate the most significant storm conditions in the area (SSE 1993). These clockwise-spiralling storms have generated wind speeds 50–120 knots (SSE 1991). Tropical cyclones develop in the eastern Indian Ocean, and the Timor and Arafura Seas during the summer months. Three to four cyclones per year are typical, with the official cyclone season being November through to April (BoM 2013). In Indonesia, the main variable in climate is not temperature or pressure, but rainfall, which varies greatly by month and place, ranging from 997 millimetres (mm) to 4,927 mm.

The South West bioregion experiences a Mediterranean style climate that is characterised by cool, wet winters and hot, dry summers. In winter, wind patterns are characterised by a prevailing westerly wind stream. This enables winter cold fronts and strong westerly winds to regularly penetrate the south-west, with cold fronts crossing the coast every week or so. Apart from the passage of storms, typically lasting one day or less, the weather is otherwise mild in winter with winds variable and relatively weak. In summer, cold fronts rarely penetrate into the south of the state with any strength and hot easterly winds prevail.

2.3 Oceanography

Major drivers of marine ecosystems include ocean currents, tides, waves, temperature and salinity. The dominant offshore sea surface current is the Leeuwin Current (Figure 2-5), which carries warm tropical water south along the edge of Western Australia's continental shelf, reaching its peak strength in winter and becoming weaker and more variable in summer (Condie et al. 2006). The current is typically located seaward of the shelf break (200 m isobath) and is a narrow, surface current, extending to a depth of 150 m (BHPB 2005, Woodside 2005) and a width of 50–100 km (DEWHA 2008). The formation of meanders and eddies are also a feature of the Leeuwin Current and a number of eddies occur south of Shark Bay (DEWHA 2008). The strength of the Leeuwin Current is influenced by seasonal variability in the pressure gradient (DEWHA 2008).

The nearshore Ningaloo Current flows northwards opposite to the Leeuwin Current, along the outside of the Ningaloo Reef and across the inner shelf from September to mid-April, (BHPB 2005, Woodside 2005). The Indonesian Throughflow is the other important current influencing the upper 200 m of the outer North West Shelf (Woodside 2005). This current brings warm and relatively fresh water to the region from the western Pacific via the Indonesian Archipelago (Figure 2-5). Modelling undertaken by Woodside and CSIRO Marine and Atmospheric Research indicates that significant east–west flows occur across the North West Shelf to the north of the North West Cape, possibly linking water masses in the area (Woodside 2005, Condie et al. 2006).

Currents in the coastal zone and over the inner to mid-shelf are largely driven by tides and winds, whereas offshore, over the continental shelf, slope and rise are influenced by large scale regional circulation (DEWHA 2008).

Tides increase in amplitude from south to north, corresponding with the increasing width of the shelf (Holloway 1983). Tides in the area are generally semi-diurnal (i.e. two high tides and two low tides per day) with a spring/neap cycle. The northern area experiences some of the largest tides in the world. In the Kimberley, the daily tidal range is up to 10 m during spring tides and less than 3 m during some neap tides. Mid-shelf tidal currents are predicted to have average speeds of approximately 0.25 knots during neap tides and up to 0.5 knots during spring tides (NSR 1995, WNI 1995).

The wave climate in the northwest is composed of locally-generated wind waves (seas) and swells that are propagated from distant areas (WNI 1995). In summer the seas typically approach from the west and southwest, while in winter the seas typically approach from the south and east. Mean sea wave heights are typically less than 1 m and peak heights of less than 2 m are experienced in all months of the year (WNI 1995).

Indonesian waters, especially the eastern part of the archipelago, play an important role in the global water mass transport system, in which warm water at the surface conveys heat to the deeper cold water in what is known as the great ocean conveyor belt (refer Figure 2-5). The eastern archipelago is the only place in the Pacific Ocean that connects with the Indian Ocean at lower latitudes. The water mass transport from the Pacific to the Indian Ocean through various channels in Indonesia is called Arlindo (Arus Lintas Indonesia), also known as the Indonesian Throughflow (ADB 2014). Surface currents in

Indonesian waters are more strongly influenced by circulation from the Pacific Ocean than from the Indian Ocean. The currents are also greatly influenced by the winds of the prevailing monsoon.

Average swell heights are low, around 0.4–0.6 m in all months. The greatest exposure to swells is from the west (SSE 1993). Tropical cyclones have generated significant swell heights of up to 5 m in this area, although the predicted frequency of swells exceeding 2 m is less than 5% (WNI 1996). In the open ocean, sustained winds result in wind-forced currents of approximately 3% of the wind speed (Holloway & Nye 1985).

Tides in the South West Capes area are mixed (i.e. diurnal and semi-diurnal) and generally less than one metre, with a typical daily range of about 0.7 m during spring tides and about 0.5 m during neap tides. Tides of this magnitude produce weak currents compared to wind and wave driven flows (Hill & Ryan 2002 cited in DEC 2013).

Waters on the continental shelf are usually thermally-stratified, with a marked change in water density at approximately 20 m (SSE 1993). Surface temperatures vary annually, being warmest in March (32°C) and coolest in August (19°C). Vertical gradients are related to the seasonality of sea surface temperatures, and are greatest during the warm-water season (SSE 1991). Near-bottom water temperature on the North West Shelf is approximately 23°C, with no discernible seasonal variation.

Salinity is relatively uniform at 34–35 ppt throughout the water column and across the North West Shelf. Due to the low rainfall there is little freshwater run-off from the adjacent mainland (Blaber *et al*. 1985).

Pronounced shifts in water column characteristics can occur following the passage of tropical cyclones (McKinnon *et al*. 2003). Changes in water temperature and salinity characteristics can result from changes in local heating and evaporation following the southward movement of warmer water due to southward-moving cyclones, and can have flow-on effects to primary and secondary productivity (McKinnon *et al*. 2003).

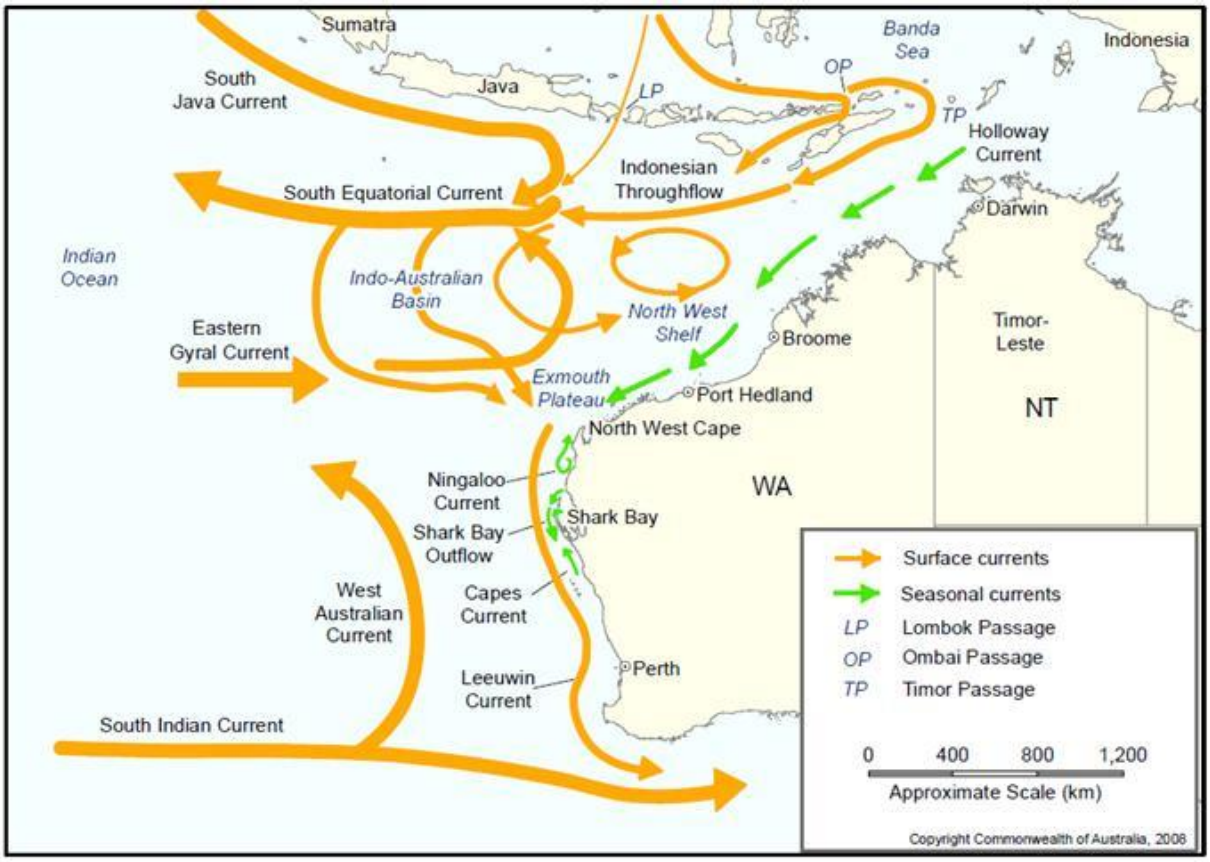


Figure 2-5: Surface currents in WA

Source: DEWHA (2008a)

3. Benthic & Pelagic Habitats

Benthic habitats are defined as those subtidal habitats lying below the lowest astronomical tide (LAT). The benthic habitats within waters in the area of interest lie at depths ranging from LAT down to more than 6,000 m at Argo and Cuvier abyssal plains (DEWHA 2008, 2008a).

Benthic habitats are partially driven by light availability. Primary producers (photosynthetic corals, seagrasses and macroalgae) are limited to the photic zone, whereas benthic invertebrates including filter feeding communities may be found in deeper waters. The depth of the photic zone varies spatially and temporally and is predominantly dependent on the volumes of suspended material in the water column. The photic zone in the offshore Pilbara is approximately 70 m whereas in oceanic waters in the northwest and coastal waters of the southwest the photic zone may extend to 120 m (2008a).

The following section broadly categorises benthic habitats as four biological communities; coral, seagrasses, macroalgae and non-coral benthic invertebrates. These communities are discussed in terms of the twelve IMCRA v. 4.0 bioregions. Some broad scale benthic habitat mapping exists for the Northwest and Central Western Shelf Provinces and this is shown in **Figure** 3-1 and **Figure** 3-2.

3.1 Coral Reefs

Corals are both primary producers and filter feeders and thus play a role in the provision of food to marine fauna and in nutrient recycling to support ecosystem functioning (CALM & MPRA 2005a).

Corals create settlement substrate and shelter for marine flora and fauna. Studies have shown that declines in the abundance, or even marked changes in species composition of corals, has a marked impact on the biodiversity and productivity of coral reef habitats (Pratchett *et al*. 2008). As part of the reef building process, scleractinian corals are also important for protection of coastlines through accumulation and cementation of sediments and dissipation of wave energy (CALM & MPRA 2005a).

The waters in the area of interest contain extensive coral communities. Coral reefs in the area fall into two general groups: the fringing reefs around coastal islands and the mainland shore; and large platform reefs, banks and shelf-edge atolls offshore (Woodside 2011). The distribution of corals in area is governed by the availability of hard substrate for attachment and light availability.

Coral reefs are dynamic environments that regularly undergo cycles of disturbance and recovery. Depending on how frequent and severe the disturbances are, recovery can take a few years or more than a decade. Disturbances can include bleaching, cyclones and disease outbreaks (AIMS 2011).

Corals in the northwest and central provinces have experienced bleaching events and subsequent recovery. Bleaching is the process where symbiotic algae are expelled from the coral tissue, often leading to the death of the colony. Causes of bleaching include high temperatures (Scott Reef; 1998), anoxic conditions (Bill's Bay; 2008) or smothering (Waples & Hollander 2008, AIMS 2011). Coral susceptibility to bleaching and their ability to recover is an important consideration in the context of potential anthropogenic impacts.

Four bioregions (Northwest Province, Northwest Transition, Central Western Province and Central Western Shelf Transition) lie in deep waters below the photic zone. Two bioregions (Southwest Transition and Southwest Shelf Province) occur in waters that are too cold to support tropical coral reefs species. Photosynthetic corals are not present in either of these locations and hence these bioregions are not discussed further.

3.1.1 Southwest Shelf Transition

The coral reefs of the Houtman Abrolhos Islands are the most southern extensive coral community along the west coast. Smaller localised pockets do occur as far south as Rottnest Island and even extend to Cape Naturaliste in the Southwest Shelf Province. The reefs around the Abrolhos Islands comprise 211 known species of corals and all but two of the coral species are tropical (DoF 2012). The greatest diversity and density of corals is found on the reef slopes, shallow reef perimeters and lagoon patch reefs in the more sheltered northern and eastern sides of each of the three limestone platforms that support the island groups (DoF 2012).

3.1.2 Central Western Shelf Province

The Central Western Shelf Province occurs on the continental shelf between Coral Bay and Busselton and is generally flat with depths ranging from 0-100 m. The province includes Shark Bay and Bernier, Dorre and Dirk Hartog Islands.

Studies at Shark Bay recorded 80 species of coral (Marsh 1990). The study determined that salinity and seasonal temperature gradients restrict the distribution of corals to areas that have normal salinity in the western half of the Bay, a few species occur in the metahaline waters but none in the hyper saline areas (Marsh 1990). The eastern shores of Bernier, Dorre and Dirk Hartog Islands provide the most favourable habitats for coral growth due to shelter, and water with relatively small salinity and temperature fluctuations. Some sections of these islands support prolific coral growth (up to 100% cover) both in the sheltered leeward and exposed areas. This bioregion is a transitional zone between the predominantly tropical flora and fauna of the north and temperate flora and fauna further south (CALM & NPNCA 1996).

3.1.3 Central Western Shelf Transition

A significant proportion of this bioregion is covered by the Ningaloo Reef. The Ningaloo Reef is unique in that it is the largest fringing reef in Australia and is the only large reef found on the western side of a continent in the southern hemisphere.

A 300 km section of the coast, from Red Bluff to North West Cape and extending to Bundegi in Exmouth Gulf, is included in the Ningaloo Marine Park. Ningaloo Reef supports variable lagoonal, intertidal and subtidal coral communities along its length. Ningaloo Reef is characterised by a high diversity of hard corals with at least 217 species representing 54 genera of hermatypic (reef building) corals recorded to date (Veron & Marsh 1988). The most diverse coral communities are found in the shallow relatively clear water, high energy environment of the fringing barrier reef and low energy lagoonal areas to the west of North West Cape (CALM & MPRA 2005a).

Coral diversity reduces with increasing depth, and corals are uncommon at depths greater than 40 m (Waples & Hollander 2008). At depths between 20 and 30 m hard corals have been found to be more dominant in the northern areas of the Ningaloo Marine Park, whereas in southern areas other sessile invertebrates such as sponges, as more prevalent (Waples & Hollander 2008).

3.1.4 Northwest Transition

This bioregion lies mostly over the continental slope and the abyssal plain in deep waters that preclude photosynthetic coral growth (DEWHA 2008). However, in contrast with the surrounding area, the Rowley Shoals are three distinct reef systems (Mermaid, Clerke and Imperieuse Reefs) approximately 30–40 km apart that rise vertically to the surface from depths of between 500 and 700 m. The marine reef fauna of the Rowley Shoals is considered to be exceptionally rich and diverse, including species typical of the oceanic coral reef communities of the Indo-West Pacific. As many of these species are not found in the inshore tropical waters of northern Australia, such populations are of regional significance (DEWHA 2008).

A 1993 survey at Mermaid Reef recorded 214 species of scleractinian corals (Done *et al*. 1994). The survey found that coral assemblages of the Rowley Shoals are broadly comparable to those found on the reefs of the outer Great Barrier Reef and in the Coral Sea. While the coral fauna is similar to Scott Reef, it differs considerably from that of north-western Australia (Veron 1986). Veron (1986) notes that the clear water of the Rowley Shoals allows coral communities to exist over a great range of depths, while the strong wave action on the outer coral slopes and the wide tidal range result in distinct patterns of zonation.

3.1.5 Northwest Shelf Province

This province contains numerous small coastal islands in addition to larger archipelago and offshore island groups. Many of these features are surrounded by shallow waters with small barrier and fringing reefs that support coral communities. Key areas recognised for coral communities in this bioregion are discussed below.

The Dampier Archipelago supports coral reefs in shallow waters near islands and submerged pinnacles. The most significant coral reefs have formed along the seaward slopes of Delambre Island, Hamersley Shoal, Sailfish Reef, Kendrew Island and north-west Enderby Island (CALM & MPRA 2005b). Field trips in the Dampier Archipelago between 1972 and 1998 recorded 229 species of corals from 57 genera (Griffith 2004). Surveys of the Dampier Port and inner Mermaid Sound recorded approximately 120 coral species from 43 genera (Blakeway & Radford 2005) with coral reefs dominated by acroporids and pocilloporids. The greatest coral cover (up to 70%) was recorded in the eastern half of the archipelago (Wells *et al*. 2003).

The Montebello, Lowendal and Barrow Islands include 315 islands associated with extensive coral reefs, the most significant of which occur in the sheltered waters on the eastern side of the islands. Examples of these significant reefs include Dugong Reef, Batman Reef and reefs along the Lowendal Shelf (DEC & MPRA 2007a). Dominant corals include acroporids and poritids, with greater than 70% cover recorded for some areas (Chevron 2010). Subtidal coral reef communities around the islands are highly diverse, with at least 150 species of hard corals recorded from fringing and patch coral reef areas (DEC & MPRA 2007a).

Coral distribution near the mainland is restricted by lack of light due to natural turbidity. Corals may exist as sparse coral colonies in some locations, rather than extensive coral communities. Within Exmouth Gulf, coral communities are less common but are present on fringing reefs surrounding islands, as solitary corals distributed across areas of hard substrate, or on larger isolated patch reefs.

An epibenthic dredge survey of nearshore areas north of Broome identified 14 species of hard corals from six families (Keesing *et al*. 2011). Limited coral surveys conducted at Broome (15 species) and the Lacepede Islands (ten species) (Veron & Marsh 1988) suggest the species diversity in this locality may be low. However, low species diversity observed during the dredge survey may reflect the limited sampling frequency, limited depth range (11–23 m) or inadequate sampling in habitats considered favourable for the proliferation of hard corals (hard substrate). In contrast, other surveys of nearshore locations in the region have recorded much higher levels of species diversity. Veron and Marsh (1988) stated that 102 species of hard corals have been recorded from the Kimberley coast and nearshore reefs and Cairns (1998) recorded 87 species of azooxanthellate hard coral species from north-western Australian waters.

3.1.6 Timor Province

Although water depths in this province are generally deep (200 m to almost 6,000 m) there are several reefs and islands that are regarded as biodiversity hotspots (DEWHA 2008).

Ashmore Reef, Cartier Island, Hibernia, Scott and Seringapatam reefs are areas of enhanced local biological productivity, within an area of relatively unproductive waters. Ashmore Reef National Nature Reserve supports one of the greatest number of coral species of any reef off the West Australian coast, with 255 species of reef-building corals in 56 genera (Veron 1993). Taxonomic revisions and additional surveys have resulted in a net increase in species numbers to 275 (Griffith 1997, Ceccarelli *et al*. 2011). Species are typical of the indo-pacific region and none are unique or considered endemic. However, 41 species (15% of the total hard coral species at the site) are listed as vulnerable on the IUCN Red List. In 1998, hard coral covered an area of around 717 ha at Ashmore Reef. The majority of hard corals occur in the deep lagoon (265 ha) and shallow reef top (315 ha) with small areas in the shallow lagoons, and reef edge/slope habitats (Skewes *et al*. 1999a).

The species composition of all the hard coral reefs in the bioregion is very similar and reflects strong links with Indo-West Pacific fauna, largely as a result of the dispersal of coral spawn via regional currents. The reefs and islands in this bioregion are thought to be important biological stepping-stones between centres of biodiversity in the Indo–Pacific and reef ecosystems further south (DEWHA 2008).

Seringapatam reef is a regionally important scleractinian coral reef as it has a high biodiversity, which is comparable to Ningaloo Reef. Results from the Western Australian Museum (WAM) survey in 2006 noted 159 species of scleractinian corals with a hard coral cover of approximately 16% (WAM 2009).

Scott Reef consists of two reefs, North Scott Reef and South Scott Reef, which are separated by a deep (400–700 m) channel. North Scott Reef is an annular reef which encloses a lagoon that is connected to the ocean. South Scott Reef is a crescent-shaped reef which forms an arc and partially encloses another lagoon. Light penetration at Scott reef is high due to low turbidity. Light penetration depths to the deeper part of South Reef Lagoon are in excess of 50m with corals able to survive at depths of up to 70 m (Woodside Energy Limited *et al* 2010).

Hibernia Reef consists of an approximately oval-shaped reef, with large areas of the reef becoming exposed at low tide. Hibernia Reef is also characterised by a deep central lagoon and drying sand flats.

There are a number of shoals and banks in the NMR and NWMR. Relatively few studies have been undertaken of these features with the majority of the understanding derived from the Big Bank Shoals study (Heyward *et al*. 1997) and PTTEP surveys initiated in response to the Montara incident (Heyward *et al*. 2010; Heyward *et al.* 2011).

In general, the submerged features are characterised by abrupt bathymetry, rising steeply from the surrounding outer continental shelf at depths of 100 m–200 m. The shoals and banks tend to flatten at depths of 40-50 m, with horizontal plateau areas of several square kilometres generally present at 20-30 m depths (Heyward *et al*. 2010). The shoals and banks support a diverse and varied range of benthic communities, including algae, reef-building soft corals, hard corals and filter-feeders (Heyward *et al.* 1997, Heyward *et al.* 2011). The plateau areas were dominated by benthic primary producer habitat, with interspersed areas of sand and rubble patches (Heyward *et al*. 2011).

3.1.7 Northwest Shelf Transition

Coral communities of the Northwest Shelf Transition have historically not been well studied. However, based on the scale of reef development and the diversity of coral species recorded through limited surveys, it is highly likely that further surveys will demonstrate that the Kimberley contains a coral reef province of global significance (Masini *et al*. 2009).

Coral reefs in the province include fringing reefs around coastal islands and some mainland shores. Development of coral communities in inshore areas is limited due to persistent high turbidity. Known examples of coral reefs in the bioregion are given below, however further mapping is required.

Benthic habitat surveys at Adele and Long Islands in 2009 and 2010 revealed extensive development of hard and soft coral communities (Richards *et al*. 2013). Scleractinian coral communities at Adele Island were diverse, supporting 176 species in intertidal and subtidal areas up to 14 m depth. At Long Island approximately 200 species of scleractinian corals were recorded in intertidal and subtidal areas. These surveys also identified two significant and unique habitats; a zone of mixed corallith and rhodolith habitat at Adele Island and an Organ Pipe Coral habitat zone with unusually high benthic cover at Long Island (Richards *et al*. 2013).

Studies by DEC and the LNG industry indicate that fringing and emergent coral reefs are well developed in the Heyward island group, around islands in the Bonaparte Archipelago, and off mainland shores of Cape Voltaire and Cape Bougainville. Surveys by INPEX of Maret, Bethier and Montalivet islands, which were largely restricted to the intertidal zone, have recorded 280 species of coral from at least 55 genera, making the Kimberley Bioregion the most coral-diverse area in Western Australia (INPEX 2008).

Montgomery Reef has been identified as a key feature in the area. Montgomery Reef is a huge submerged rock platform covering approximately 400 km^2. Corals occur in the subtidal area around Montgomery Reef, and in the many rock pools on the platform where there is shaded from the sun by algae or rock ledges (DEWHA 2008). A survey of benthic habitats at Montgomery Reef was conducted in 2009 by AIMS but a literature search found no published results from this survey (AIMS 2014).

Browse Island is surrounded by a minor fringing coral reef. Assemblages at Browse Island are characteristic of coral platform reefs throughout the Indo-West Pacific region, particularly Cartier Island. Coral diversity was greatest on the reef faces and shallow lagoons but these areas were of very limited extent (URS 2010a).

Hard corals have been recorded at Echuca Shoals but the community was low in both species richness and abundance (URS 2010a). The presence of occasional large outcrops suggests that larger coral structures have occurred previously and may still occur elsewhere on the shoal (RPS Environmental 2008).

3.1.8 International Waters

Important areas outside of the IMCRA bioregions include:

Christmas Island

Fringing coral reefs around Christmas Island are relatively simple with 88 coral species previously identified which are identified to support and over 600 fish species (Director of National Parks, 2012).

Indonesia (west)

Indonesia has an estimated 75,000 km2 coral reef ecosystem distributed throughout the archipelago (Tomascik et al. 1997 cited in Hutumo and Moosa 2005). Fringing reefs are the most common reef types with scleractinian corals as being the most dominant and important group. 452 species of hermatypic scleractinian coral were collected from Indonesian waters by Tomascik et al. (1997 cited in Hutumo and Moosa 2005), a study presented by Suharsono (2004 cited in Hutumo and Moosa 2005), indicated that 590 species of scleractinian corals exist in Indonesian waters. Acropora, Montipora and Porites are the most important reef building corals in Indonesia.

The Lesser Sunda Ecoregion encompasses the chain of islands and surrounding waters from Bali, Indonesia to Timor-Leste. This region contains suitable habitat for corals on shallow water substrates formed by limestone and lava flows and is thought to contain more than 500 species of scleractinian reef-building corals (DeVantier et al. 2008). Coral species composition is influenced by regional and local scale seasonal upwellings that typically occur from April to May each year on the southern side of the islands. The ecoregion is considered important for coral endemism, particularly the areas of Bali-Lombok, Komodo and East Flores. Fringing coral reefs tend to be less developed on the southern, more exposed shorelines (Wilson et al. 2011).

Timor Leste

See **Section 3.1.6** for a description habitat typical of shoals and banks in the Timor Sea.

3.2 Seagrasses

Seagrasses are biologically important for four reasons:

1. As sources of primary production;
2. As habitat for juvenile and adult fauna such as invertebrates and fish;
3. As a food resource; and
4. For their ability to attenuate water movement and trap sediment (Masini *et al*. 2009).

Twenty-five species of seagrass have been recorded in Western Australia, the highest diversity in the world (Masini *et al*. 2009). Waters extending from Busselton to the Northern Territory border support predominantly tropical species although temperate species are also found, particularly between Busselton and Exmouth (Walker 1987). One species, *Cymodocea angustata*, is endemic to Western Australia (DPAW 2013).

The main seagrasses of the region are small, ephemeral species that grow on soft sediments and have a seed bank in the surficial sediments that allows them to recover quickly from disturbance (Walker 1989). Small, ephemeral species of seagrass tend to form mixed associations with macroalgae (CALM

& MPRA 2005b, DEC & MPRA 2007a, BHPBIO 2011) and usually covers less than 5% of the substrate (BHPBIO 2011, van Keulen & Langdon 2011).

Areas occupied by seagrass vary markedly both seasonally and interannually and it is not clear why some areas of suitable substrate will support seagrass in one year but not the next. It appears that recruitment to what may otherwise be suitable substrate is haphazard, lending weight to the descriptions of these seagrass communities as ephemeral (CALM & MPRA 2005b, DEC & MPRA 2007a).

Two bioregions (Northwest Province and Central Western Transition) lie entirely in deep waters below the photic zone. Seagrasses are not present hence these bioregions are not discussed further.

3.2.1 Southwest Shelf Province

Geographe Bay is a large relatively sheltered area with that supports extensive beds of tropical and temperate seagrass that have a high diversity of species and endemism (DEWHA 2008). They are thought to account for about 80% of benthic primary production in the area. These seagrass beds provide important nursery habitat for many shelf species that use the shallow seagrass habitat as nursery grounds for several years before moving out over the shelf to their adult feeding grounds along the shelf break.

The Geographe Bay seagrass meadows are among the most extensive temperate seagrass communities on the west coast (MPRSWG 1994 cited in DEC, 2013), and include 10 species from five genera (*Amphibolis, Posidonia, Halophila, Heterozostera* and *Thalassodendron*). Geographe Bay is dominated by stands of the narrowleaf tape-weed (*Posidonia sinuosa*) that covers approximately 70% of Geographe Bay. It has smaller areas of *Posidonia angustifolia*, *Amphibolis griffithii*, *A. antarctica* and minor species, which have irregular distributions both spatially and temporally (Lord 1995 cited in DEC 2013). *Thalassodendron pachyrhizum*, *Posidonia* spp. and *Amphibolis* spp. are also found in depths of between 27 and 45 m (Walker *et al*. 1994 cited in DEC 2013).

3.2.2 Southwest Shelf Transition

Species diversity of seagrasses in this bioregion is the highest in the world, with 14 species occurring (DEWHA 2008). In total, 10 seagrass species have been recorded at the Abrolhos ranging from small, delicate species to larger, more robust types that grow in large meadows (DoF 2012). Small paddle-weeds grow in protected lagoon areas or deep waters between the islands, such as Goss Passage and the larger species may be found growing on reef as well as in sandy areas (DoF 2012). *Thalassodendron pachyrhizum*, which is encountered growing on the exposed reef crest area, has been recorded at a number of the island groups. There are also two species of wire-weed (*Amphibolis* species), endemic to southern Australia, found at the Abrolhos (DoF 2012). The most abundant seagrass is *Amphibolis antarctica*, while *Amphibolis griffithii* appears to be restricted to bays such as Turtle Bay in the Wallabi Group.

The larger ribbon-weeds (*Posidonia* species) grow in sheltered bays and lagoons where the sand cover is deeper and more stable (e.g. Turtle Bay, the Gap, East Wallabi Island, the lagoon on the west side of West Wallabi Islands and around North Island) (DoF 2012).

Nine species of seagrass are found in the Perth region, including at Rottnest Island where *Amphibolis* thrives in clear waters overlying limestone rock (Amalfi 2006). Seagrasses are a major component of the ecosystem on the Rottnest Shelf, thriving in waters ranging in depth from intertidal to 45m (Amalfi 2006). All of the seagrass species identified with the exception of *Syringodium isoetifolium* and *H. ovalis* are endemic to temperate areas of southern Australia (Amalfi 2006). At Rocky Bay, on the north side of the island where it is protected from big swells and strong south to south-westerly winds, a mix of dense seagrass meadow consisting of *Amphibolis* and *Posidonia* thrive. The meadows around Rottnest Island serve as nurseries for juveniles of many fish species, and are home to species such as the cobbler and long-headed flathead (Amalfi 2006).

3.2.3 Central Western Shelf Province

Shark Bay contains the largest reported seagrass meadows in the world (approximately 4,000 km^2), as well as some of the most species-rich seagrass assemblages (Walker 1989). Twelve species of seagrass are found in the Bay with the dominant species being *Amphibolis antarctica*. Seagrass is a fundamental component of biological processes in Shark Bay; it has modified the physical, chemical and biological characteristics of the Bay and provides food, habitat and nursery grounds for many species (CALM & NPNCA 1996).

An inshore survey of benthic habitats near Busselton recorded dense coverage of *Amphibolis* spp. on limestone pavement. *Halophila* spp., *Heterozostera* spp. and *Syringodium isoetifolium* were recorded on sandy substrates (DoF 2004).

3.2.4 Central Western Shelf Transition

Nine species of seagrasses have been found throughout Ningaloo Reef (van Keulen & Langdon 2011). Some delineation of temperate and tropical species exists; however, several species were found throughout the Ningaloo Reef. Halophila ovalis was the most commonly found seagrass at Ningaloo and was generally found growing in sandy patches between coral bomboras. Amphibolis antarctica is a large meadow forming species that has been found growing in large clumps in Bateman Bay, north of Coral Bay (van Keulen & Langdon 2011).

3.2.5 Northwest Transition

The Rowley Shoals provide the only suitable shallow substrate for seagrasses in this predominantly deep bioregion. Sparse seagrass is found within subtidal coral reef communities of the Rowley Shoals but is not a major habitat type. Two species of seagrass, *Thalassia hemprichii* and *Halophila ovalis*, have been recorded at Mermaid Reef (Huisman *et al*. 2009). Earlier studies at Mermaid and Imperieuse Reef recorded the above two species and a third species; *Thalassodendron ciliatum* (Walker & Prince 1987).

3.2.6 Northwest Shelf Province

In the Northwest Shelf Province, seagrasses are present but sparsely distributed to depths of approximately 30 m (LEC & Astron 1993, URS 2009, CALM 2005a). The abundance and distribution of tropical (and subtropical) seagrass species can vary greatly due to seasonal changes in water quality (turbidity, light penetration) and conditions (wave action, temperature), with biomass tending to peak in summer (Lanyon & March 1995).

Studies between Quondong and Coulomb Points north of Broome identified seagrass communities of *Halophila* spp. patchily distributed across large areas, from the lower intertidal and out to a depth of approximately 20 m (DEC 2008, Fry *et al*. 2008). Similarly, *Halophila decipiens* was the only seagrass collected from epibenthic dredge studies at five localities near Broome from Gourdon Bay to Packer Island (Keesing *et al.* 20011).

Roebuck Bay is located south of Broome and includes large areas of intertidal mudflats. Extensive seagrass meadows occur in the northern regions of Roebuck Bay and are dominated by *Halophila ovalis* and *Halodule uninervis*. *Halophila minor* and *Halodule pinifolia* have also been reported at this location (Prince 1986, Walker & Prince 1987, Seagrass-Watch 2013).

In the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area, seagrass occurs in the larger bays and sheltered flats of the area (CALM & MPRA 2005b). Six species of seagrass, including three Halophila species, have been recorded on the subtidal soft sediment habitats (CALM & MPRA 2005b). Seagrasses do not form extensive meadows within the proposed reserves, but rather form interspersed seagrass/macroalgal beds. The largest areas of seagrass are found between Keast and Legendre islands, and between West Intercourse Island and Cape Preston (CALM & MPRA 2005b).

Surveys near Onslow found that *Halophila* spp. were the most widespread of the seagrasses in that region. Seagrasses were found to be generally sparsely distributed (<10% cover), occurring in small patches within larger areas of suitable substrate. Small areas of higher (>50%) seagrass cover occurred in shallow clear water areas but were not common (URS 2009, URS 2010b, Chevron 2010).

Similarly, in the Montebello/Barrow Islands Marine Conservation Reserves, seagrasses appear not to form extensive meadows but are sparsely interspersed between macroalgae. Seven seagrass species have been recorded in the Reserves (DEC & MPRA 2007a) with *Halophila* spp. the most common seagrass species on shallow soft substrates and sand veneers. Distributions of these species extend from the intertidal zone to approximately 15m water depth (DEC & MPRA 2007a). Surveys to the northwest and southeast of Barrow Island from 2002 to 2004 did not identify any significant seagrass meadows but confirmed the presence of sparse coverage of *Halophila* and *Halodule* spp. in shallow areas east of Barrow Island (RPS BBG 2005).

A significant meadow of large seagrasses at Mary Anne Reef east of Onslow was identified almost 30 years ago and its presence today is unconfirmed. The meadow was several hundred hectares of *Cymodocea angustata* at 30–50% cover, occurring primarily at a depth of 2–3 m (Walker & Prince 1987).

3.2.7 Timor Province

Seagrass has been reported on the reef flats of offshore reefs of this bioregion (Whiting 1999, Hale & Butcher 2013). Five species of seagrass were reported at Ashmore Reef with *Thalassia hemprichii* being the dominant species (Pike & Leach 1997, Skewes *et al*. 1999b, Brown & Skewes 2005). The total area of seagrass at Ashmore Reef in 1999 was estimated to be 470 ha (Skewes *et al*. 1999b). However, much of this was very sparse cover and there were only 220 ha of seagrass with a greater than 10% cover (Brown & Skewes 2005). Seagrass grew in a sparse, patchy distribution across the sand flats, but had a higher coverage on the reef flat area, where it extended to within 100 m of the reef crest. The area of greatest cover and diversity was in the west and south-west areas of the reef on the inner reef flat (Brown & Skewes 2005). These seagrass meadows support a small but significant population of dugongs estimated at around 100 individuals comprising all age classes from calves to adults (Hale & Butcher 2005).

Similarly, Scott Reef supports five species of seagrass (URS 2006), with *Thalassia hemprichii* most abundant (Skewes *et al*. 1999a, URS 2006). The area of seagrass at Scott Reef is significantly less than that recorded for Ashmore Reef (approximately 100 ha) (Woodside 2011). The highly energetic environment and significant tidal exposure of Scott Reef restricts the area of habitats potentially suitable for seagrass establishment to a small proportion of the total area, resulting in low abundance (Skewes *et al*. 1999a, URS 2006).

Seringapatam Reef was found to have a seagrass cover of 2 ha out of 5,519 ha (0.04%) composed of *Thalassia hemprichii* and *Halophila ovalis* in approximately equal quantities (Skewes *et al*. 1999a). This finding contrasts with a more recent survey where only one species of seagrass (*Halophila decipiens*) was recorded at Seringapatam (Huisman *et al*. 2009).

Skewes *et al*. (1999a) did not observe any seagrass communities at Hibernia Reef.

3.2.8 Northwest Shelf Transition

Extensive and diverse intertidal seagrass meadows are known from islands in the southern Kimberley, particularly in the Sunday Island One Arm Point area (Walker 1995, Walker & Prince 1987). Ten species of seagrasses have been recorded at One Arm Point, with the majority of meadows low to moderate in abundance and dominated by *Thalassia hemprichii* with *Halophila ovalis*, *Halodule uninervis* and *Enhalus acoroides* (Seagrass-Watch 2013).

While some seagrasses have been collected from intertidal sites in the central and north Kimberley (Walker *et al*. 1996, Walker 1997), these areas were not found to be species rich and did not support extensive seagrass meadows like those found in the southern Kimberley.

Subtidal seagrass meadows in the Northwest Shelf Transition are not well mapped, although dugongs are known to feed on seagrass communities in coastal waters of the Joseph Bonaparte Gulf (DEWHA 2008).

3.2.9 International Waters

Important areas outside of the IMCRA bioregions include:

Indonesia (west)

Within Indonesian waters, the lower intertidal and upper subtidal zones are considered important areas for the growth of seagrass (Hutumo and Moosa, 2005). Pioneering vegetation in the intertidal zone is dominated by *Halophila ovalis* and *Halodule pinifolia* while *Thalassodendron ciliatum* dominate the lower subtidal zones. Wide areas of the Indonesian coastal waters are covered by dense beds of seagrass.

Seagrass habitats are widely distributed across the Lesser Sunda Ecoregion. Preliminary data from the United Nations Environment Program's (UNEP) World Conservation Monitoring Centre (WCMC) has identified the following areas as potential areas of importance for seagrass, many of which are outside the area of interest (DeVantier *et al.* 2008):

+ North-west Bali;
+ South-west and west Lombok;
+ North-east Sumbawa;
+ Komodo Islands;
+ Savu; and
+ South coast of Timor Leste.

The Kepulauan Seribu National Park is also known for its rich diversity of seagrasses (refer to **Section 9.8**).

3.3 Macroalgae

Macroalgae are important contributors to primary production and nutrient cycling in the region, providing food and habitat for vertebrate and invertebrate fauna. Macroalgae are also recognised for their role in spatial subsidies; the movement of nutrients or energy between neighbouring habitats. Spatial subsidies involving macroalgae include the movement of wrack from macroalgal beds to bare substrates and shorelines (Orr 2004).

Macroalgae are primarily associated with hard substrates. They occur in moderate to high cover on exposed hard substrates, but typically have lower cover on hard substrates that are covered with a veneer of sediment (SKM 2009, BHPBIO 2011). Macroalgae exhibit very high seasonal and interannual variation in biomass (Heyward *et al*. 2006) and distribution, abundance and biodiversity (Rio Tinto 2009, BHPBIO 2011). The distribution of hard substrates therefore indicates areas that may support macroalgal communities, although abundance and diversity may fluctuate annually.

Macroalgae are susceptible to disturbance from factors such as sedimentation, scouring and turbidity but the marked seasonality in biomass, abundance, diversity and distribution suggests macroalgae are likely to be resilient to acute, short-term disturbance acting at local scales. Macroalgae may be more susceptible to impacts acting over longer time scales (years) and at certain times of the year, where recruitment at a regional scale could be affected. Indirect impacts affecting the numbers, distribution and community structure of herbivorous fish can also be expected to have impacts (either positive or negative) on macroalgal habitats (Vergès *et al*. 2011).

Two bioregions (Northwest Province and Central Western Transition) lie entirely in deep waters below the photic zone. Benthic macroalgae are not present hence these bioregions are not discussed further.

3.3.1 Southwest Shelf Province

Species diversity of macroalgae is very high. The south coast of the bioregion is characterised by a relatively higher diversity of temperate macro-algal species compared with the Southwest Shelf Transition. These colonise the exposed rocky shorelines and rocky reefs (DEWHA2008a).

3.3.2 Southwest Shelf Transition

The Houtman Abrolhos have known species of benthic algae with macroalgae communities considered important in supporting a diversity of marine life.

More than 340 species of macroalgae (including 54 species of green algae, 71 species of brown algae, and 222 species of red algae) have been recorded from rock platforms around Rottnest Island (Amalfi 2006).

3.3.3 Central Western Shelf Province

Although seagrasses are the most visually dominant organisms found in Shark Bay (Walker *et al*. 1989) macroalgae are also a significant component within the system, with 161 taxa of benthic macroalgae reported from the location (Kendrick *et al*. 1990). The seagrass meadows host a large number of epiphytic algal species (Harlin *et al*. 1985, Kendrick *et al*. 1988), which numerically dominate the algal flora of the area. Eighty algal species were epiphytic on the seagrass *Amphibolis antarctica*, and of these, over half have been reported both as epiphytes and benthic algae. Benthic macroalgae can be found in growing on occasional subtidal rock (limestone–sandstone) platforms and extensive sand flats that occur throughout Shark Bay, and as drift within seagrass meadows (Kendrick *et al*. 1990).

The benthic algae of Shark Bay are not predominantly temperate as is the case with the seagrasses (Walker *et al*. 1989) and seagrass epiphytes (Kendrick *et al*. 1988). The majority of taxa are either of tropical or cosmopolitan distribution. Their local distribution within Shark Bay is correlated with salinity, with benthic algal species richness lower in areas of high salinity (Kendrick *et al*. 1990).

Limestone platforms occur along the bioregion's coastline and high energy environments are likely to be dominated by large brown algae including *Ecklonia radiata* and *Sargassum* spp. with articulated coralline algae making up the understorey. More diverse algae assemblages may be observed in sheltered locations such as potholes and ledges (DoF 2004).

3.3.4 Central Western Shelf Transition

Macroalgal beds along the Ningaloo coastline are generally found on the shallow limestone lagoonal platforms and occupy about 2,200 ha of the Ningaloo Marine Park and Muiron Islands Marine Management Area (CALM & MPRA 2005a). Macroalgal communities within the area have been broadly described (Bancroft & Davidson 2001). The dominant genera are the brown algae Sargassum, Padina, Dictyota and Hydroclathrus (McCook et al. 1995).

3.3.5 Northwest Transition

Although macroalgae is present at the Rowley Shoals, it is not recognised as a key habitat component in the Mermaid Reef Marine National Nature Reserve Plan of Management (EA 2000) or the Rowley Shoals Marine Park Management Plan (DEC & MPRA 2007b).

There is nothing to suggest that the algal flora of the Rowley Shoals is unique within the Indo-Pacific (Huisman *et al*. 2009). A study of macroalgae at 16 locations at Mermaid Reef recorded over 100 species (Huisman *et al*. 2009). The algal flora recorded at the Rowley Shoals represents a small portion of the highly diverse Indo-Pacific flora. The majority of species that were recorded at Mermaid Reef had been previously recorded from mainland north-western Australia or from Indonesia (Huisman *et al*. 2009).

3.3.6 Northwest Shelf Province

Macroalgae are diverse and widespread throughout the Northwest Shelf Province. They are restricted to depths where sufficient light penetrates to the substrate and therefore tend to be most common in shallow subtidal waters down to approximately 20 m depth.

In the nearshore regions of the Pilbara, macroalgae are often a dominant component of the mosaic of benthic organisms found on hard substrates in shallow water. In these shallow waters, regular disturbance to reef habitats from seasonal changes in sedimentation/ erosion patterns and the less frequent impacts of cyclones and storms through sedimentation and scouring may substantially alter the distribution and composition of the benthic communities associated with reefs, including macroalgal habitats (BHPBIO 2011).

Macroalgae dominate shallow (<10 m) submerged limestone reefs and also grow on stable rubble and boulder surfaces in the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area (CALM & MPRA 2005b). Huisman and Borowitzka (2003) reported approximately 200 species of macroalgae from the Dampier Archipelago. Low relief limestone reefs that are dominated by macroalgae, account for 17% (approximately 35,460 ha) of the marine habitats within the proposed Marine Management Area (CALM 2005a).

Epibenthic dredge surveys along the coastline north of Broome identified 43 species of algae from 22 families (Keesing *et al*. 2011). The lower species diversity collected by this study is attributed to the method of collection and limited depth range (11–23 m) (Keesing *et al*. 2011).

Macroalgae occur around the numerous small offshore islands within this bioregion (including Thevenard Island, Airlie Island and Serrurier Island) associated with limestone pavement and protected areas of soft sediments. Dominant species are consistent with those described for the Dampier Archipelago (Woodside 2011).

In the shallow offshore waters of the Pilbara region, macroalgae are the dominant benthic habitat on hard substrates in both the Montebello and Barrow Islands Marine Parks and are the main primary producers (DEC & MPRA 2007a, Chevron 2010). Shallow water habitats outside these marine parks are also likely to support substantial areas of macroalgal habitat wherever conditions are suitable.

Macroalgae occupy approximately 40% of the benthic habitat area in the Montebello/ Lowendal/ Barrow Island region (CALM 2005b). At least 132 macroalgal taxa occur around Barrow Island, with most thought to be widely distributed in the tropical Indo-Pacific region (Chevron 2005).

Macroalgae monitoring around the Lowendal and Montebello Islands since 1996 (The Ecology Lab 1997, IRCE 2002 2003 2004 2006 2007, URS 2009) has found macroalgal cover and biomass to be naturally spatially and temporally variable. *Sargassum* spp. represented 70% of the macroalgal assemblage in 2009, compared to 96% in 2002 (URS 2009). Sargassum spp. cover as a percentage of total macroalgae cover was significantly lower in 2009 than in previous years, primarily due to an increase in filamentous algae at a number of sites (URS 2009).

3.3.7 Timor Province

Macroalgae at Ashmore Reef are estimated to cover over 2,000 ha, mostly on the reef slope and crest areas (Hale & Butcher 2013). The algal community is dominated by turf and coralline algae, with fleshy macroalgae comprising typically less than 10% of total algal cover (Skewes *et al*. 1999b).

Surveys at Scott and Seringapatam Reefs recorded over 100 species of marine algae (Huisman *et al*. 2009). The marine algal community was similar between reefs and also similar to the Rowley Shoals. Algae found at these offshore atolls forms a small subset of the Indo-Pacific algal flora, with virtually all of the species identified thus far having been previously collected from north-western Australia or from localities further north. Although further research is necessary, at present there is nothing to suggest that the macroalgae communities of these offshore atolls are unique within the Indo-Pacific (Huisman *et al*. 2009).

3.3.8 Northwest Shelf Transition

There is a lack of information regarding the marine benthic flora of north-west Western Australia and no comprehensive marine flora list exists for the region (Huisman 2004). However, about 70 algae species were collected during a survey of intertidal reefs on the central Kimberley coast in 1997 (Walker 1997).

Tropical macroalgae species are typically associated with areas of hard substrate and various types of macroalgae occur on rock platforms intermingled with coral and sponge. Abundance and biomass typically exhibit strong seasonal trends (Heyward *et al*. 2006).

The diversity and abundance of algae in the Kimberley is probably linked to the region's extreme tidal exposure and highly turbid waters, reducing light penetration and resulting in deposition of fine sediments (Walker 1997). However, the role of algae appears crucial to the growth of reefs in the highly turbid waters of the Kimberley coast and islands (Brooke 1997). *Sargassum* spp. and coralline algae may be dominant (DPAW 2013).

3.3.9 International Waters

No information on macroalgae in international waters has been identified other than for Timor Leste waters.

Timor Leste

See **Section 3.1.6** for a description habitat typical of shoals and banks in the Timor Sea.

3.4 Non-Coral Benthic Invertebrates

The offshore marine environment from Busselton to the Northern Territory border is overwhelmingly dominated by soft sediment seabeds; sandy and muddy substrates, occasionally interspersed with hard substrates covered with sand veneers, and rarely, exposed hard substrate. In shallow waters, non-coral benthic invertebrates may form part of the mosaic of benthic organisms found on hard substrates, alongside macrophytes and coral colonies. As light reduces with water depth, non-coral benthic invertebrates are the dominant community, albeit at low densities.

Non coral benthic invertebrates feed by filtering small particles from seawater, typically by passing the water over a specialised filtering structure. Examples of filter feeders are sponges, soft and whip corals and sea squirts.

3.4.1 Southwest Transition

There is little available information on benthic biological communities of this bioregion however deep sea crabs, such as the champagne crab and crystal crab are known to inhabit the seafloor of the slope (DEWHA 2008a).

3.4.2 Central Western Province

The understanding of marine life in this bioregion is mostly confined to the demersal fish on the continental slope. The exception to this is the Perth Canyon which although poorly understood is known to have unique seafloor features with ecological properties of regional significance.

3.4.3 Western Shelf Province

The Central Western Shelf Province occurs on the continental shelf in water depths from 0 to 100 m. Biological communities of the shelf are likely to include a sparse invertebrate assemblage of sea cucumbers, urchins, crabs and polychaetes on sand substrates. Hard substrates are likely to contain sessile invertebrates such as sponges and gorgonians. The biological communities of this bioregion share many similarities with the adjoining temperate region (DEWHA 2008).

Stromatolites occur in Shark Bay. Although they are a microbial colony (prokaryote), and not an invertebrate (eukaryote), they are described here as a unique benthic biological community.

Stromatolites are rock-like structures built by cyanobacteria. Shark Bay's stromatolites are 2,000 to 3,000 years old and are similar to life forms found on Earth up to 3.5 billion years ago. Until about 500 million years ago, stromatolites were the only macroscopic evidence of life on the planet; hence they provide a unique insight into early life forms and evolution. The stromatolites are located in the hypersaline environment of Hamelin Pool and are one of the reasons for the area's World Heritage Listing (DPAW 2009).

3.4.4 Central Western Transition

The Central Western Transition extends from the shelf break to the continental slope with some parts of the bioregion occurring on the abyssal plain. Water depths range from 80 m to almost 6,000 m. Sediments are dominated by muds and sands that decrease in grain size with increasing depth. The present level of understanding of the marine environment in this bioregion is generally poor. The harder substrate of the slope in waters of 200–2,000 m deep is likely to support populations of epibenthic fauna including bryozoans and sponges. These support larger infauna and benthic animals such as crabs, cephalopods, echinoderms and other filter feeding epibenthic organisms. In the deeper waters of the abyss, the benthic communities are likely to be sparse (DEWHA 2008).

3.4.5 Central Western Shelf Transition

The Central Western Shelf Transition is located entirely on the continental shelf and is comprised mainly of sandy sediments in depths between 0 and 80 m (DEWHA 2008).

Some sponge species and filter-feeding communities found in deeper waters offshore from the Ningaloo Reef appear to be significantly different to those of the Dampier Archipelago and Abrolhos Islands, indicating that the Commonwealth waters have some areas of potentially high and unique sponge biodiversity (Rees *et al*. 2004).

3.4.6 Northwest Province

The Northwest Province is located entirely on the continental slope in water depths of predominantly between 1,000–3,000 m and is comprised of muddy sediments. Despite the present poor knowledge of the benthic communities on the Exmouth Plateau, information on sediments in the bioregion indicates that benthic communities are likely to include filter feeders and epifauna. Soft-bottom environments are likely to support patchy distributions of mobile epibenthos, such as sea cucumbers, ophiuroids, echinoderms, polychaetes and sea pens.

3.4.7 Northwest Transition

The Northwest Transition is located from the shelf break (200 m water depth) over the continental slope to depths of more than 1,000 m at the Argo Abyssal Plain. Benthic habitat mapping surveys and epibenthic sampling conducted by CSIRO at the continental slope (approximately 400 m water depth) showed that all survey sites predominantly comprised soft muddy sediment, which was often riffled. Gravel, boulders and small outcrops were occasionally recorded. Epifaunal abundance was similar all sites, with epifauna limited to sparsely distributed isolated individuals. Epifauna included isolated scattered sessile crinoids, anemones, glass sponges and seapens. Occasional non-sessile fauna included urchins, prawns and other decapods, holothurians and sea stars. Modelling indicated a 1 km long beam trawl across the continental shelf (~400 m water depth) would be expected to yield sparse (<20 individuals) and low diversity (<10 species) of epibenthic fauna (≥1 cm body size) (Williams *et al*. 2010). Deeper on the continental slope at ~700 m and ~1,000 m, habitats were similar to those observed at 400 m (Williams *et al*. 2010).

Although soft sediment habitat may appear monotonous and featureless, there is likely to be some marked differences in terms of ecological functioning and faunal composition between shelf and deep-sea areas, with the 200 m isobath widely believed to represent a key boundary (Wilson 2013, Brewer *et al*. 2007, Gage & Tyler 1992). Beyond the 200 m isobath, deep-sea benthic communities rely exclusively on the settling of organic detritus from the overlying water column as a food source. The spatial and temporal distribution of benthic fauna depends on factors such as sediment characteristics, depth and season (Wilson 2013).

Due to contrasting depths, the Rowley Shoals supports a diverse marine invertebrate community including a number of endemic species. Invertebrate species (excluding corals) at the Rowley Shoals include sponges, cnidarians (jellyfish, anemones), worms, bryozoans (sea mosses), crustaceans (crabs, lobsters, etc.), molluscs (cuttlefish, baler shells, giant clams, etc.), echinoderms (starfish, sea urchins) and sea squirts (DEC & MPRA 2007b).

3.4.8 Northwest Shelf Province

This bioregion is located primarily on the continental shelf in water depths from 0 to 200 m (DEWHA 2008). The sandy substrates on the shelf within this bioregion are thought to support low density benthic communities of bryozoans, molluscs and echinoids (DEWHA 2008). Sponge communities are also sparsely distributed on the shelf, but are found only in areas of hard substrate. The region between Dampier and Port Hedland has been described as a hotspot for sponge biodiversity (Hooper & Ekins 2004).

Epibenthic dredge surveys in nearshore areas around Broome covered 1,350 m^2 of seabed in depths between 11 and 23 m. The survey recorded 357 taxa comprising 52 sponges, 30 ascidians, 10 hydroids, 52 cnidarians (not including scleractinian corals), 69 crustaceans, 73 molluscs and 71 echinoderms. The most important species on soft bottom habitats in terms of biomass was the heart urchin *(Breynia desorii)*, whilst sponges were the dominant fauna by biomass on hard bottom habitats. The biomass of other filter feeders, especially ascidians, soft corals, gorgonians was also high, indicating the importance of these groups in characterising hard bottom habitats.

In 2007, CSIRO conducted extensive benthic habitat mapping surveys and epibenthic fauna (living on the surface and ≥1 cm body size) sampling in deep waters (100–1,000 m) spanning thirteen sites between Barrow Island and Ashmore Reef running along the continental shelf and across the continental slope of the North West Shelf (Williams *et al*. 2010). At the continental shelf margin (~100 m water depth) Williams *et al*. (2010) reported that similar benthic habitats occurred at each survey site across the breadth of the North West Shelf. Benthic habitats at this depth comprised a mix of riffled muddy sand (sometimes as a veneer over rocky subcrops) together with gravel to pebble-sized rubble, cobbles, boulders and some rock outcrops. Typical epifauna found at these depths included scattered isolated hydroids, sea fans and soft corals and often small sponges. Other fauna observed at some of the sites included scattered isolated sea whips, crinoids, sea pens, urchins and anemones. Epibenthic fauna along the continental shelf margin were quantified as sparse and low diversity (Williams *et al*. 2010). Modelling indicated that a trawl sample of 1 km length would generally be expected to yield approximately 80 individuals represented by 15 species (Williams *et al*. 2010) in 100 m depth waters.

At the shelf edge (~200 m water depth), two sites were surveyed. Both sites were similar to the continental shelf margin, except the northern site mainly comprised coarse material. Epifauna observed at the northern site was similar at 200 m as at 100 m. At the southern site, epifauna included sparse and scattered individual soft corals, anemones, glass sponges and stalked crinoids (Williams et al. 2010). Modelling indicated epibenthic fauna were sparse and had low diversity, numbering approximately 20–40 individuals in a 1 km long trawl sample represented by approximately 5–10 species (Williams *et al*. 2010).

Baseline studies undertaken in nearshore areas of the Pilbara (SKM 2009, Rio Tinto 2009, BHPBIO 2011) and offshore areas around Barrow Island (Chevron 2010) have shown that filter feeder communities are a dominant component of benthic habitats in depths >10 m where reduced light appears to inhibit extensive development of hard corals and macroalgae. The pavement habitats between Barrow Island and the mainland are covered by a sediment veneer that appears to periodically move, exposing areas of pavement reef. Sessile benthic organisms that require hard substrates for attachment, such as gorgonians, are frequently seen emerging through a shallow veneer of sand. This type of substrate (sediment veneer) with sparse filter feeder communities is common throughout this area (SKM 2009, Rio Tinto 2009, BHPBIO 2011).

3.4.9 Timor Province

The Timor Province is located on the continental slope and abyssal plain and water depths range from 200 m to almost 6,000 m. Benthic studies in this bioregion are scarce, however data from the North West Slope Trawl Fishery suggests that muddy sediments in the Timor Province support significant populations of crustaceans (Brewer *et al*. 2007). Additionally, research into the demersal fish communities of the continental slope has identified the Timor Province as an important bioregion. This is due to the presence of a number of endemic fish species, and two distinct demersal community types associated with the upper slope (water depths of 225–500 m) and mid-slope (water depths of 750–1,000 m) (Last *et al*. 2005). The current understanding of the relationship between demersal fish communities and benthic environments on the continental slope is rudimentary (DEWHA 2008).

The soft, non-reef building corals are less well studied at Ashmore Reef than the hard corals (Hale & Butcher 2013). In 1986, 39 soft coral taxa were recorded within the Ashmore Reef, including the vulnerable blue coral (*Heliopora coerulea*) which was moderately common on the reef flats (Marsh 1993). In 1998, the total cover of soft coral at Ashmore Reef was 323 ha and *Sarcophyton* spp. was the dominant taxa covering around 19 ha in total (Skewes *et al*. 1999b, Hale & Butcher 2013). Over 130 species of sponges have been recorded at the Ashmore Reef National Nature Reserve (Russell & Hanley 1993).

3.4.10 Northwest Shelf Transition

The Northwest Shelf Transition is located on the continental shelf with a small area extending onto the continental slope, with water depths ranging from 0–330 m. Nearshore areas may support significant filter feeding communities but these have not yet been described (Masini *et al*. 2009).

Pipeline route surveys north of the Kimberley in water depths from 10–250 m recorded a seabed largely devoid of hard substrate, with only sparse epibenthic fauna noted on the predominantly sandy substrate. Occasional epibenthic fauna (featherstars, gorgonians, bryozoans, sea urchins, hydroids and sponges) were recorded in areas where rocky substrate or outcrops were present (URS 2010a).

In contrast, benthic surveys at Echuca Shoals identified broad areas of hard substrate with substantial epibenthic fauna. The shallow shoal areas were dominated by a flat ‘reef’ platform with crinoids, sea whips, soft corals and low densities of hard corals. With increasing depth (25–80 m) soft corals and sponges became increasingly dominant. At greater depths (80–100 m) the density of epibenthic fauna decreased substantially with sea whips and sea fans became dominant (URS 2010a).

3.4.11 International Waters

No information on non-coral benthic invertebrates in international waters has been identified other than for Timor Leste waters.

Timor Leste

See **Section 3.1.6** for a description habitat typical of shoals and banks in the Timor Sea.

3.5 Plankton

Plankton abundance and distribution is patchy, dynamic and strongly linked to localised and seasonal productivity (Evans *et al.* 2016). Fluctuations in abundance and distribution occur both vertically and horizontally in response to tidal cycles, seasonal variation (light, water temperature and chemistry, currents and nutrients) and cyclonic events. As a key indicator for ecosystem health and change, Plankton distribution and abundance has been measured for over a century in Australia (Richardson *et al.* 2015). The compilation of this data has been made publicly available through the Australian Ocean Data Network (Australian Ocean Data Network 2017) and has recently been used in the Australia State of the Environment 2016 report (Jackson *et al.* 2017) to nationally assess marine ecosystem health. According to their findings, warming ocean temperatures has extended the distribution of tropical phytoplankton species (which have a lower productivity), further south resulting in a decline in primary productivity in oceanic waters north of 35°C, especially the North West Shelf (Evans *et al.* 2016). Trends of primary productivity across Australia are however variable with the South West of Australia experiencing an increase in productivity and northern Australia experiencing no change between 2002-2016 (Evans *et al.* 2016).

Within the area of interest, peak primary productivity varies on a local and regional scale. For example, peak phytoplankton biomass in waters surrounding Broome has been observed in May with a high variability recorded in August, whereas recorded phytoplankton biomass in waters surrounding Geographe Bay has been found to peak during winter and is localised close to the coast (Bloundeau-Patissier *et al.* 2011). In general, these peaks are linked to mass coral spawning events, peaks in zooplankton and fish larvae abundance and periodic upwelling. Regional upwelling is most common close to the coast and where surface waters diverge. Despite the suppression of major upwelling along the WA coast by the Leeuwin Current, known key upwelling regions include the Ningaloo region (Hanson & McKinnon 2009) & Cape Mentelle (Pattiaratchi 2007). It is also expected that a high abundance of plankton will occur within areas of localised upwelling in the area of interest where the seabed disrupts the current flow.

In waters surrounding Indonesia, seasonal peaks in phytoplankton biomass is linked to monsoon related changes in wind. When the winds reverse direction (offshore vs. onshore), nutrient concentrations decrease/increase because of the suppression/enhancement of upwelling (NASA 2017). Annual variability of phytoplankton productivity in waters surrounding Indonesia is heavily influenced by the El Niño-Southern Oscillation climate pattern (NASA 2017). For example, phytoplankton productivity around Indonesia increases during El Niño events.

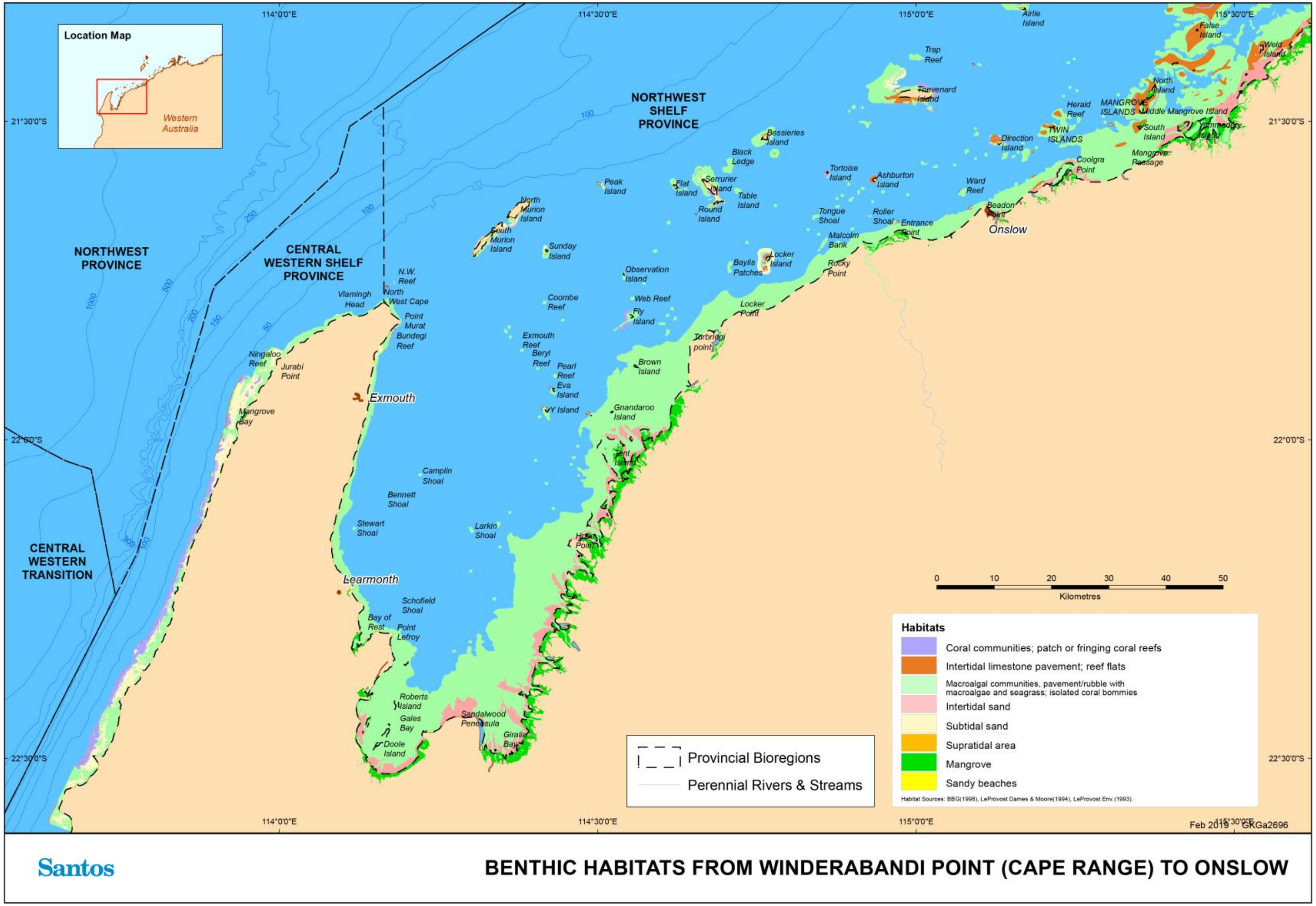


Figure 3-1: Benthic habitats from Winderabandi Point to Onslow

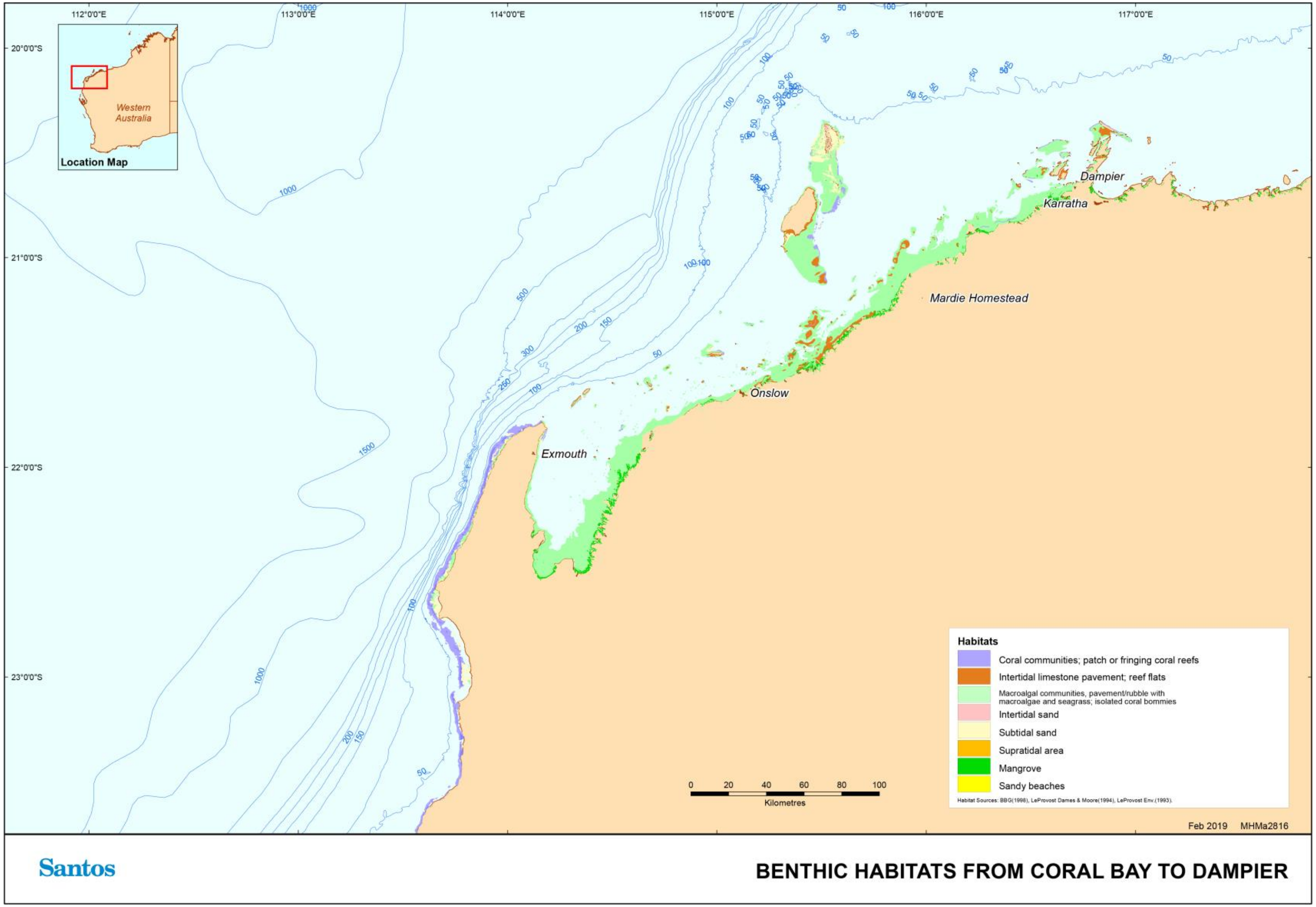


Figure 3-2: Benthic habitats from Coral Bay to Dampier

4. Shoreline Habitats

Shoreline habitats are defined as those habitats that are adjacent to the water along the mainland and of islands that occur above the LAT and most often in the intertidal zone.

The following section broadly categorises shoreline habitats as the following biological communities; mangroves, intertidal mud/sand banks, beaches, and rocky shores. These communities are discussed in **Sections 4.1- 4.5**, in terms of the 13 IMCRA v. 4.0 bioregions where relevant and where information is available.

Figure 3-1 and **Figure** 3-2 broadly illustrate these habitats within the Northwest Shelf Province and Central Western Shelf Transition.

4.1 Mangroves

Mangroves commonly occur in sheltered coastal areas in tropical and sub-tropical latitudes (Kathiresan and Bingham, 2001). Up to eight species of mangroves are found further north in the Central Western Shelf Transition region, but at most locations the dominant mangrove (in terms of area of intertidal zone occupied) is *Avicennia marina*, with the stilt rooted mangrove *Rhizophora stylosa* often occurring as thin zones of dense thickets within the broad zone of *A. marina*. Mangroves are found wherever suitable conditions are present including wave dominated settings of deltas, beach/dune coasts, limestone barrier islands and ria/archipelago shores (Semeniuk 1993). Mangrove plants have evolved to adapt to fluctuating salinity, tidal inundation and fine, anaerobic, hydrogen sulfide rich sediment (Duke *et al.* 1998).

Mangroves are important primary producers and have a number of ecological and economic values.

For example, they play a key role in reducing coastal erosion by stabilising sediment with their complex root systems (Kathiresan and Bingham 2001). They are also recognised for their capacity to help protect coastal areas from the damaging effects of erosion during storms and storm surge. Mangroves are also important in the filtration of run-off from the land which helps maintain water clarity for coral reefs which are often found offshore in tropical locations (NOAA 2010). The intricate matrix of fine roots within the soil also binds sediments together.

Mangroves play an important role in connecting the terrestrial and marine environments (Alongi 2009). Numerous studies (e.g. Nagelkerken *et al.* 2000, Alongi 2002, 2009, Kathiresan and Bingham 2001) have shown mangroves to be highly productive and an important breeding and nursery areas for juvenile fish and crustaceans, including commercially important species (Kenyon *et al*. 2004). They also provide habitat for many juvenile reef fish species.

Mangroves also play an important ecosystem role in nutrient cycling and carbon fixing (NOAA 2010). The trees absorb carbon dioxide from the atmosphere and the organic matter such as fallen leaves forms nutrient rich sediments creating a peat layer that stores organic carbon (Alongi 2009, Ayukai 1998). For these reasons the EPA of Western Australia recognise mangroves as Benthic Primary Producer Habitat (BPPH), defined as “functional ecological communities that play important roles in maintaining the integrity of marine ecosystems and the supply of ecological services” (EPA 2009 p10).

The muddy sediments that occur in mangrove forests are home to a variety of epibenthic, infaunal and meiofaunal invertebrates (Kathiresan and Bingham 2001). Crustaceans known to inhabit the mud in mangrove systems include fiddler crabs, mud crabs, shrimps and barnacles. Within the water channels of the estuary, various finfish are found from the smaller fish such as gobies and mudskippers (which are restricted to life in the mangroves) through to larger fish such as barramundi (*Lates calcarifer*) and the mangrove jack (*Lutjanus argentimaculatus).* Mangroves and their associated invertebrate-rich mudflats are also an important habitat for migratory shorebirds from the northern hemisphere, as well as some avifauna that are restricted to mangroves as their sole habitat (Garnet and Crowley 2000).

The three key State regulatory documents relevant to the protection and management of mangroves in Western Australia are:

- EPA (2001) Guidance Statement for Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline. Guidance Statement No. 1;
- EPA (2011) Guidance for the assessment of benthic primary producer habitat loss in and around Port Hedland; and
- EPA (2016) Technical Guidance – Protection of Benthic Communities and Habitats.

4.1.1 Central Western Shelf Province

Shark Bay (in the Central Western Shelf Province) supports the southern-most area of substantial mangrove habitat in Western Australia (Rule *et al*. 2012). The mangroves of Shark Bay comprise only one species, the white mangrove *Avicennia marina*, and these trees occur around the coastline in widely dispersed and often isolated stands of varying size.

4.1.2 Central Western Shelf Transition

The regional mangroves from Exmouth to Broome (within the Central Western Shelf Transition and southern part of the Northwest Shelf Province) represent Australia's only 'tropical-arid' mangroves. The most significant stand of mangroves in the Central Western Shelf Transition is Mangrove Bay on the western side of the Cape Range Peninsula in the Ningaloo Marine Park. This small area of mangrove (37 ha) represents the largest area of mangrove habitat within the Ningaloo Marine Park and is considered extremely important from a biodiversity conservation perspective (CALM 2005).

4.1.3 Northwest Shelf Province

In the Pilbara region, the coast is a complex of deltas, limestone barrier islands and lagoons, with a variable suite of substrates. As a result, mangroves in this region form relatively diverse fringing stands, albeit often stunted in stature but at times quite extensive in area. The mangroves along the Pilbara coastline are the largest single unit of relatively undisturbed tropical arid zone habitats in the world. The area has nine mangrove taxa and a total of 632 km^2 mangroves (MangroveWatch 2013). As with most arid zone mangroves, Pilbara mangroves are characterised by open woodlands and shrublands that are of relatively lower productivity than the mangrove communities of the wet tropics because of the extreme water and salinity stresses that affect the intertidal zone in the Pilbara (EPA 2001). Significant stands of mangroves in the Pilbara include:

- Exmouth Gulf: mangrove assemblages within the Bay of Rest on the western shore of the Gulf and the extensive mangrove system on the eastern shore of the Gulf that extends as a series of tidal flats and creek channels from Giralia Bay to Yanrey Flats (Astron 2014). These areas of mangrove are also designated as 'regionally significant' by the EPA (2001). The importance of these mangroves to the Exmouth Prawn Fishery is discussed in Kangas et al. (2006);
- Mainland coast and nearshore islands: mangrove assemblages at Ashburton River Delta, Coolgra Point, Robe River Delta, Yardie Landing, Yammadery Island and the Mangrove Islands are all designated as 'regionally significant' by the Western Australian EPA (2001) and the EPA will give these mangrove formations the highest degree of protection with respect to geographical distribution, biodiversity, productivity and ecological function; and
- Montebello, Barrow and Lowendal Islands: mangrove assemblages all lay within designated reserves. The mangrove communities of the Montebello Islands are considered globally unique as they occur in lagoons of offshore islands (DEC 2007). Mangrove stands identified on Varanus Island occur on the west coast in discrete patches within the tidal and supratidal zones, at South Mangrove Beach and a small embayment (Astron 2016). Mangrove stands on Varanus Island have been identified as healthy, with similar stands also identified as present on Bridled Island to the north of Varanus Island (Astron 2016).

The mangroves of the Kimberley are particularly diverse and relatively untouched. They occupy a variety of coastal settings including rocky shores, beaches and tidal flats (Cresswell and Semeniuk

2011). They belong to the Indo-Malaysian group of Old World Mangroves centred in the Indian-Pacific area (Cresswell and Semeniuk 2011). Of the eighteen species of mangrove plants known to Australia all are represented in the Kimberley including *Avicennia marina, Aegialitis annulata, Aegiceras corniculatum, Rhizophora stylosa, Ceriops tagal, Osbornia octodonta, Bruguiera exaristata, Camptostemon schultzii, Excoecaria agallocha, Sonneratia alba,* and *Xylocarpus australasicus* (Pendretti and Paling, 2001; Waples, 2007). Of these, ten occur only in the Kimberley (Waples 2007). *Rhizophora stylosa* and *Avicennia marina* are the most common mangrove species along the Western Australian Coast.

Mangroves line much of the coastal area within the western Kimberley (and within the proposed Horizontal Falls Marine Park area). They are known to line the shore in the upper reaches of Talbot Bay and to fringe many of the islands of the Buccaneer Archipelago. There are large stands in the southern section of Dugong Bay. Kingfisher Islands has been noted to exhibit extensive mangroves where 10 species of mangrove have been recorded (Wilson 2013). Mangroves line the shores of the southern coast of Collier Bay and large tracts are found in Walcott Inlet and Secure Bay (Duke *et al.*, 2010). The mangroves on the eastern side of the inlet extend about 30 km inland (Gueho 2007, Pendretti and Paling 2001, Zell 2007)). Further along the coast mangroves have been identified lining much of the shores of Doubtful Bay. Mangroves are also known to line the shores of the Sale River and have been identified in George Water. For detailed maps of mangrove distribution refer to Pendretti and Paling (2001).

4.1.4 Northwest Shelf Transition

Mangroves are also a prominent feature of the North Kimberley. Fringing mangroves have developed around the edge of Prince Frederick Harbour and to the east of Cape Voltaire extending along the shores of Walmesly Bay and Port Warrender (Zell 2007). This region is humid and *Xylocarpus granatum* is localised here (Cresswell and Semeniuk 2011). The rocky coastline between Cape Pond and Cape Voltaire does not lend itself to mangrove development; instead coastal woodland grows on the shores above high water mark. Mangroves are interspersed with rocky outcrops and beaches around much of the Admiralty Gulf, Vansittart Bay and Napier Broome Bay (with extensive stands around the Drysdale estuary). Cape Londonderry marks the westerly limit of *Scyphiphora hydrophylacea* (Duke *et al.* 2010).

Between Cape Londonderry and Cape Dussejour mangrove communities are sparse, and limited to a few small stands in the bays as this part of the coastline is dominated by high relief rocky shores which are exposed to the prevailing easterly winds (Wilson 1994). Extensive mangroves do however line the shores of the islands and rivers in the Cambridge Gulf, where 12 mangrove species have been recorded (Wilson 2013). The mangroves of the Ord River are notable in terms of their structural complexity and diversity. Fourteen species of mangrove have been recorded in the boundaries (Pedretti and Paling 2001). The mangroves of the Cambridge Gulf are important for saltwater crocodiles and mangrove bird communities. A unique type of flycatcher which is an intermediate between *Microcea flavigater* and *Microeca tormenti* has been identified in the mangroves of the Cambridge Gulf (Johnstone 1984). Additionally, the area is important for maintaining stocks of the commercially exploited species of the Red-Legged Banana Prawns (*Penaeus indicus)* (Kenyon *et al.* 2004).

4.1.5 International Waters

Subawa's south coast in Indonesia is thought to contain the most significant stand of mangroves in the Lesser Sunda Ecoregion (DeVantier *et al*. 2008). Other significant stands have been mapped at the following locations (DeVantier *et al.* 2008):

- North-west and south east Bali;
- North coast of Nusa Lembongan;
- North-east and east Sumba;
- South-west, north-west, north and east Flores and Maumere;
- Komodo Island, and nearby islands; and

- South west, south, central and north Timor Leste.

Several Indonesian National Parks, including Karimunjawa National Park, Kepulauan Seribu National Park, Meru Betiri National Park, Bali Barat National Park and Komodo National Park contain mangrove forest (refer to **Section 9.8**).

4.2 Intertidal Mud/Sand Flats

Intertidal mudflats form when fine sediment carried by rivers and the ocean is deposited in a low energy environment. Tidal mudflats are highly productive components of shelf ecosystems responsible for recycling organic matter and nutrients through microbial activity. This microbial activity helps stabilise organic fluxes by reducing seasonal variation in primary productivity which ensures a more constant food supply (Robertson 1988). Intertidal sand and mudflats support a wide range of benthic infauna and epifauna which graze on microscopic algae and microbenthos, such as bivalves, molluscs, polycheate worms and crustaceans (Zell 2007).

The high abundance of invertebrates found in intertidal sand and mudflats provides an important food source for finfish and shellfish which swim over the area at high tide. Mudflats have also been shown to be significant nursery areas for flatfish. During low tide, these intertidal areas are also important foraging areas for indigenous and migratory shorebirds. Mudflats also play a vital role in protecting shorelines from erosion (Wade and Hickey 2008).

4.2.1 Central Western Shelf Province

Shark Bay in the Central Western Shelf Province has an EPBC protected intertidal ecological community 'Subtropical and Temperate Coastal Saltmarsh'. It is the northerly limit for this community and there is a transition zone for many saltmarsh species (CALM 1996). The EPBC 'Listed Advice' (DoE 2014) reports that sediments associated with these communities generally consist of poorly-sorted anoxic sandy silts and clays, and may have salinity levels that are much higher than seawater due to evaporation. The drainage characteristics of coastal soils, along with tidal patterns and elevation, can strongly influence the distribution of flora and fauna within the Coastal Saltmarsh ecological community (DoE 2014).

4.2.2 Northwest Shelf Province

Within Northwest Shelf Province both Roebuck Bay and Eighty Mile beach are areas with significant intertidal mudflats that are used by birds in spring and summer including species listed as threatened under the WC Act or EPBC Act, or listed on the IUCN Red List of Threatened Species (2009). Intertidal mudflats are also an important feature of the Kimberley coast forming in many bays and inlets of the region (Waples 2007). The sediments that dominate these flats are generally of terrigenous origin (Wilson 2013).

The mudflats of the Kimberley coast have been shown to be important for migratory birds of the East Asian-Australasian Flyway, which is estimated to support more than five million migratory shorebirds (Barter 2002, Bennelongia Pty Ltd 2010, Wade and Hickey 2008). The migratory birds visit the mudflats of the Kimberley coast to feed on benthic organisms prior to embarking on a 10,000–15,000 km migration to their breeding grounds in the Artic (Wade and Hickey 2008).

4.2.3 Northwest Shelf Transition

Extensive mud flats are located in Collier Bay, where the highest tidal range in Australia is found. (Wilson 2013, Zell 2007). A study by (Duke *et al*. 2010, Masini *et al*. 2009) also identified fringing mudflats around Walcott Inlet, and Doubtful Bay. The tidal mudflats of Walcott Inlet are up to 5 km wide and support a rich intertidal invertebrate community (Gibson and Wellbelove, 2010). These invertebrate communities in turn also support large numbers of waterbirds (Wilson 1994).

Extensive intertidal mudflats occur in Prince Frederick Harbour and are generally backed by mangroves. The mudskipper is known to feed on these mudflats at low tide. Intertidal flats are also a feature of the estuary of the Mitchell River. The mudflats of Port Warrender are known to support 20 shorebird species and tern species and it is likely the other mudflats in the region also support high numbers of birds. The ecological significance of the wetlands of the Mitchell River has been recognised in *A Directory of Important Wetlands in Australia*. Mud and sand flats are also known to surround much of Deep Bay and Napier Broome Bay.

Intertidal sand and mudflats are a common feature of the East Kimberley. Large sand bars are present on the river mouths of the King George River, Berkeley River and Lyne River and intertidal mudflats are extensive along the edges of the Cambridge Gulf. The estuary is wide and very shallow in some sections, and the silt and clay is continually picked up and redeposited by strong tidal currents (Robson *et al.* 2008). The tidal flats of the Ord River in the Cambridge Gulf have been listed as a wetland of international importance for the conservation of waterbirds under the RAMSAR convention. The area supports a variety of fauna including shorebirds and mudskippers. Tidal mudflats are also extensive along the coast between the Cambridge Gulf and the Western Australian-Northern Territory Border.

4.2.4 Timor Province

Details on habitats in the Timor Province is provided in **Section 12.3.12**.

4.2.5 International Waters

Although no specific areas of intertidal mud or sand flats have been identified for international waters, the southern coasts of the islands that make up the Lesser Sunda Ecoregion of Indonesia and Timor Leste do contain numerous estuarine habitats. These estuaries are likely to contain intertidal and tidal sand and mud flats that support a range of benthic invertebrate species that in turn attract other species such as birds and fish. Such estuaries in the Ecoregion are typically mangrove lined. Within the Lesser Sunda Ecoregion, the following areas are recognised as containing estuarine habitat (Wilson et al. 2011):

+ Lombok;
+ Sumba;
+ Central south and central north coasts of Sumbawa;
+ North-east coast of Flores; and
+ South-west coast of Timor.

The Irebere Estuary, located on the south-eastern coast, Tilomar located on the southern coast and Nino Konis Santana located on the eastern coast of Timor Leste has been recognised as an Important Bird Area (Birdlife International 2018).

Several National Parks in the Ecoregion also contain estuarine habitats (likely to include intertidal sand and mud flats), including Karimunjawa National Park (refer to Section 9.8).

4.3 Intertidal Platforms

Intertidal platforms are areas of hard bedrock and/ or limestone with or without a sediment veneer of varying thickness. These platforms can vary from low to high relief and provide a habitat for a diverse range of intertidal organisms (Morton and Britton in Jones 2004, SKM 2009, 2011, Hanley and Morrison 2012) and some species of shore birds (Garnet and Crowley 2000). They are common within each of the coastal bioregions within the area of interest.

4.3.1 Southwest Shelf Province and Southwest Shelf Transition

Intertidal platforms within the Northwest and Southwest bioregions support a mosaic of fauna and flora that typically exhibits strong variability in percent cover, community composition, abundance and diversity both between and within reefs at varying spatial and temporal scales (SKM 2009, 2011). Reef platforms typically exhibit zonation of fauna and flora from upper to lower levels on the intertidal zone, with increasing diversity, abundance and biomass lower in the intertidal (Morton and Britton in Jones 2004, SKM 2009, 2010, 2011, Hanley and Morrison 2012).

On the south coast of the Southwest Shelf Province, the coastal geomorphology changes from the predominant limestone reefs to eroded Precambrian rocks. Intertidal platforms are also common along the Southwest Shelf Transition. Shark Bay in the Central Western Shelf Province has a high diversity of intertidal marine habitats as a result of the diversity of benthic substrate, salinity and the broad geographical features which influence depth, water movement and turbidity (CALM 1996, DSEWPaC 2013). This includes extensive, limestone platforms (as well as sand flats, mud flats, salt marsh and mangroves and beaches (CALM 1996).

4.3.2 Central Western Shelf Province and Transition

Limestone pavements extend out from the beach into subtidal zones, e.g. along the Ningaloo Coast and North West Cape; and higher relief platforms (>0.5 m off high water mark) are also present at a number of headlands along the North West Cape.

4.3.3 Northwest Shelf Province and Northwest Shelf Transition

Large tidal regimes are likely to be the defining environmental factor influencing the distribution of intertidal flora and fauna in the Northwest Shelf Province and Northwest Shelf Transition. The intertidal area of the Kimberley has an extreme tidal range (hypertidal) which creates unique environmental conditions and habitats not seen else anywhere else in the world. As a remote area many of the habitats are untouched and they are recognised as having significant conservation value (DPaW 2013). DPaW (2013) reports that as a result of the monsoonal influxes of freshwater and land-derived nutrients distinctive tropical marine ecosystems have occurred.

4.3.4 International Waters

While no significant areas of intertidal platforms have been identified in international waters, the high energy southern coastlines of the islands of the Lesser Sunda Ecoregion of Indonesia (and also including Timor Leste) are likely to have areas of exposed pavements consisting of limestone and remnant lava flows (Wilson *et al*. 2011).

4.4 Sandy Beaches

Sandy beaches are those areas within the intertidal zone where unconsolidated sediment has been deposited (and eroded) by wave and tidal action. Sandy beaches can vary from low to high energy zones; the energy experienced influences the beach profile due to varying rates of erosion and accretion. Sandy beaches are found across the area of interest and vary in length, width and gradient. They are interspersed among areas of hard substrate (e.g. sandstone) that form intertidal platforms and rocky outcrops. There is a wide range of variation in sediment type, composition, and grain size along the area of interest.

Sandy beaches provide habitat to a variety of burrowing invertebrates and subsequently provide foraging grounds for shorebirds (Garnet and Crowley 2000). The number of species and densities of benthic macroinvertebrates that occur in the sand are typically inversely correlated with sediment grain-size and exposure to wave action, and positively correlated with sedimentary organic content and the amount of detached and attached macrophytes (Wildsmith *et al.* 2005). However, the distributions of these faunas among habitats will also reflect differences in the suite of environmental variables that characterize those habitats (Wildsmith *et al.* 2005).

Sandy habitats are important for both resident and migratory seabirds and shorebirds (refer **Section 0**). While sand flats and beaches generally support fewer species and numbers of birds than mudflats of similar size; some species such as the beach thick knee (*Esacus giganteus*) a crab eater, are commonly associated with sandy beaches (Garnet and Crowley 2000). Sandy beaches can also provide an important habitat for turtle nesting and breeding (see marine reptile turtle **Section 6**).

4.4.1 Southwest Shelf Province

The hooded plover (*Thinornis rubricollis*) is a shorebird found on several beaches within the South West capes. Hooded plovers live on sandy surf beaches and prefer beaches backed by dunes rather than cliffs (DEC 2013). In addition to this, beaches in the South West province provide a variety of socio economic values including tourism, commercial and recreational fishing, and support other recreational activities.

4.4.2 Southwest Shelf Transition

Sandy beaches throughout the Abrolhos host breeding populations of the Australian Sea Lion. The Abrolhos represent the northernmost breeding population of Australian sea lions. The current population at the Abrolhos is estimated to be approximately 90 (DoF 2012).

In addition to this, beaches in the South West province provide a variety of scioc economic values including tourism, commercial and recreational fishing, and support of other recreational activities.

4.4.3 Northwest Shelf Province

Eighty Mile Beach Marine Park is one of the Australia's largest uninterrupted sandy beaches (stretching 220 km) and is an important feeding grounds for small wading birds that migrate to the area each summer, travelling from countries thousands of kilometres away (DEC 2012). It is also a listed Ramsar wetland (see **Section 9** on Protected Areas).

4.4.4 Northwest Shelf Transition

Sand habitat within the Camden Marine Park is mainly associated with shorelines and inlets on both mainland and island shores. Some beach deposits on islands in the Kimberley are composed of skeletal carbonate sand, while they may also consist of sediments from inland areas carried to the sea by rivers and gullies (DPaW 2014). The sediment coarseness of the sand may vary, and may also be littered with dead shell, rock and/or coral material. Sea cucumbers that ingest sand and filter out microscopic food are often common in this habitat (DPaW 2014).

Generally, in this region, sand habitat is adjacent to either dense mangrove stands or rocky cliffs (DPaW 2014). Beaches can be highly influenced by tide and weather conditions. Those that overlie rock are likely to shift and be ephemeral in nature.

4.4.5 International Waters

No significant areas of sandy beaches in international waters have been identified. However, the southern coastlines of the islands of the Lesser Sunda Ecoregion of Indonesia and Timor Leste are known to contain sandy beaches consisting of soft black sand, formed by volcanic activity. Within this region, a number of National Parks are considered important sites for turtle nesting beaches, including the Meru Betiri National Park (refer to **Section 9.8**).

4.5 Rocky Shorelines

Rocky shorelines are found across the area of interest and are often indicative of high energy areas (wave action) where sand deposition is limited or restricted (perhaps seasonally or during a cyclone). They are formed from limestone pavement extending out from the beach into subtidal zones, for example along the Ningaloo Coast and North West Cape; higher relief platforms (>0.5 m off high water mark) are also present at a number of headlands along the North West Cape. This habitat is also widespread heading south towards Perth.

Rocky shores can include pebble/ cobble, boulders, and rocky limestone cliffs (often at the landward edge of reef platforms). Rocky outcrops typically consist of hard bedrock, but some of the coastline has characteristic limestone karsted cliffs with an undercut notch. Rocky shorelines can vary from habitats where there is bedrock protruding from soft sediments to cliff like structures that form headlands. Rocky shorelines are an important foraging area for seabirds and habitat for invertebrates found in the intertidal splash zone (Morton and Britton in Jones 2004). For example, oyster catchers and ruddy turnstones feed along beaches and rocky shorelines (see seabirds in **Section 8.2.2**).

4.5.1 International Waters

The Lesser Sunda Ecoregion contains numerous rocky shores, particularly on the exposed southern coastlines of the islands that make up the ecoregion. Areas of rocky shores include the following (DeVantier *et al*. 2008):

+ The Bukit Peninsula and Nusa Penida areas of Bali;
+ South Lombok;
+ South-east Sumbawa;
+ Nusa Tengara; and
+ SumbaTimor Leste, including Roti Island, Fatu and Atapupu.

5. Fish and Sharks

Fish distributions in the area of interest are discussed with respect to the IMCRA Provincial Bioregions which were defined using CSIRO's 1996 regionalisation of demersal fish on the continental shelf to the shelf break, and their 2005 regionalisation of demersal fish on the continental slope to approximately 1,200 m depth (DEH 2006). The EPBC species listed as threatened and migratory found in the area of interest, according to the Protected Matters search (**Appendix A**), are shown in **Table 5-1** along with their WA conservation listing (as applicable) and discussed in **Section 5.2** below.

The following WA conservation codes apply to WA fauna:

- Threatened Species (listed under Biodiversity Conservation Act 2016):
  - Critically Endangered
  - Endangered
  - Vulnerable
- Specially protected species (listed under Biodiversity Conservation Act 2016):
  - Migratory
  - Species of special conservation interest (conservation dependant fauna)
  - Other specially protected species
- Priority species (non-statutory state based administrative process):
  - Priority 1, 2 and 3: poorly-known species – possible threatened species that do not meet survey criteria or are otherwise data deficient. Ranked in order of priority. In urgent need of further survey.
  - Priority 4: species that are adequately known, are either: rare but not threatened; meet criteria for near threatened; or delisted as threatened species within last five years for reasons other than taxonomy. Requiring regular monitoring.

A detailed account of commercial and recreational fisheries that operate in the region is provided in in the Commercial Fisheries **Section 14.6** and detailed in *The State of the Fisheries Report* 2016/2017 (Gaughan and Santoro, 2018).

Table 5-1: EPBC listed fish and shark species in the area of interest

Species	**Conservation Status**			**Likelihood of occurrence in area of interest**	**Biologically important area in area of interest**
	Environment Protection and Biodiversity Conservation Act 1999	***Biodiversity Conservation Act 2016*** [1]	**Other WA Conservation Code**		
Blind gudgeon (*Milyeringa veritas)*	Vulnerable	Vulnerable	-	Species or species habitat known to occur within area.	None - No BIA defined

[1] The Wildlife Conservation (Specially Protected Fauna) Notice 2018 has been transitioned under regulations 170, 171 and 172 of the Biodiversity Conservation Regulations 2018 to be the lists of Threatened, Extinct and Specially Protected species under Part 2 of the Biodiversity Conservation Act 2016.

Balstons pygmy perch (*Nannatherina balstoni*)	Vulnerable	Vulnerable	-	Species or species habitat likely to occur within area.	None - No BIA defined
Blind cave eel (*Ophisternon candidum)*	Vulnerable	Vulnerable	-	Species or species habitat known to occur within area.	None - No BIA defined
Grey nurse shark (*Carcharias taurus*)	Vulnerable	Vulnerable	-	Species or species habitat known to occur within area.	None - BIA not found in area of interest
Great white shark (*Carcharodon carcharias*)	Vulnerable & Migratory	Vulnerable	-	Foraging, feeding or related behaviour known to occur within area	Yes – Refer to **Table 5-3**
Whale shark (*Rhincodon typus*)	Vulnerable & Migratory	Specially protected (species otherwise in need of special protection)	-	Foraging, feeding or related behaviour known to occur within area	Yes – Refer to **Table 5-3**
Northern river shark (*Glyphis garricki)*	Endangered		Priority 1	Breeding likely to occur within the area.	None - BIA not found in area of interest
Dwarf sawfish (*Pristis clavata)*	Vulnerable & Migratory		Priority 1	Breeding known to occur within area	Yes – Refer to **Table 5-3**
Freshwater sawfish (*Pristis pristis)*	Vulnerable & Migratory		Priority 3	Species or species habitat known to occur within area.	Yes – Refer to **Table 5-3**
Narrow sawfish (*Anoxypristis cuspidate)*	Migratory	-	-	Species or species habitat known to occur within area.	None - No BIA defined
Green sawfish (*Pristis zijsron)*	Vulnerable & Migratory	Vulnerable	-	Breeding known to occur within area	Yes – Refer to **Table 5-3**
Shortfin mako *(Isurus oxyrinchus)*	Migratory	-	-	Species or species habitat likely to occur within area	None - No BIA defined
Longfin mako *(Isurus paucus)*	Migratory	-	-	Species or species habitat likely to occur within area	None - No BIA defined
Reef manta ray	Migratory	-	-	Species or species habitat	None - No BIA defined

(Manta alfredi)				known to occur within area	
Giant manta ray *(Manta birostris)*	Migratory	-	-	Species or species habitat known to occur within area	None - No BIA defined
Porbeagle *(Lamna nasus)*	Migratory	-	-	Species or species habitat may occur within area	None - No BIA defined

In addition a review of conservation dependent species[2] identified five species of fish / sharks that may occur in the area of interest:

- Orange roughy (Hoplostethus atlanticus);
- Southern Blue Fin Tuna (Thunnus maccoyii);
- Southern Dogfish (Centrophorus zeehaani);
- School Shark (Galeorhinus galeus); and
- Scalloped Hammerhead (Sphyrna lewini).

5.1 Regional Surveys

Within the 'area of interest' a number of important geographical areas for fish exist, including Ningaloo Marine Park, Montebellos/Barrow Island Marine Park and the Rowley Shoals.

5.1.1 Southwest Shelf Province

At least 150 species have been identified within the capes region as being reef-associated (Hutchins 1994 cited in DEC 2013). Of these, 77% are warm temperate species, 18% are subtropical species and 5% are tropical (DEC 2013).

The most abundant finfish species across the region identified during surveys were the Maori wrasse (*Opthalmolepis lineolatus*), red banded wrasse (*Pseudolabrus biserialis*), McCulloch scalyfin (*Parma mccullochi*), and western king wrasse (*Coris auricularis*). The yellow headed hulafish (*Trachinops noarlungae*), black headed puller (*Chromis klunzingeri*), rough bullseye and common bullseye (*Pempheris multiradiata* and *P. klunzingeri*) were also common at Eagle Bay and Geographe Bay (Westera *et al.* 2007 cited in DEC 2013).

5.1.2 Southwest Shelf Transition

A total of 389 finfish species have been recorded at the Abrolhos (DoF 2012). The Abrolhos and their surrounding coral and limestone reef systems consist of a combination of abundant temperate macroalgae with coral reefs, supporting substantial populations of large species such as baldchin groper and coral trout. Some of the species occurring in the Abrolhos are dependent on larvae carried southward by the Leeuwin Current from areas further north, such as Shark Bay or Ningaloo Reef. Similarly, populations of some of the species occurring at Rottnest Island are dependent on larvae generated from breeding populations at the Abrolhos (DoF 2012).

More than twenty species of sharks have been identified at the Abrolhos (DoF 2012). These sharks include:

[2] Conservation dependent species are listed species under the EPBC Act and are considered as part of the Commonwealth marine area.

- Port Jackson sharks (Heterodontus portusjacksoni);
- Tiger shark (Galeocerdo cuvier);
- Whaler sharks (Carcharhinus brachyurus); and
- Wobbegongs (Orectolobus maculatus).

Abrolhos waters are considered to be an important food source for sharks, due to the resident fish populations. Various species of rays have been recorded at the Abrolhos. These include the manta ray and the white spotted eagle ray (DoF 2012).

5.1.3 Central Western Province

The Perth Canyon appears to be an important ecological feature attracting krill and fish aggregations that in turn attract larger species such as predatory fish and pygmy blue whales (DSEWPaC 2012). Demersal slope fish assemblages in this bioregion are characterised by high species diversity. Scientists have described 480 species of demersal fish that inhabit the slope of this bioregion and 31 of these are considered endemic to the bioregion. Demersal fish on the slope in this bioregion in particular have high species diversity compared with other more intensively sampled oceanic regions of the world. Below 400 m water depth demersal fish communities are characterised by a diverse assemblage where relatively small, benthic species (grenadiers, dogfish and cucumber fish) dominate.

The southern part of the 'area of interest' (Central Western Shelf Province) is located near Shark Bay and is the northern limit of a transition region between temperate and tropical marine fauna. Of the 323 fish species recorded from Shark Bay, 83% are tropical species with 11% warm temperate and 6% cool temperate species (CALM 1996).

5.1.4 Central Western Shelf Transition

Ningaloo is the largest fringing coral reef in Australia, forming a discontinuous barrier that encloses a lagoon that provides habitat for many fish species. Gaps that regularly intercept the main reef line provide channels for water exchange with deeper, cooler waters (CALM 2005). Ningaloo Reef is a well known biodiversity hotspot, supported by the direct link between the reef and the ancient reef systems found closer to the equator by the Leeuwin Current (Kemps 2010). Approximately 500 species of fish have been reported to inhabit the reef (Kemps 2010). The Piercam project from inception in 2005 to 2013, identified 165 fish species from 50 families at the Point Murat Navy Pier alone, located within the Ningaloo Marine Park (Whisson & Hoschke 2013).

Seasonal aggregations of whale sharks occur at Ningaloo each year (CALM 2005). There is limited data available on species diversity and distribution of sharks in the Ningaloo area as chondrichthyan biodiversity for the area has not been specifically recorded. Despite this, it is possible that the Ningaloo Reef Marine Park contains the largest and most diverse collection of sharks on the Australian coastline (Stevens *et al.* 2009). It was estimated in 2009 by Last and Stevens (cited in Stevens *et al.* 2009), that there are likely to be 118 species of chondrichthyan fishes occurring in the park. Of these species, 59 are shark species predicted to be found at depths of less than 200 m (Stevens *et al.* 2009).

The lagoon at Ningaloo Reef appears to provide a juvenile habitat and nursery area for shark species such as the grey nurse shark (*C. Taurus*), black-tipped reef shark (*Carcharhinus melanopterus*) and other reef sharks (Carcharhinidiae), (Stevens *et al.* 2009). A study conducted on the distribution and abundance of elasmobranches in the Ningaloo Marine Park, 2009, tracked the movements of six key shark species. Species such as *Galeocerdo cuvier* (tiger shark) and *Sphyrna mokarran* (great hammerhead) were found to remain for brief time periods in the park, in contrast to other species found to re-visit the Ningaloo area (Stevens *et al.* 2009). Several species of sharks within Ningaloo have been identified as key indicator species for the health of the system (Stevens *et al.* 2009).

Barrow Island includes Biggada Reef, an ecologically significant fringing reef, and the Montebello Islands comprise over 100 islands, the majority of which are rocky outcrops; providing fish habitat (DEC 2007a). Within the Barrow/Montebello region, at least 380 fish species have been recorded (de Lestang & Jankowski 2017). Most species exhibit wide distributions, with local species composition closely resembling that of the Dampier Archipelgao. Coral habitats support the most diverse fish community in this region, comprising, among others, many species of damselfish (*Pomacentridae*), parrotfish (*Scaridae*), snappers (*Lutijanidae*) and groupers (*Serranidae*) (de Lestang & Jankowski 2017). The region's macroalgal habitats are considered important nursery areas for a diverse range of fish species, such as emperor (*Lethrinidae*), threadfin bream (*Nemipteridae*), tuskfish (*Labridae*) and trevally (*Carangidae*) (de Lestang & Jankowski 2017).

RAMSAR wetlands within the area (e.g. Eighty Mile Beach and Ashmore Reef National Nature Reserve) can also provide important habitat for fish (see section on RAMSAR wetlands).

5.1.5 Northwest Shelf Province and Northwest Province

The demersal zone of the North-west shelf (NWS) (which includes the Northwest Province and Northwest Shelf Province) hosts a diverse assemblage of fish of tropical Indo-west Pacific affinity, with up to 1,400 species known to occur, with a great proportion of these occurring in shallow coastal waters (Allen *et al*. 1988). Last *et al*. (2005) and Fox & Beckley (2005) described the North-west Province as being characterised by a high level of endemism and species diversity. Certain areas of increased biological activity (e.g. Glomar Shoals) attract demersal fish species such as Rankin cod, red emperor, crimson snapper and spangled emperor that are exploited by commercial trawl and trap fisheries (Sainsbury *et al*. 1992, Fletcher and Santoro 2013).

The shallow waters (<30 m) of the Dampier Archipelago, in the Northwest Shelf Province, support a characteristic and rich fish fauna of 650 species from a variety of habitats including coral and rocky reefs, mangroves, sand and silty bottoms and sponge gardens (Hutchins 2003 & 2004). The majority of these species are found over hard substrate, but significant numbers are also found from soft bottom and mangrove areas. The outer islands of the Archipelago are inhabited predominantly by coral reef fishes whereas inner areas close to the mainland are occupied by mangrove and silty-bottom dwellers. The inter-island passages have a relatively rich soft bottom fauna. EPBC Act protected fish species within the Dampier Archipelago include the dwarf sawfish (*Pristis clavata*).

The fish fauna of the archipelago is less diverse than the islands of the West Pilbara to the south, but are closely related to the fauna at the offshore Montebello Islands (Hutchins 2004). The fish fauna of Barrow/ Lowendal/ Montebello Islands are widespread throughout the Indo-west Pacific region.

Within the southern portion of the Northwest and Northwest Shelf Province, small pelagic fish (e.g. lantern fishes) comprise a third of the total fish biomass (Bulman 2006) and inhabit a range of marine environments, including inshore and continental shelf waters. These small pelagic fish play an important ecological role, not only for this particular area but for the entire North-west Marine Region. They feed on pelagic phytoplankton and zooplankton and provide a food source for a wide variety of predators such as marine mammals, sharks, large pelagic fish and seabirds, thus providing a vital link between many of the region's trophic systems (Mackie *et al*. 2007).

Pelagic fish in the Northwest and Northwest Shelf Province include tuna, mackerel, herring, pilchard and sardine, and game fish such as marlin and sailfish (BBG 1994, Brewer *et al*. 2007), some of which are targeted by both commercial and recreational fishers. In particular, adult and juvenile southern bluefin tuna are thought to migrate through the NWS on their way to and from spawning grounds in the north-eastern Indian Ocean. However, the timing of these migrations and the use of regional currents to assist their migration is still unclear. The oceanic waters of the NWS are also believed to provide important spawning and nursery grounds for a number of large pelagic fish species.

Table 5-2 provides a summary of the key fish species and likely timing of their spawning in the region (DoF correspondence).

5.1.6 Northwest Shelf Transition

Creek systems, mangroves and rivers, and ocean beaches within this region provide habitat for a variety of species including barramundi, tropical emperors, mangrove jack, trevallies, sooty grunter, threadfin and cods (Fletcher and Santoro 2013). The offshore atolls and the continental shelf waters in the Northwest Shelf Transition are also geographically important for fish species. They support species of recreational and commercial interest, including saddle-tail snapper and red emperor, cods, coral and coronation trout, sharks, trevally, tuskfish, tunas, mackerels and billfish (DEC 2009).

The Rowley Shoals within the Northwest Shelf Transition comprise three oceanic reef systems approximately 30–40 km apart, namely Mermaid Reef, Clerke Reef and Imperieuse Reef. The Shoals are thought to provide a source of invertebrate and fish recruits for reefs further south and as such are regionally significant (DEC 2007b). See **Section 11** on State Marine Parks and Nature Reserves for further details on important geographical areas for fish.

5.1.7 Timor Province

The diversity of demersal fish assemblages on the continental slope in the Timor Province (as well as the Northwest Transition and the Northwest Province) is high compared to elsewhere along the Australian continental slope (DEC 2009). Elements of the Timor Province are not well known, due to limited survey data in the northern limits of the region. The province is geographically extensive and includes 418 fish species, 64 of which are endemic to the region (Last *et al.* 2009). Key indicator species include *Bembrops nelsoni*, *Bythaelurus* sp., *Halicmetus* sp., *Malthopsis* spp, *Neobythites australiensis*, *Nobythites bimaculatus*, *Neobythites macrops*, *Neobythites soelae*, *Parapterygotrigla* sp., *Physiculus roseus* (Last *et al.* 2005).

Scott and Seringapatam Reefs are regionally important for the diversity of their fauna, including 558 fish species (DoE 2014). Scott Reef has enormous habitat diversity and is considered a hot spot for fish, with five endemic species (DoE 2014). Scott Reef has biogeographic significance due to the presence of species which are at or close to the limits of their geographic ranges, including fish known previously only from Indonesian waters such as cardinalfish, azure damselfish (*Chrysoptera hemicyanea*), comb-tooth blenny (*Escnius schroederi*) and several Gobiids (DoE 2014).

The diversity of fish at Ashmore Reef is also higher than other comparable reefs in the bioregion with over 760 species recorded (Russell *et al.* 2005, Kospartov *et al.* 2006. The majority of fish species are shallow water, benthic taxa that typically inhabit depths down to 100 m and are widely distributed throughout the Indo-West Pacific (Russell *et al.* 2005). The most species rich groups are gobies (*Gobiidae*), damselfishes (*Pomacentridae*), wrasses (*Labridae*), cardinal fishes (*Apogonidae*), moray eels (*Muraenidae*), butterflyfishes (*Chaetodontidae*), and rockcods and groupers (*Serranidae*) (Allen 1993, Russell *et al*. 2005).

Table 5-2: Spawning and aggregation times of key commercially caught fish species within the North West Shelf

Species		Month											
Species Common Name	**Species Latin Name**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Blacktip shark	*Carcharhinus tilstoni* and *C. limbatus*												
Goldband snapper	*Pristipomoides multidens*												
Rankin cod	*Epinephelus multinotatus*												
Red emperor	*Lutjanus sebae*												
Sandbar shark	*Carcharhinus plumbeus*												
Spanish mackerel	*Scomberomorus commerson*												
Pink snapper	*Pagrus auratus*												
Baldchin groper	*Choerodon rubescens*												
Crystal (snow) crab	*Chaceon spp*												
King George whiting	*Sillaginodes punctate*												
Spangled emperor	*Lethrinus Nebulosus*												

5.2 Fish Species

Three species of fish listed as threatened under the EPBC Act (**Table 5-1**) were identified in the Protected Matters search (**Appendix A**):

- Balston's pygmy perch (Nannatherina balstoni);
- Blind gudgeon (Milyeringa veritas); and
- Blind cave eel (Ophisternon candidum).

In addition the Barrow cave gudgeon *(Milyeringa justitia*) has been identified as relevant threatenedspecies under the Biodiversity Conservation Act 2016. This species is not listed under the EPBC Act.

5.2.1 Blind Gudgeon, Balston's Pygmy Perch and Blind Cave Eel

Both the blind gudgeon (*Milyeringa veritas*) and blind cave eel (*Ophisternon candidum*) are known to occur on the Cape Range Peninsula (in the Central Western Shelf Transition) (Humphreys and Feinberg 1995), and a related species of the genus Milyeringa, the Barrow cave gudgeon *(Milyeringa justitia*) has also been noted at Barrow Island (Humphreys 1999). The Barow cave gudgeon is listed as Vulnerable under the WA Biodiversity Conservation Act 2016. They have been recorded in waters ranging from fresh to seawater at depths of up to 33 m in caves and 50 m in wells and bores. Both species are restricted to either caves or groundwater (Humphreys and Blyth 1994) and are the only two vertebrate animals known from Australia for this (DoE 2014a). The Balston's pygmy perch distribution ranges from

Moore River (75 km north of Perth) at the northern extent to Two Peoples Bay near Albany. This freshwater species is typically associated with shallow waters near riparian vegetation and is considered to have low salinity tolerance, making it unlikely to occur in estuarine conditions (DoEE, 2016).

5.2.2 Syngnathids

The EPBC Protected Matters search also identified 63 'listed marine species' of fish which are largely from the family Syngnathidae (**Appendix A**). Syngnathids are a group of bony fishes that include seahorses, pipefishes, pipehorses and sea dragons, although taxonomic uncertainty still surrounds a number of these (DEWHA 2012a). Knowledge about the distribution, abundance and ecology of syngnathids is limited.

5.3 Sharks, Rays and Sawfishes

The diversity of marine environments in the waters within the North-west Marine Region has led to a rich fauna of cartilaginous fish (sharks and rays). Of the approximately 500 shark species found worldwide, 19% (94) are found in the region (DEWHA 2008). The EPBC Act Protected Matters search (**Appendix A**) identified four species of shark, and three species of sawfishes listed as threatened within the search area between south west WA and N.T. border (**Table 5-1**), including:

+ Grey nurse shark (Carcharias taurus);
+ Great white shark (Carcharodon carcharias);
+ Northern River shark (Glyphis garricki);
+ Whale shark (Rhincodon typus);
+ Dwarf sawfish (Pristis clavata);
+ Freshwater sawfish (Pristis pristis); and
+ Green sawfish (Pristis zijsron).

In addition, the narrow sawfish (Anoxypristis cuspidate), two species of ray, the reef manta ray (*Manta alfredi*) and giant manta ray (*Manta birostris*) and the longfin and shortfin mako sharks are listed as migratory within the search area (**Table 5-1).**

The biologically important areas (BIAs) for relevant species detailed above are illustrated in **Figure 5-1, Figure 5-2** and **Figure 5-3**.

5.3.1 Grey Nurse Shark

The grey nurse shark (*Carcharias taurus*) is listed as vulnerable under the EPBC Act and the *Biodiversity Conservation Act 2016*and may be found within the area of interest. In Australia, the grey nurse shark is now restricted to two populations, one on the east coast from southern Queensland to southern NSW and the other is predominantly found around the southwest coast of WA, but has been recorded on the North West Shelf (DEWHA 2012b, Pogonoski *et al*. 2002). It is believed that the east and west coast populations do not interact and ongoing research will probably confirm that the populations are genetically different (Last and Stevens 2009).

While it is thought that grey nurse sharks have a high degree of site fidelity, some studies (McCauley 2004) suggest that grey nurse sharks move between different habitats and localities, exhibiting some migratory characteristics. In certain areas grey nurse sharks are vulnerable to localised pressure due to high endemism. The status of the west coast population is poorly understood although they are reported to remain widely distributed along the WA coast and are still regularly encountered, albeit with low and indeterminate frequency (Chidlow *et al*. 2006).

Grey nurse sharks are often observed hovering motionless just above the seabed, in or near deep sandy-bottomed gutters or rocky caves, and in the vicinity of inshore rocky reefs and islands (Pollard *et al*. 1996). The species has been recorded at varying depths, but is generally found between 15–40 m

(Otway & Parker 2000). Grey nurse sharks have also been recorded in the surf zone, around coral reefs, and to depths of around 200 m on the continental shelf (Pollard *et al*. 1996). Grey nurse sharks feed primarily on a variety of teleost and elasmobranch fishes and some cephalopods (Gelsleichter *et al*. 1999, Smale 2005).

No grey nurse shark BIAs were identified in the area of interest.

5.3.2 Great White Shark (White Shark)

The great white shark (*Carcharodon carcharias*) is listed as vulnerable and migratory under the EPBC Act and is listed as vulnerable under the *Biodiversity Conservation Act 2016* . In Australia, great white sharks have been recorded from central Queensland around the south coast to northwest WA, but may occur further north on both coasts (Last and Stevens 2009). There are no known aggregation sites for white sharks in the North-west marine region, but the species has been recorded in NWS waters during humpback migrations (DEWHA 2012). They are widely but not evenly distributed in Australian waters and are considered uncommon to rare compared to most other large sharks (CITES 2004).

Study into great white shark populations is difficult (Cailliet 1996) given the uncertainty about their movements, emigration, immigration and difficulty in estimating the rates of natural or fishing mortality.

Great white sharks can be found from close inshore around rocky reefs, surf beaches and shallow coastal bays to outer continental shelf and slope areas (Pogonoski *et al*. 2002). They also make open ocean excursions and can cross ocean basins (for instance from South Africa to the western coast of Australia and from the eastern coast of Australia to New Zealand). Great white sharks are often found in regions with high prey density, such as pinniped colonies (DEWHA 2009). The relevant great white shark BIA's in the area of interest are detailed in **Table 5-3** and is shown on **Figure 5-1**.

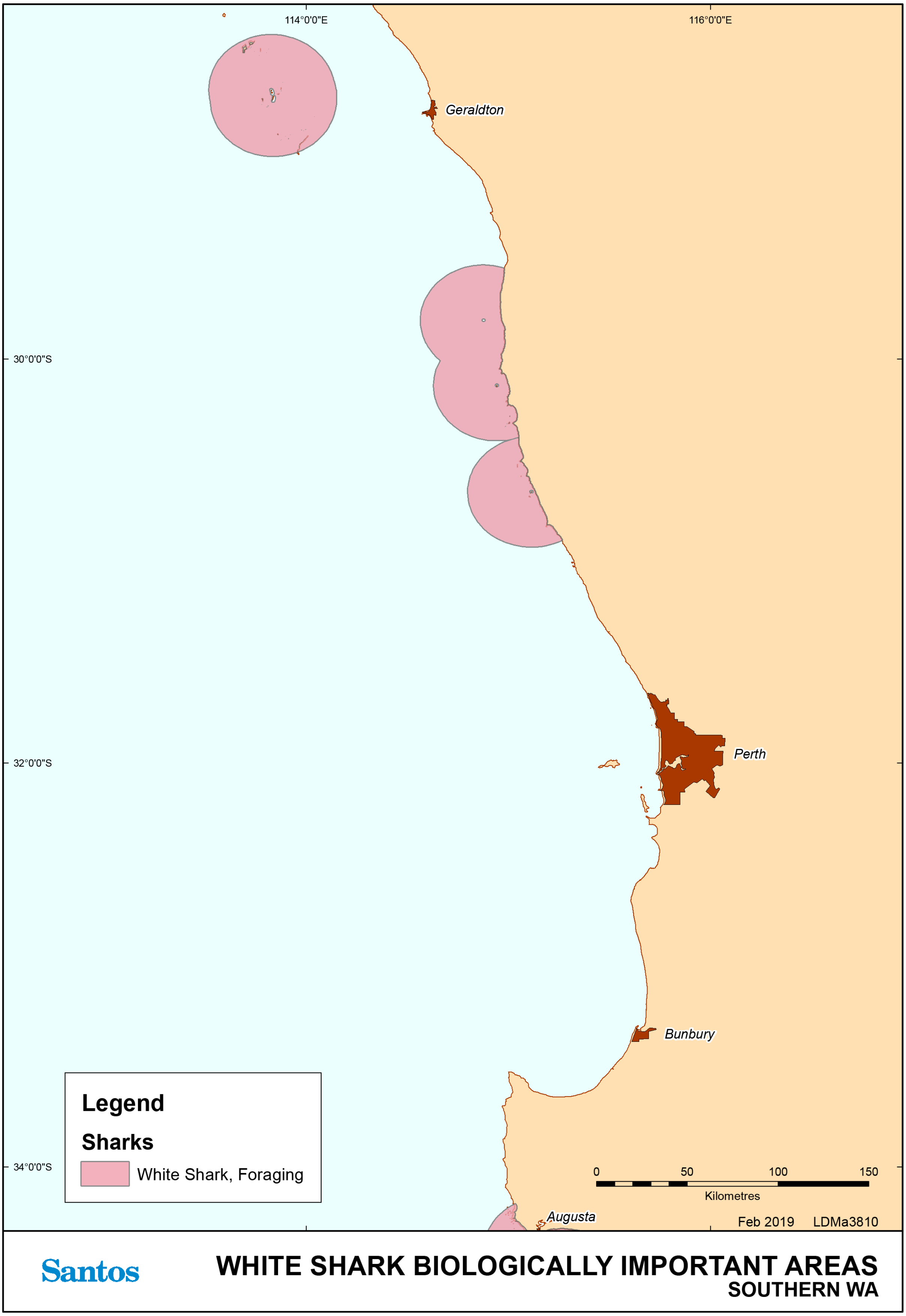


Figure 5-1: Biologically important area – great white shark

5.3.3 Northern River Shark

The northern river shark (*Glyphis garricki*) is listed as Endangered under the EPBC Act and is one of the rarest species of shark in the world. Adults only recorded in marine habitats, whereas neonates, juveniles and subadults recorded in freshwater, estuarine and marine environments. It is also listed as a Priority 1 conservation species in WA.

The associated recovery plan (Sawfish and River Sharks Multispecies Recovery Plan, Commonwealth of Australia 2015) identifies adults and juveniles are being known in WA marine waters north of Derby. Pupping and juvenile sharks are identified as known to occur in Cambridge Gulf and pupping is also identified as likely to occur in King Sound. Under the associated recovery plan all areas where aggregations of individuals have been recorded displaying biologically important behaviours such as breeding, foraging, resting or migrating are considered critical to the survival of the species unless population data suggests otherwise.

5.3.4 Whale Shark

The whale shark (*Rhincodon typus*) is listed as Vulnerable and Migratory under the EPBC Act and is also listed as a specially protected species under the *Biodiversity Conservation Act 2016 as a species of special conservation interest (conservation dependent fauna)*. It is the largest of all fish (>18 m; Borrell *et al*. 2011; Chen *et al*. 1997, Compagno 2001) and is a migratory species with worldwide geographical ranges between 30º N and 35º S (Last and Stevens 2009). There is a general lack of knowledge on many aspects of whale shark biology, including definitive migration patterns. The species is oceanic but often forms aggregations in coastal waters at sites throughout the tropics. Typically, these aggregations are seasonal and often coincide with specific productivity events that are a focus of feeding for the animals. For example, whale sharks aggregate to feed on dense swarms of copepods in Baja California (Clarke and Nelson 1997), fish spawn off Belize (Heyman *et al*. 2001) and red crab larvae at Christmas Island (Meekan *et al*. 2009).

One of the best known aggregation sites for whale sharks occurs along the central and NW coast of Western Australia from March to July and is focused at Ningaloo Reef, within the Exmouth region. The small size and general absence of female whale sharks from Ningaloo Reef suggests that the region may be important for feeding rather than breeding (Norman and Stevens 2007). The timing of this aggregation coincides with a pulse in seasonal productivity that results in large abundances of tropical krill on which these filter feeding sharks feed (Meekan *et al*. unpubl data, Jarman and Wilson 2004). At Ningaloo Reef, whale sharks are often found swimming close to the reef front, within a few kilometres of the shore and in water of less than 50 m deep. A tourist industry based on snorkelling with the sharks in this area has developed over the last 15 years and is now estimated to be worth over $4m annually to the local economy of the Ningaloo region.

Estimates of the size of the population participating in the Ningaloo aggregation are between 300 and 500 individuals (Meekan *et al*. 2006), but research indicates that the Ningaloo population of whale sharks is declining (Bradshaw *et al*. 2007).

Preliminary research on the migration patterns of whale sharks in the western Indian Ocean, and isolated and infrequent observations of individuals, indicate that a small number of the Western Australian population migrate through the NWS. Wilson *et al*. (2006) tagged 19 whale sharks in 2003 and 2004, with long term movements patterns successfully recorded from six individuals. All travelled northeast into the Indian Ocean after departing Ningaloo Reef, with one tracked to Ashmore Reef and another to Scott Reef. Whale sharks are occasionally observed from Santos WA's offshore oil and gas facilities on the NWS (Harriet Alpha and Stag platforms).

This species was listed as Vulnerable under the EPBC Act in 2001, and is also classified as Vulnerable on the World Conservation Union's Red List of Threatened Species (Norman 2005). In WA, whale sharks are protected under the*Biodiversity Conservation Act 2016*, the *Conservation and Land Management Act 1984* and the *Fish Resources Management Act 1994*. The relevant whale shark BIA's in the area of interest are detailed in **Table 5-3** and is shown on **Figure 5-2**.

The objective of the Whaleshark (Rhincodon typus) Recovery Plan 2005 – 2010, Commonwealth of Australia, 2005, is to maintain existing levels of protection for the whale shark in Australia while working to increase the level of protection afforded to the whale shark within the Indian Ocean and Southeast Asian region to enable population growth so that the species can be removed from the threatened species list of the EPBC Act.

DBCA has a wildlife management program to manage whaleshark interactions in reserves - *Whale shark management with particular reference to Ningaloo Marine Park, Wildlife Management Program no. 57 (2013).*

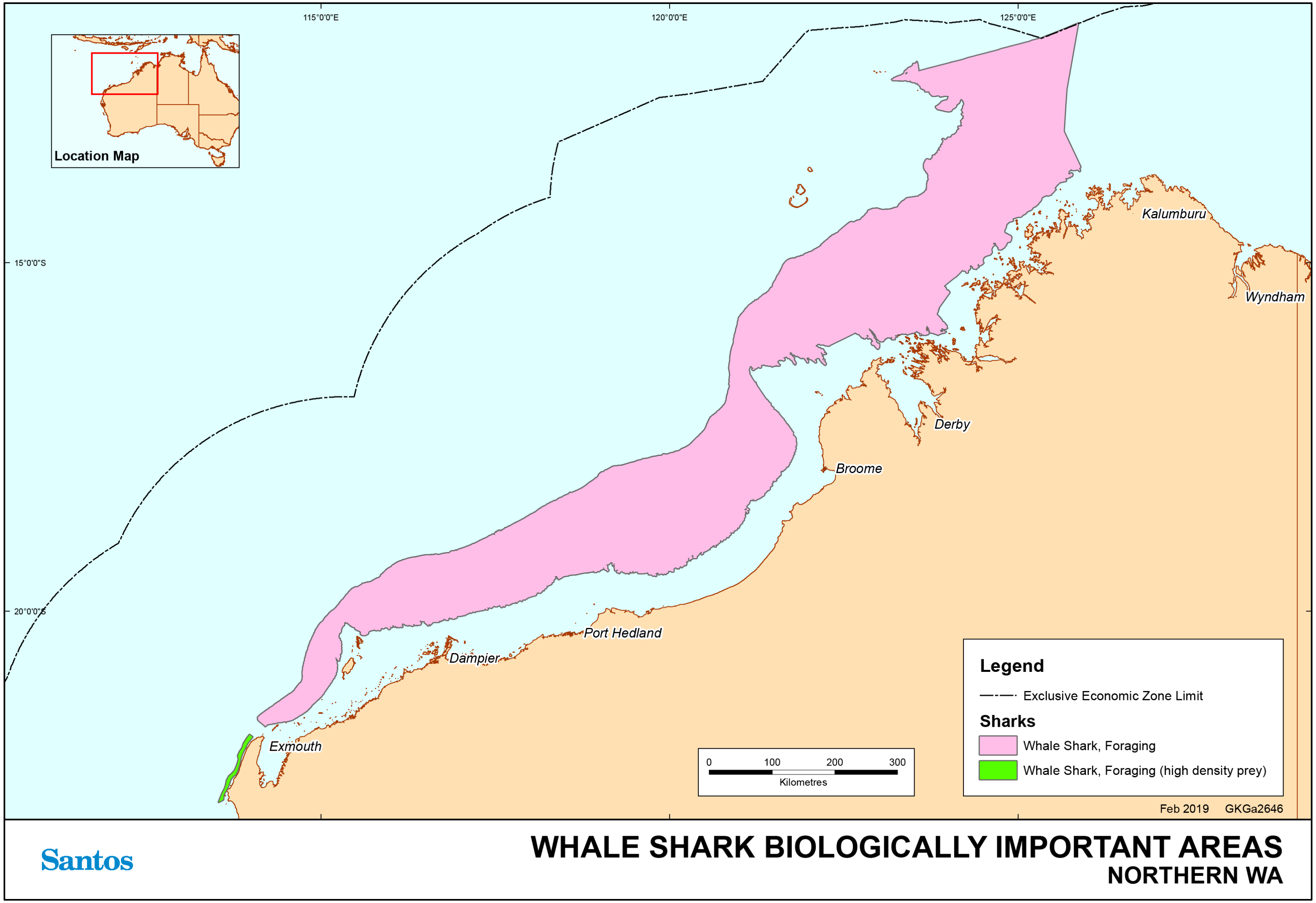


Figure 5-2: Biologically important area – whale shark

5.3.5 Dwarf Sawfish

The dwarf sawfish (*Pristis clavata*) is listed as vulnerable under the EPBC Act and thought to be restricted to Australia (DoE 2014b). It is also listed as a Priority 1 conservation species in WA. The Australian distribution of the dwarf sawfish is considered to extend across northern Australia and along the Kimberley and Pilbara coasts (Last and Stevens 2009, Stevens *et al*. 2005). However, the majority of records of dwarf sawfish in WA have come from shallow estuarine waters of the Kimberley region which are believed to be nursery (pupping) areas, with immature juveniles remaining in these areas up until three years of age (Thorburn *et al*. 2004). Adults are known to seasonally migrate back into inshore waters (Peverell 2007); although it is unclear how far offshore the adults travel as captures in offshore surveys are very uncommon. The species' range is restricted to brackish and salt water (Thorburn *et al*. 2007).

The recovery plan identifies pupping as known to occur in the King Sound, the Cambridge Gulf and 80 Mile Beach, with pupping likely to occur identified at a number of locations along the Pilbara and Kimberly Plan. Under the associated recovery plan all areas where aggregations of individuals have been recorded displaying biologically important behaviours such as breeding, foraging, resting or migrating are considered critical to the survival of the species unless population data suggests otherwise.

The relevant sawfish BIAs in the area of interest are detailed in **Table 5-3** and are shown on **Figure 5-3**.

5.3.6 Freshwater and Green Sawfish

The freshwater sawfish (*Pristis pristis)* and green sawfish (*Pristis zijsron)* are both listed as Vulnerable under the EPBC Act. The freshwater sawfish is listed as a Priority 1 conservation species in WA, while the green sawfish is listed as Vulnerable under the *Biodiversity Conservation Act 2016.*

Both species are wider-ranging than the dwarf sawfish and are also found in the Indo-west Pacific (DoE 2014c, DoE 2014d). Important areas for sawfishes include King Sound, and the Fitzroy, Durack, Robinson and Ord rivers for the freshwater sawfish; and Cape Keraudren for the green sawfish (Stevens *et al*. 2008, Thorburn *et al*. 2007, 2008).

Sawfishes generally inhabit inshore coastal, estuarine and riverine environments. The freshwater sawfish has been recorded in north-west Australia from rivers (including isolated water holes), estuaries and marine environments (Stevens *et al*. 2005). Newborns and juveniles primarily occur in the freshwater reaches of rivers and in estuaries, while most adult freshwater sawfish have been recorded in marine and estuarine environments (Peverell 2005, Thorburn *et al*. 2007). It is believed that mature freshwater sawfish enter less saline waters during the wet season to give birth (Peverell 2005) and freshwater river reaches play an important role as nursery areas (DoE 2014c).

The green sawfish has predominantly been recorded in inshore coastal areas, including estuaries and river mouths with a soft substrate, although there have been records of sawfish offshore in depths up to 70 m (Stevens *et al*. 2005). This species does not occupy freshwater habitats (DoE 2014d).

Short-term tracking has shown that green sawfish appear to have limited movements that are tidally influenced, and they are likely to occupy a restricted range of only a few square kilometres within the coastal fringe, with a strong association with mangroves and adjacent mudflats (Stevens et al. 2008). Sawfishes feed close to the benthos on a variety of teleost fishes and benthic invertebrates, including cephalopods, crustaceans and molluscs (Compagno & Last 1999, Last & Stevens 2009, Pogonoski *et al*. 2002, Thorburn *et al*. 2007, 2008).

The relevant sawfish BIAs in the area of interest are detailed in **Table 5-3** and are shown on **Figure 5-3**.

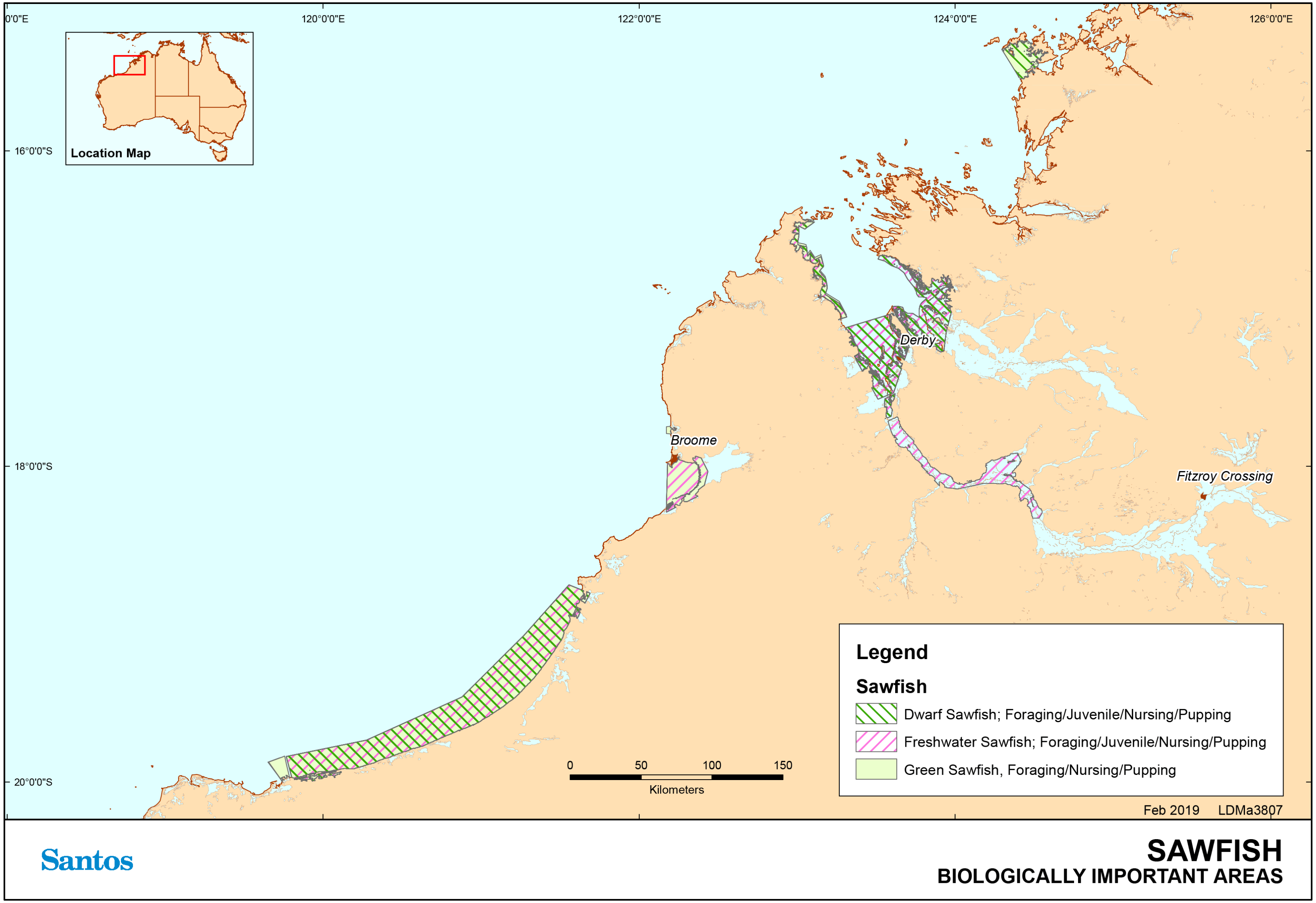


Figure 5-3: Biologically important areas – sawfish

5.3.7 Narrow Sawfish

The narrow sawfish (*Anoxypristis cuspidate*) is listed as Migratory under the EPBC Act. It is a marine or marginal (brackish water) species found from inshore waters to a depth of 40 m (Compagno *et al.* 2006). Though details of its ecology are not precisely known, it probably spends most of its time on or near the bottom in shallow coastal waters and estuaries. A study showed the narrow sawfish to be the most abundant amongst the sawfish sampled in the Gulf of Carpentaria (Peverell, 2005) which holds some consistency with the offshore distribution of the species as shown by a study of Northern Prawn Fishery by-catch. Peverell (2005) also used catch data of offshore surface net fisheries to conclude that narrow sawfish also inhabit the mid-water column and can thus be described as a benthopelagic animal. The narrow sawfish is known to form aggregations of mature females during the months of October to November. Its Australian distribution is unclear though it is most common in the Gulf of Carpentaria with southward ranges extending to Broad Sound in Queensland and the Pilbara Coast (circa 116°E), Western Australia (Last & Stevens, 2009).

5.3.8 Giant Manta Ray / Reef Manta Ray

The giant manta ray appears to be a seasonal visitor to coastal or offshore sites. Giant manta rays are often seen aggregating in large numbers to feed, mate, or clean. Sightings of these giant rays are often seasonal or sporadic but in a few locations their presence is a more common occurrence. This species is not regularly encountered in large numbers and, unlike some other rays do not often appear in large schools (>30 individuals) when feeding. Overall, they are encountered with far less frequency than the smaller manta species, despite having a larger distribution across the globe (IUCN, 2014b).

The giant manta ray occurs in tropical, sub-tropical and temperate waters of the Atlantic, Pacific and Indian Oceans. They are commonly sighted along productive coastlines with regular upwelling, oceanic island groups and particularly offshore pinnacles and seamounts. The giant manta ray is commonly encountered on shallow reefs while being cleaned or is sighted feeding at the surface inshore and offshore. It is also occasionally observed in sandy bottom areas and seagrass beds (IUCN, 2014b).

The Reef manta ray has a circumtropical and sub-tropical distribution, existing in the Pacific, Atlantic and Indian Oceans. Within this broad range, however, actual populations appear to be sparsely distributed and highly fragmented. This is likely due to the specific resource and habitat needs of this species.

Overall population size is unknown, but subpopulations appear, in most cases, to be small (about 100–2,000 individuals). A proportion of the individuals in some populations undertake significant coastal migrations (IUCN, 2016). Since the species is migratory it is possible that individuals may be encountered in the operational area, however, given that they generally don't aggregate in large groups, high numbers are not expected to be encountered during the activities.

5.3.9 Shortfin Mako and Longfin Mako Sharks

The shortfin mako and longfin mako sharks are listed as Migratory under the EPBC Act. The longfin mako is widely distributed but rarely encountered oceanic shark that ranges from Geraldton around the north coast to at least Port Stephens in New South Wales (DSEWPaC, 2012). The shortfin mako is an oceanic and pelagic species, although they are occasionally seen inshore. They are found throughout temperate seas but are rarely found in waters colder than 16°C.

5.4 Biologically Important Areas / Critical Habitat – Fish

Biologically important areas (BIAs) are spatially defined areas where aggregations of individuals of a species are known to display biologically important behaviour such as breeding, foraging, resting or migration**.** BIA are identified by the DoEE, they have no legal status, but are designed to assist decision making under the EPBC Act. They are not designed to identify protected areas, but may inform such processes. **Table 5-3** below provides an overview of BIAs in the area of interest for fish.

The DoEE may make recovery plans for threated fauna listed under the EPBC Act. The EPBC Act requires that 'habitat critical to the survival of the listed threatened species' is identified in recovery plans, relevant recovery plans are listed in **Section 13.2**. BIAs may overlap these sites, but may be identified for other purposes. DoEE state that the criteria used to identify 'habitat critical to the survival of the species' are more complex than those used it identify BIA.

In addition, both the EPBC Act and WA Biodiversity Conservation Act 2016 and associated regulations (2018) provide for the listing of critical habitat - habitat 'critical to the survival of the threatened species'. To date no critical habitat in WA has been listed under either Act.

Table 5-3: Biologically important areas - fish

Species	Scientific name	Aggregation area and use	Specific geographic locations for species
Great white shark	*Carcharodon carcharias*	Foraging – associated with pinniped colonies in the mid-west and south west	Waters off pinniped colonies throughout the South-west Marine Region
Whale shark	*Rhincodon typus*	Foraging – Ningaloo Reef	Ningaloo Marine park and adjacent Commonwealth waters Northward from Ningaloo along 200 m isobath
Dwarf sawfish	*Pristis clavata*	Foraging – Eighty Mile Beach, King Sound, Camden Sound Nursing - Eighty Mile Beach, King Sound, Fitzroy River & May Robinson River Pupping – Eighty Mile Beach, King Sound, Fitzroy River & May Robinson River Juvenile – King Sound, Fitzroy River & May Robinson River	Eighty Mile Beach Camden Sound - eastern shore Fitzroy River Mouth, May & Robinson River - tidal tributaries King Sound (Inshore waters)
Freshwater sawfish	*Pristis pristis*	Nursing – King Sound Foraging – King Sound, Roebuck Bay, Eighty Mile Beach Pupping – Roebuck Bay, Eighty Mile Beach Juvenile – Roebuck Bay	Eighty Mile Beach King Sound - tidal tributaries Roebuck Bay
Green sawfish	*Pristis zijsron*	Pupping – Cape Keraudren, Eighty Mile Beach, Roebuck Bay, Willie Creek, Cape Leveque Foraging - Cape Keraudren, Roebuck Bay, Cape Leveque, Camden Sound Nursing - Cape Keraudren, Eighty Mile Beach	Eighty Mile Beach Camden Sound Cape Keraudren Cape Leveque Roebuck Bay Willie Creek

6. Marine Reptiles

Thirty-two species of listed marine reptiles under the Commonwealth *EPBC Act 1999* are known to occur in Australian waters in the area of interest, according to the Protected Matters search (**Appendix A**). An examination of the species profile and threats database (DoEE 2018) showed that some listed reptile species are not expected to occur in significant numbers in the marine and coastal environments in the area of interest due to their terrestrial distributions. Hence, these species are not discussed further.

Of the remaining reptile species identified in the Protected Matters search (**Appendix A**), eight are listed as threatened and seven are listed as migratory. These species are show in **Table 6-1** along with their WA conservation listing (as applicable)[3]. BIAs within the area of interest area discussed in **Table 6-3.**

Table 6-1: EPBC listed marine reptile species in the area of interest

Species	Conservation Status		Likelihood of occurrence in area of interest	Biologically important area in area of interest
	Environment Protection and Biodiversity Conservation Act 1999	***Biodiversity Conservation Act 2016***		
Green turtle *Chelonia mydas*	Vulnerable Migratory	Vulnerable	Breeding known to occur within area	Yes – refer to **Table 6-3**
Flatback turtle *Natator depressus*	Vulnerable Migratory	Vulnerable	Breeding known to occur within area	Yes – refer to **Table 6-3**
Hawksbill turtle *Eretmochelys imbricata*	Vulnerable Migratory	Vulnerable	Breeding known to occur within area	Yes – refer to **Table 6-3**
Loggerhead turtle *Caretta*	Endangered Migratory	Endangered	Breeding known to occur within area	Yes – refer to **Table 6-3**
Olive Ridley turtle *Lepidochelys olivacea*	Endangered Migratory	Endangered	Foraging feeding or related behaviour known to occur within area	Yes – refer to **Table 6-3**
Leatherback turtle *Dermochelys coriacea*	Endangered Migratory	Vulnerable	Foraging feeding or related behaviour known to occur within area	Yes – refer to **Table 6-3**
Short-nosed seasnake *Aipysurus apraefrontalis*	Critically Endangered	Critically Endangered	Species or species habitat known to occur within area	None - No BIA defined
Leaf-scaled seasnake *Aprasia rostrate rostrata*	Critically Endangered	Critically Endangered	Species or species habitat known to occur within area	None - No BIA defined

[3] An overview of WA fauna conservation codes is provided in **Section 5** (fish and sharks).

6.1 Marine Turtles

Six species of marine turtle occur in, use the waters, and nest on sandy beaches in Western Australia. These are the green turtle (*Chelonia mydas*), flatback turtle (*Natator depressus*), hawksbill turtle (*Eretmochelys imbricata*), loggerhead turtle (*Caretta caretta*), Olive Ridley turtle (*Lepidochelys olivacea)* and leatherback turtle (*Dermochelys coriacea*) (**Table** 6-1).

These six species are listed on the EPBC Act List of Threatened Species as either 'endangered' or 'vulnerable' and all six species are also listed as 'migratory'. They are also listed as threatened species under the *Biodiversity Conservation Act 2016.*

A summary of the different habitat types used during the various life stages of marine turtle species identified in the area of interest is given in **Table** 6-2**.**

Table 6-2: Summary of habitat types for the life stages of the six marine turtle species in the area of interest (DSEWPaC, 2012b)

Life Stage		Green turtle	Flatback turtle	Hawksbill turtle	Loggerhead turtle	Olive Ridley turtle	Leatherback turtle
Post-hatchling		Open ocean pelagic habitats (poorly studied for Australian populations)	Coastal waters (poorly studied for Australian populations)	Open ocean pelagic habitats (poorly studied for Australian populations)	Pelagic (poorly studied for Australian populations)	Pelagic (poorly studied for Australian populations)	Pelagic (no data for Australian populations)
Adult	Mating	Offshore from nesting beaches.	Currently unknown for North West Shelf region.	Offshore from nesting beaches.	Little is known for North West Shelf region but expected to occur either en-route or adjacent to nesting beaches.	Not recorded within North West Shelf region.	Not recorded within North West Shelf region.
	Nesting	Typically, high energy, steeply sloped beaches with deep sand and deep water approach.	Typically, low-energy beaches that are narrow with a low to moderate slope. Beach approach obstructed by broad intertidal mud or limestone platforms.	Typically beaches close to nearshore coral reefs and sediment comprised of coarse sand and coral rubble.	Poorly studied for North West Shelf region by generally prefer high energy, relatively narrow, steeply sloped, coarse-grained beaches.	Not recorded within North West Shelf region.	Not recorded within North West Shelf region.
	Internesting	Shallow coastal waters within several kms of nesting beach. Inter-nesting buffers of 20 km identified around all nesting habitats	Shallow nearshore waters within 5-60 km of nesting beach. Inter-nesting buffers of 40-60 km identified around all nesting habitats	Shallow coastal waters within several kms of nesting beach. Inter-nesting buffers of 20 km identified around all nesting habitats	Shallow coastal waters within several kms of nesting beach. Inter-nesting buffers of 20 km identified around all nesting habitats	Not recorded within North West Shelf region. Inter-nesting buffers of 20 km identified around all nesting habitats	Not recorded within North West Shelf region.
	Foraging	Neritic habitats associated with seagrass and algae, and mangrove habitats.	Turbid, shallow inshore waters, subtidal, soft-bottomed habitats of the continental shelf.	Subtidal and intertidal coral and rocky reef habitats of the continental shelf.	Subtidal and intertidal coral and rocky reefs, seagrass and deeper soft-bottomed habitats of the continental shelf.	Many feed within continental shelf waters, however it is not known if others are pelagic, as with the east Pacific population.	Mostly pelagic but will forage close to shore and over continental shelf in temperate waters.

6.1.1 Loggerhead Turtle

The loggerhead turtle (*Caretta caretta*) has a worldwide distribution, living and breeding in subtropical to tropical locations (Limpus 2008). Breeding aggregations in Australia occur on both the east coast (Queensland and NSW) and the west. The annual nesting population in Western Australia is thought to be 3,000 females annually (Baldwin *et al*. 2003), and this is considered to support the third largest population in the world (Limpus 2008).

The WA distribution of sandy beach nesting areas extends from Shark Bay to the southern area of the NWS, with occasional late summer nesting crawls recorded as far north as Barrow and Varanus Island and the Lowendal and Rosemary Islands (DSEWPaC 2012d). Major nesting locations include the Muiron Islands, the Ningaloo Coast south to Carnarvon and the islands around Shark Bay, which includes Dirk Hartog Island, one of the principal nesting and inter-nesting sites in WA (Limpus 2008). The Recovery Plan for Marine Turtles in Australia (2017) identifies the Muiron Islands (as a principal rookery), and all waters within a 20 km radius as habitat critical to the survival of loggerhead turtles.

Estimates of up to 5,000 female loggerhead turtles have been predicted within the Ningaloo Marine Park and Muiron Islands Marine Management Area (Waayers 2010). Earlier surveys found higher proportions of nesting loggerheads in the southern areas of the reserves (CALM 2005a). Aerial surveys conducted in 2000 and 2001 in the Exmouth region recorded only 12 sightings in Commonwealth waters and these turtles were most likely loggerheads (BHP 2005). In a survey commissioned by Santos WA around the islands in the Exmouth Region, loggerhead turtles were recorded nesting on Flat Island north of the Exmouth Gulf which was the first time they had been recorded in that location (Astron 2014).

Loggerhead nesting and breeding occurs from November to March, with a peak in late December/ early January (Limpus 2008). However, there is variability each year as illustrated in a study by Santos WA (Astron 2014) around the islands in the Exmouth Region where higher numbers of nesting turtles were recorded in October 2013 than in the subsequent January 2014 surveys.

Foraging areas are widespread for loggerhead turtle populations and migrations from nesting to feeding grounds can stretch thousands of kilometres, including feeding grounds as far north as the Java Sea of Indonesia for the WA population (Limpus 2008). Shark Bay has been identified as a critical feeding habitat for loggerhead turtles (Environment Australia 2003). Loggerhead turtles are carnivorous and feed primarily on benthic invertebrates from depths of up to approximately 50 m to near shore tidal areas including areas of rocky and coral reef, muddy bays, sand flats, estuaries and seagrass meadows (Limpus 2008).

Figure 6-1 illustrates the BIAs and critical habitats (draft) for loggerhead turtles (as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017)).

Santos

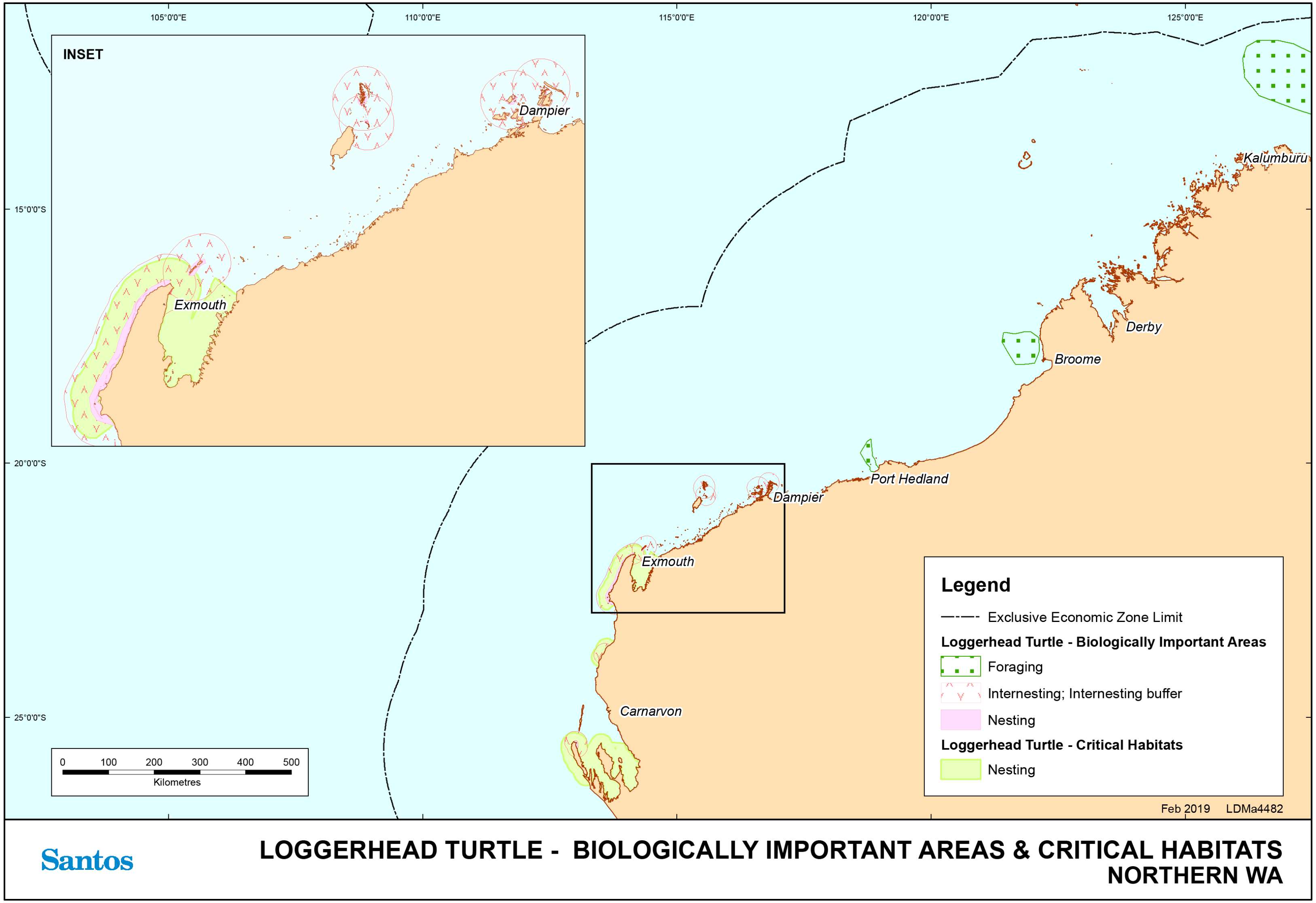


Figure 6-1: Biologically Important Areas and Critical Habitats – Loggerhead Turtle

6.1.2 Green Turtle

Australian population of green turtles is estimated to be approximately 70,000 and is divided into seven genetically distinct breeding aggregations. The species is widespread and abundant in WA waters with an estimated 20,000 individuals occurring, arguably the largest population in the Indian Ocean (Limpus 2008b). There are three distinct breeding stocks in western Australian waters which include: the North West Shelf (NWS) stock, the Scott Reef stock and the Ashmore Stock (Dethmers *et al*. 2006, Limpus 2008a).

The NWS population is one of the largest in the world and the most significant rookery is the western side of Barrow Island (Prince 1994, Limpus 2008a). Other principal rookeries include the Lacepede Islands, Montebello Islands, Dampier Archipelago, Browse Island and North West Cape (Prince 1994, Limpus 2008a, DSEWPaC 2012b). See **Table 6-3** for a complete list.

Surveys by Waayers (2010) within the Ningaloo Marine Park and Muiron Islands Marine Management Area estimated up to 7,500 female green turtles used these areas. In 2014, Santos WA commissioned a survey of the islands in the Exmouth Region which found that North and South Muiron Islands were significant nesting sites for green turtles with over 100 green turtles nesting overnight on one beach at North Muiron Island (Astron 2014). The green turtle is also known to breed in large numbers in the dunes above the extensive beaches found on Serrurier Island, with counts indicating the island supports the second largest rookery in the Pilbara (Oliver 1990).

Lower density green turtle nesting has also been recorded on Jurabi coast, Thevenard Island, Lowendal Islands and in Exmouth Gulf (Limpus 2008a). Only low numbers of green turtles have been observed nesting on Varanus Island, as well as Airlie Island (Pendoley Environmental 2011). From monitoring undertaken in 2016/17 by Santos WA on Varanus Island; three green turtles were observed to nest over a four week tagging effort (Astron 2017).

Green turtle nesting abundance and timing fluctuates significantly from year to year depending on environmental variables, locality and food availability (Pendoley Environmental 2011). Nesting of green turtles has been recorded from August to March on Serrurier Island (Woodside 2002), from December to March along coast adjacent to Ningaloo (CALM 2005a) and from October to February on Varanus Island (Pendoley Environmental 2011). On Barrow Island, mating aggregations may commence from October with peak nesting from December to January, with hatchlings emerging through summer and early autumn. However, nesting on Barrow Island has been recorded all year round (Chevron 2005 and 2008, Pendoley 2005). Nesting on the Scott Reef-Sandy Islet and Browse Island has been observed all year round with peaks between December and January (Commonwealth of Australia 2017). The re-nesting period for female green turtles is approximately five years (Hamann *et al*. 2002).

Green turtles spend the first five to ten years of their life drifting on ocean currents, before moving to reside in shallower benthic habitats, including tropical coral and rocky reefs and seagrass beds. Green turtles have been known to migrate more than 2600 km between feeding and breeding grounds (Limpus 2008a).

Green turtles are omnivores, mainly feeding in shallow benthic habitats on seagrass and/ or algae, but are also known to feed on sponges, jellyfish and mangroves (Limpus 2008a). Green turtles are unlikely to forage or dwell within deeper off shore waters due to the water depths; however, they may occasionally migrate through it.

Figure 6-2 illustrates the BIAs and critical habitats (draft) for green turtles (as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017)).

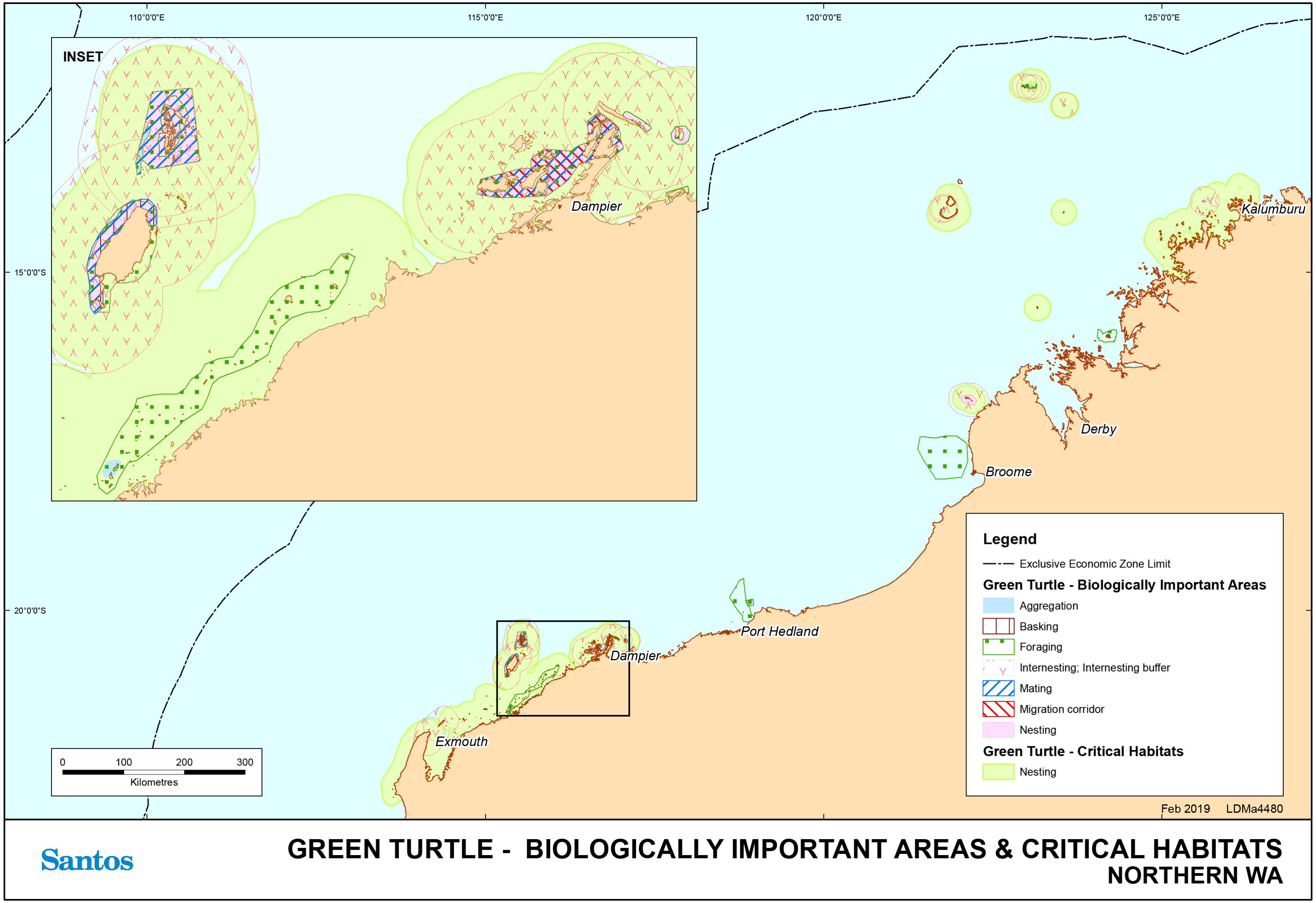


Figure 6-2: Biologically Important Areas and Critical Habitats – Green Turtle

6.1.3 Hawksbill Turtle

Hawksbill turtles (*Eretmochelys imbricata*) have a global distribution throughout tropical and sub-tropical marine waters. The Western Australian stock is concentrated on the NWS (Dampier Archipelago) (Limpus 2009a), and is considered to be one of the largest hawksbill populations remaining in the world. The estimated number of nesting hawksbill turtles in WA waters is between 2,000 and 4,500 individuals (Morris 2004).

In WA, their nesting range is relatively small and extends from the Muiron Islands to the Dampier Archipelago, a distance of approximately 400 km. The most significant breeding areas, that support hundreds of nesting females annually, are around sandy beaches within the Dampier Archipelago, Montebello Islands, Lowendal Islands and Barrow Island (Pendoley 2005, Limpus, 2009a).

The largest known nesting area for the NWS population is the sandy shoreline of Rosemary Island, within the Dampier Archipelago, particularly on the north-western side of the Island. It is believed that the Rosemary Island rookery may support up to 1,000 nesting females annually (Limpus 2009). Low density nesting is also known from Barrow Island, Airlie Island, Muiron Islands and North West Cape/ Ningaloo coast (Cape Range) (Limpus 2009a). Nesting hawksbills have also been found on NE Regnard Island and SW Regnard Island, confirming the Regnard Islands as hawksbill rookeries (Pendoley Environmental 2009).

The hawksbill turtle nesting population within the Exmouth region is also considered important as the populations in Western Australia represent the largest remaining population in the Indian Ocean (CALM 2005). The best estimate of numbers within the Ningaloo Marine Park and Muiron Islands Marine Management Area is between 20–700 individuals (Waayers 2010).

A snapshot survey of Varanus Island and the Lowendal Islands conducted for Santos WA during October 2012 found the five most frequented beaches by hawksbills, based on the track counts, were Beacon Island (*n*=43), Parakeelya (*n*=41), Kaia (*n*=40), Rose (*n*=30) and Pipeline (*n*=28). Results of the October 2012 three-day track census program showed that Beacon Island also hosted the highest daily number of overnight emergences by hawksbills and is therefore an important nesting beach for hawksbill turtles (Pendoley Environmental 2013).

On Varanus Island, hawksbills tend to nest in greater numbers on the eastern beaches (Pipeline Beach, Harriet Beach, and Andersons Beach) (Pendoley Environmental 2013). Between 1986 and 1999, approximately 350 individual hawksbills were tagged on Varanus Island (Apache 1999). Since 2005/2006 and 2012/2013 a total of 77 new turtles have been tagged, and 221 turtles recorded nesting, with the maximum of nesting turtles (42) tagged in 2008/2009 (Pendoley Environmental 2013). The turtle tagging program on Varanus Island in the 2012–2013 breeding season reported 17 hawksbills and six were newly tagged. Pipeline Beach remained the most frequented beach on Varanus Island (Pendoley Environmental 2013). Associated with monitoring efforts and results in 2016/17; the mean population estimate for hawksbill turtles stand at 289 (+/- 33), calculated from 16 seasons (Astron 2017). From 2016/17 monitoring, Pipeline Beach and Anderson Beach were still the more frequented beaches for hawksbill nesting, with hatch and emergence success reported within ranges for other hawksbill rookeries (Limpus 2009, Robinson 1990; cited in Astron 2017). The modelled hawksbill turtle population on Varanus Island has shown an increasing trend between 2012/13 and 2016/17 (Astron 2017).

Nesting is reported to occur between October and February in WA (Commonwealth of Australia 2017). Hawksbill turtles have been observed breeding on the NWS between July and March with peak nesting activity around the Lowendal Islands between October and December (Limpus 2009a).

Female hawksbills skip annual breeding opportunities (Kendall & Bjorkland 2001), presumably due to high energy demands of breeding (Chaloupka & Prince 2012).

Individuals may migrate up to 2,400 km between their nesting and foraging grounds (DSWEPaC 2012a). Satellite tracking of nesting turtles on Varanus Island (32 km) and Rosemary Island has shown adult turtles to feed between 50 and 450 km from their nesting beaches (DSWEPaC 2012a).

Adults tend to forage in tropical tidal and sub-tidal coral and rocky reef habitat where they feed on an omnivorous diet of sponges, algae, jelly fish and cephalopods (DSWEPaC 2012a). Hawksbill turtles are unlikely to spend significant time within off shore waters as it is too deep to act as a feeding ground. However, it is likely they may migrate through those areas.

Figure 6-3 illustrates the BIAs and critical habitats (draft) for hawksbill and olive ridley turtles (as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017)).

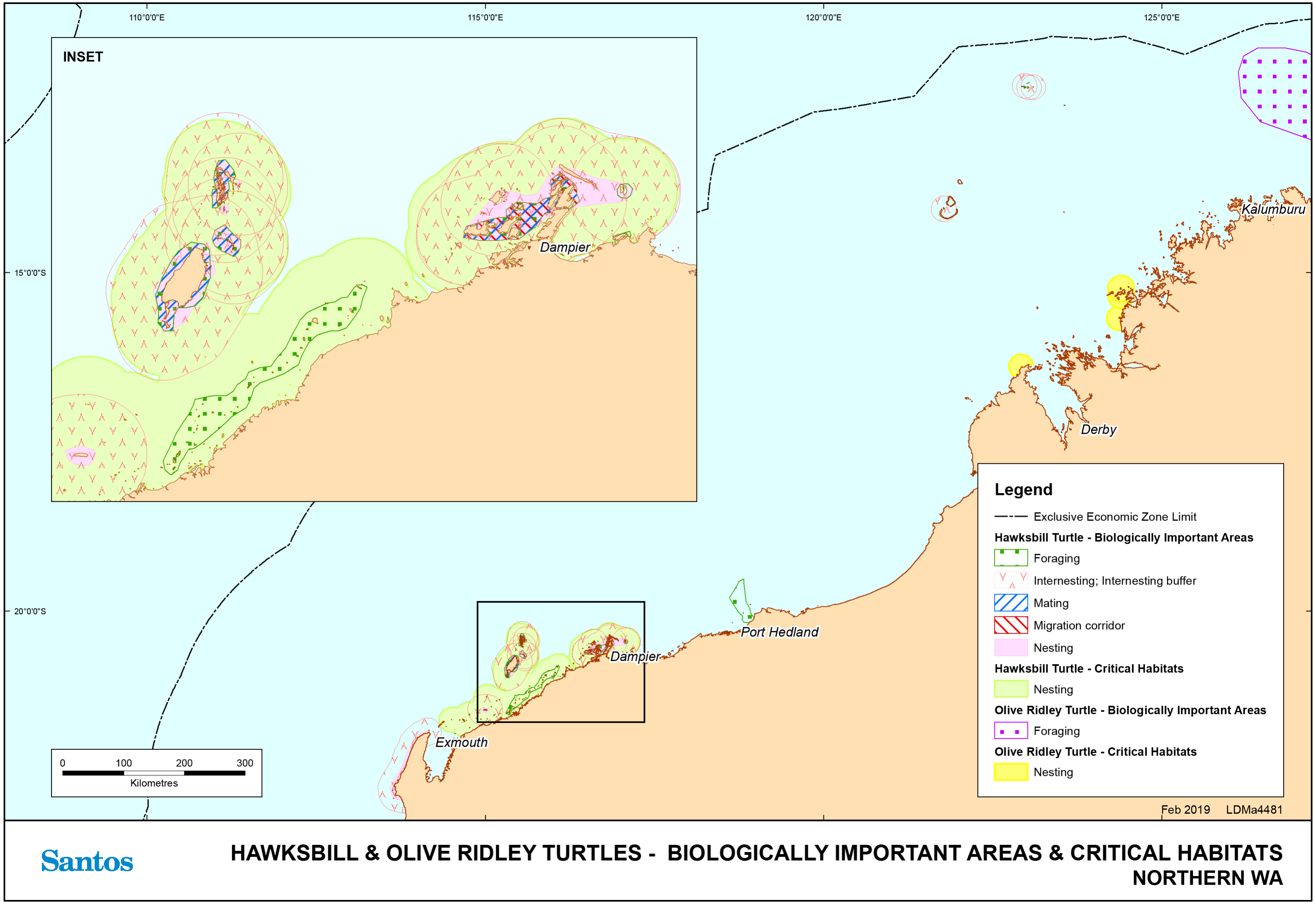


Figure 6-3: Biologically Important Areas and Critical Habitats – Hawksbill and Olive Ridley Turtle

6.1.4 Flatback Turtle

The flatback turtle (*Natator depressus*) has an Australasian distribution, with all recorded nesting beaches occurring within tropical to sub-tropical Australian waters. One third of the total breeding for the species occurs in Western Australia (WA) (Limpus, 2007). The management of the flatback turtle in Australia is broken up into four breeding units, with WA supporting two of these. The southern stock nests throughout the North West shelf (NWS) and is characterised by summer nesting, and the northern stock at Cape Domett which breeds mainly in winter (Limpus 2007).

The southern WA nesting population of flatback turtles occurs from Exmouth to the Lacepede Islands off the Kimberley coast (DSEWPaC 2012d). On the NWS, significant rookeries are centred on Barrow Island especially the east coast beaches (DSEWPaC 2012b).

Montebello Islands, Thevenard Island, Varanus Island, the Lowendal Islands, King Sound and Dampier Archipelago are also significant rookeries (Pendoley 2005, Limpus 2007, Pendoley Environmental 2011). Nesting is also widespread along the mainland beaches from Mundabullangana on the Pilbara coast north, including Cemetery Beach near Port Hedland, Eighty Mile Beach and to Broome (Limpus 2007, DSEWPaC 2012b).

There have been occasional records of nesting by flatback turtles on the Jurabi Coast and Muiron Islands (CALM 2005). During turtle surveys for Santos WA flatback turtle nesting was recorded on Bessieres Islands (Astron 2014), Serrurier, Flat, Table and Round Island in previous surveys (Pendoley Environmental 2009). Flatback turtle tracks have been seen on Forty Mile beach and evidence of flatback nesting was recorded on the same beach the next day (Pendoley Environmental 2009).

Previously the status of the flatback population(s) was undetermined and although not well quantified, it was estimated to be many thousands of females (Limpus 2007). However, Pendoley *et al*. (2014) reported both Barrow Island and Mundabullangana flatback turtles as substantial reproductive populations with 4,000 and 3,500 turtles tagged at each location between 2006/2006 and 2010/2011. Cemetery beach at Port Headland had approximately 350 turtles were tagged over two seasons of monitoring (2009/2010 and 2011/12).

Satellite tracking of adult (female) flatback turtles shows they use a variety of inshore and offshore marine areas off the east and west coasts of Barrow Island. Females inter-nest close to their nesting beaches, typically in 0–10 m of water (Chevron 2008). However, flatback turtles also travel approximately 70 km and inter-nest in shallow nearshore water off the adjacent mainland coast, before returning to Barrow Island to lay another clutch of eggs. The average inter-nesting period is 13–16 days.

From long-term tagging studies on Varanus Island and Pendoley's observations, it would appear that the nesting season for flatback turtles peaks in December and January with subsequent peak hatchling emergence in February and March. Flatbacks have been observed to nest on Varanus Island between November and February (Chevron 2008, Pendoley Environmental 2011 & 2013). Population monitoring of flatback turtles on Varanus Island, calculated from 16 seasons, indicates a mean population estimate of 226 (+/- 97). Modelled Flatback turtle populations have shown a slight decline from 2008/09 to 2016/17, which is considered to be part of fluctuations in the natural cycle (Astron 2017). Flatback turtles tend to nest on all beaches on Varanus Island (Astron 2017). Flatback hatching and emergence success is noted as higher compared to that reported for other Western Australian rookeries (Pendoley et al. 2014; cited Astron 2017).

Unlike other sea turtles, the flatback turtle lacks a wide oceanic dispersal phase and adults tend to be found in soft sediment habitats within the continental shelf of northern Australia (DSEWPaC 2012b). Little information is known on the diets of flatback turtles (DSEWPaC 2012b), however, they are believed to forage on primarily soft-bodied invertebrates (Commonwealth of Australia 2017).

Figure 6-4 illustrates the BIAs and critical habitats (draft) for flatback turtles (as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017)).

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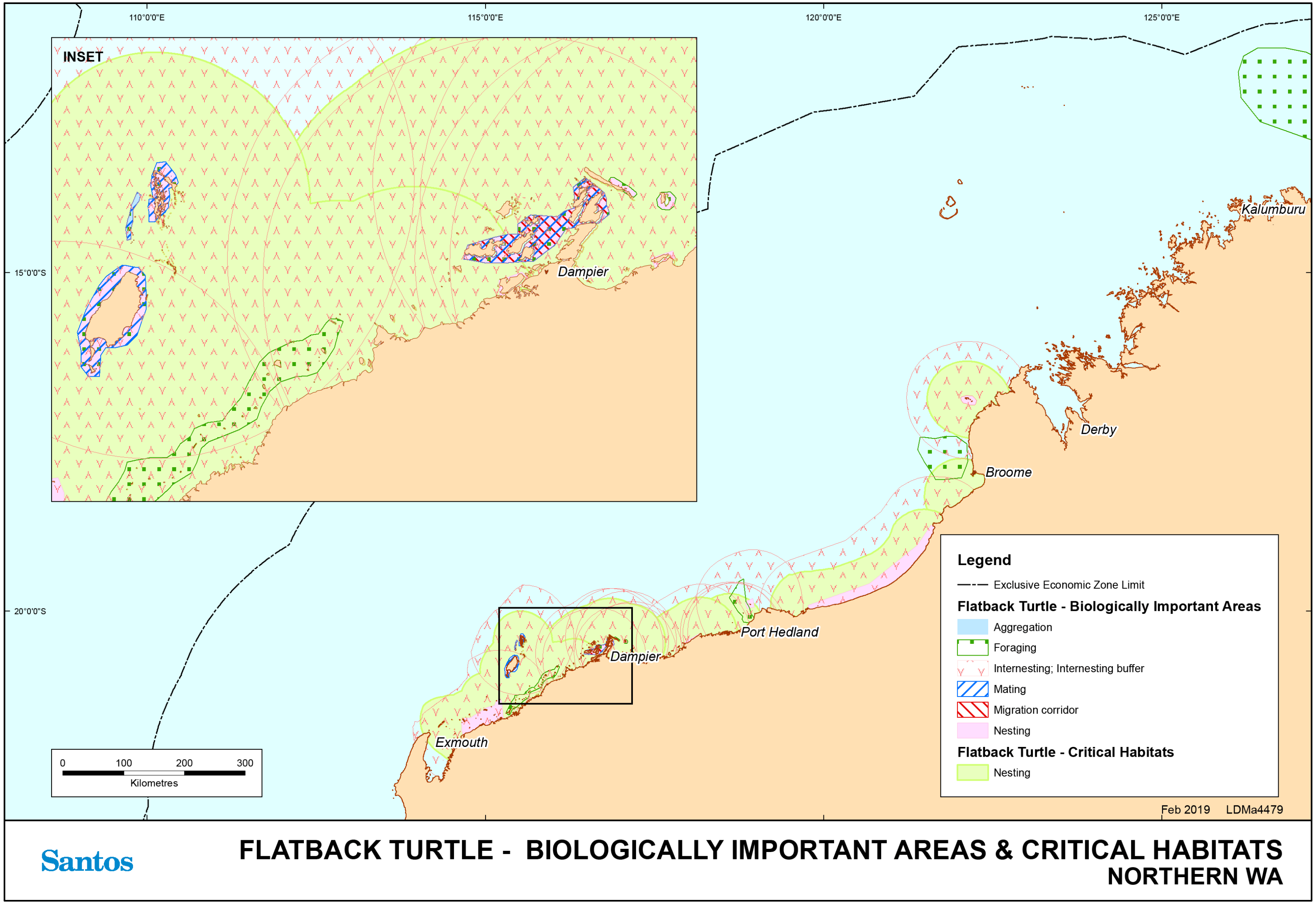

Figure 6-4: Biologically Important Areas and Critical Habitats – Flatback Turtle

6.1.5 Leatherback Turtle

The leatherback turtle *(Dermochelys coriacea)* has the widest distribution of any marine turtle, and can be found from tropical to temperate waters throughout the world (Márquez 1990). There are no major leatherback turtle centres of nesting activity that have been recorded in Australia, although scattered isolated nesting (one to three nests per annum) occurs in southern Queensland and the Northern Territory (Limpus and McLachlin 1994).

There have been several records of leatherback turtles off of the coast of WA, but no confirmed nesting sites (Limpus 2009b). Turtle observations have mainly occurred south of the NWS area and in open waters (>200 m deep) (Limpus 2009b). Due to the lack of nesting sites around Australian coastal waters, it is presumed that Leatherback turtles observed in Australian waters are migrating from neighbouring countries to utilise feeding grounds in Australia (Limpus 2009b).

The leatherback turtle will feed at all levels of the water column and is carnivorous feeding mainly on pelagic, soft-bodied marine organisms such as jellyfish, which occur in greatest concentrations in areas of upwelling or convergence (DSEWPaC 2012d). The leatherback turtle is a highly pelagic species with adults only going ashore to breed.

No leatherback turtle BIAs or critical habitats (draft) are found within the area of interest.

6.1.6 Olive Ridley Turtles

Olive Ridley turtles (*Lepidochelys olivacea*) are the least common turtle species encountered with critical nesting habitats occurring near Vulcan Island, Darcy Island, Prior Point and Llanggi and Cape Leveque (Commonwealth of Australia 2017). This species forages within the shallow benthic habitats of northern Western Australia and is thought to feed primarily on gastropods and small crabs within the benthic, soft-bottomed communities of the continental shelf (Limpus 2009). Olive Ridley turtles forage as far south as the Dampier Archipelago-Montebello Islands.

BIAs for this endangered species are known to occur in the vicinity of Joseph Bonaparte Depression (DSEWPaC 2012b, Environment Australia 2003). See **Figure 6-3** for identified olive ridley turtle BIAs and critical habitats (draft) within the area of interest (as defined in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017)).

6.2 Seasnakes

Storr *et al*. (1986) estimate nine genera and 22 species of sea snakes occur in WA waters, with 25 listed marine seasnake species being recorded in the search area **Appendix A**. Little is known of the distribution of individual species, population sizes or aspects of their ecology. Sea snakes are essentially tropical in distribution, and habitats reflect influences of factors such as water depth, nature of seabed, turbidity and season (Heatwole and Cogger 1993). Sea snakes and kraits are widespread throughout waters of the NWS in offshore and nearshore habitats. They can be highly mobile and cover large distances or they may be restricted to relatively shallow waters and some species must return to land to eat and rest. In the north-west region of Western Australia, no BIAs have been designated for sea snakes. However, both Ashmore Reef and Cartier Island are characterized for both a high density and high diversity of sea snakes (DSEWPaC 2012b).

Two species of seasnakes listed as threatened under the EPBC Act were identified in the Protected Matters search (**Appendix A**):

+ Short-nosed seasnake (*Aipysurus apraefrontalis*); and
+ Leaf-scaled seasnake (*Aipysurus foliosquama*).

6.2.1 Short-nosed Seasnake

The short-nosed seasnake (*Aipysurus apraefrontalis*) is listed as critically endangered under the EPBC Act and the *Biodiversity Conservation Act 2016.* It is a fully aquatic, small snake and is endemic to WA. It has been recorded from Exmouth Gulf, WA to the reefs of the Sahul Shelf, in the eastern Indian

Ocean. This species is believed to show strong site fidelity to shallow coral reef habitats in less than 10 m of water, with most specimens having been collected from Ashmore and Hibernia reefs (Minton & Heatwole 1975, Guinea and Whiting 2005).

The species prefers the reef flats or shallow waters along the outer reef edge in water depths to 10 m (McCosker 1975, Cogger 2000). The species has been observed during daylight hours, resting beneath small coral overhangs or coral heads in 1–2 m of water (McCosker 1975). Guinea and Whiting (2005) reported that very few short-nosed seasnakes moved even as far as 50 m away from the reef flat and are therefore unlikely to be expected in high numbers in off shore, deeper waters.

6.2.2 Leaf-scaled Seasnake

The leaf-scaled seasnake *(Aprasia rostrate rostrata)* is listed as critically endangered under the EPBC Act and the *Biodiversity Conservation Act 2016.* It occurs in shallow water (less than 10 m in depth), in the protected parts of the reef flat, adjacent to living coral and on coral substrates (DoE 2014). The species is found only on the reefs of the Sahul Shelf in Western Australia, especially on Ashmore and Hibernia Reefs (Minton and Heatwole 1975). The leaf-scaled seasnake forages by searching in fish burrows on the reef flat (DoE 2014).

6.3 Crocodiles

The salt-water crocodile (*Crocodylus porosus*) is a migratory species under the EPBC Act and is also listed under as a specially protected species (Other specially protected fauna) of the*Biodiversity Conservation Act 2016*). In Western Australia the species is found in most major river systems of the Kimberley, including the Ord, Patrick, Forrest, Durack, King, Pentecost, Prince Regent, Lawley, Mitchell, Hunter, Roe and Glenelg Rivers. The largest populations occur in the rivers draining into the Cambridge Gulf and the Prince Regent River and Roe River systems. There have also been isolated records in rivers of the Pilbara region, around Derby near Broome and as far south as Carnarvon on the mid-west coast (DEC 2009a).

6.4 Biologically Important Areas/Critical Habitats – Marine Reptiles

Table 6-3 provides an overview of BIAs in the area of interest for reptiles, as identified by the DoEE (Cwth) and critical habitats identified in associated recovery plans. The DoEE may make recovery plans for threated fauna listed under the EPBC Act. The EPBC Act requires that ‘habitat critical to the survival of the listed threatened species’ is identified in recovery plans, relevant recovery plans are listed in **Section 13.2**[4].

In addition, both the EPBC Act and WA Biodiversity Conservation Act 2016 and associated regulations (2018) provide for the listing of critical habitat - habitat ‘critical to the survival of the threatened species’. To date no critical habitat in WA has been listed under either Act.

[4] Further background information on BIA and identification of critical habitat in recovery plans is provided in Section 5.4

Table 6-3: Biologically important areas/critical habitats and geographic locations - reptiles

Species	Scientific name	Aggregation area and use	Biologically important areas within area of interest	Critical habitats within area of interest
Loggerhead turtle	*Caretta caretta*	Nesting, migration, foraging and internesting – Islands and coastline of the Kimberley region and islands of the North West Shelf	Cohen Island De Grey River Dirk Hartog Island Gnarloo Bay James Price Point Lowendal Island Montebello Island Murion Island Ningaloo Coast and Jurabi coast Rosemary Island Western Joseph Bonaparte Depression	Exmouth and Ningaloo coast Gnaraloo Bay and beaches Shark bay, all coastal and island beaches out the to the northern tip of Dirk Hartog Island
Green turtle	*Chelonia mydas*	Nesting, migration foraging and internesting – Offshore islands in the Browse Basin, North West Shelf and Kimberley/Pilbara coastlines Mating/nesting – Dampier Archipelago Basking – Middle Island	Ashmore Reef Barrow Island Browse Island Cartier Island Cassini Island Coral reef habitat west of the Montebello group. Extends the entire length of Montebellos Dampier Archipelago (islands to the west of the Burrup Peninsula) De Grey River area to Bedout Island Delambre Island Dixon Island Greens - inshore tidal and shallow subtidal areas around Barrow Island Hawksbills - shallow water coral reef and artificial reef (pipeline) habitat James Price Point Lacepede Island Legendre Island, Huay Island Middle Is. West Coast Barrow Island West Coast and North Coast Montebello Island - Hermite Island, NW Island, Trimouille Island Montebello Islands Montgomery Reef North and South Muiron Island	Mainland east of Mary island to mainland adjacent to Murrara Island including all offshore islands Ashmore Reef and Cartier Reef Browse Island Scott Reef Adele Island Lacepede Island Dampier Archipelago Barrrow Island Montebello Islands Serrier Island and Thevenard Island Exmouth Gulf and Ningaloo Coast

Species	Scientific name	Aggregation area and use	Biologically important areas within area of interest	Critical habitats within area of interest
			North Turtle Island North West Cape Scott Reef Scott Reef - Sandy Islet Seringapatam Reef String of islands between Cape Preston and Onslow, inshore of Barrow Is	
Hawksbill turtle	*Eretmochelys imbricata*	Nesting, migration, foraging and internesting – Offshore islands in the Browse Basin, North West Shelf and Kimberley/Pilbara coastlines Mating/nesting/internesting – Lowendal group, Montebello Islands	Ah chong and South East Is Ashmore Reef Barrow Island Cartier Island Dampier Archipelago (islands to the west of the Burrup Peninsula) De Grey River area to Bedout Is Delambre Island Delambre Island (and other Dampier Archipelago Islands) Greens - inshore tidal and shallow subtidal areas around Barrow Island Hawksbills - shallow water coral reef and artificial reef (pipeline) habitat Lowendal Island Group Montebello Island - Hermite Island, NW Island, Trimouille Island Montebello Island, Trimoulle and NW islands Ningaloo coast and Jurabi coast Rosemary Island Scott Reef String of islands between Cape Preston and Onslow, inshore of Barrow Island Thevenard Island Varanus Island	Cape Preston to mouth of Exmouth Gulf (including Montebello Islands and Lowendal Islands) Dampier Archipelago (including Delambre Island and Rosemary Island)
Flatback turtle	*Natator depressus*	Nesting, migration, foraging, internesting – Islands of the North West Shelf and the Pilbara/Kimberley coastlines Mating, nesting – Barrow Island	Eighty Mile beach Barrow Island Cape Domett Cape Thouin/ Mundabullangana/Cowrie Beach Coral reef habitat west of the montebello group.	Cape Domett and Lacrosse Island Lacepede Islands Eighty Mile beach Cemetary beach Eco Beach Mundabullangana Beach

Species	Scientific name	Aggregation area and use	Biologically important areas within area of interest	Critical habitats within area of interest
			Extends the entire length of Montebellos Dampier Archipelago (islands to the west of the Burrup Peninsula) De Grey River area to Bedout Is Delambre Island Dixon Island Holothuria Zone (Northern Kimberley, Holothuria Banks) Intercourse Island James Price Point Lacepede Island Legendre Island, Huay Is Montebello Island - Hermite Island, NW Island, Trimouille Island North Turtle Island Port Hedland, Cemetery Beach Port Hedland, Paradise Beach Port Hedland, Pretty Pool String of islands between Cape Preston and Onslow, inshore of Barrow Is The main nesting beach at Cape Domett is a 1.9-km-long north-west-facing sandy beach on the east of the Cambridge Gulf, East Kimberley, Western Australia (14 48.10S, 128 24.50E), located ~80 km north-north-east of the nearest town, Wyndham. Thevernard Island - South coast West of Cape Lambert Western Joseph Bonaparte Depression	Dampier Archipelago Barrow Island, Montebello Island, coastal islands from Cape Preston to Locker Island
Leatherback turtle	*Dermochelys coriacea*	None within area of interest	None within area of interest	None within area of interest
Olive ridley turtle	*Lepidochelys olivacea*	Foraging, migration – Joseph Bonaparte Gulf – Kimberley region	Western Joseph Bonaparte Depression	Cape Leveque Prior Point and Llanggi Darcy Island Vulcan Island

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7. Marine Mammals

Forty-five species of listed marine mammals are known to occur in Australian waters in the area of interest, according to the Protected Matters search (**Appendix A**). An examination of the species profile and threats database (DoEE 2017a) showed that some listed mammal species are not expected to occur in significant numbers in the marine and coastal environments in the area of interest due to their terrestrial distributions. Hence, these species are not discussed further.

Of the remaining listed species, five are listed as threatened and migratory, one is listed as threatened and ten are listed as migratory under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (BIAs for marine mammals are discussed in **Table 7-3**). These species are shown in **Table** 7-1 along with their conservation listing under the WA Biodiversity Conservation Act 2016 (as applicable)

The section below gives further details on marine mammal species listed as threatened and migratory and a summary is presented in **Table** 7-2. Identified BIAs are presented in **Table 7-3**.

Table 7-1: Marine mammals listed as threatened or migratory under the EPBC Act

Scientific Name **Common Name**	**Conservation Status**		**Likelihood of occurrence in area of interest**	**Biologically important area in area of interest**
	Environmental Protection and Biodiversity Conservation Act 1999 (Cwth)	*Biodiversity Conservation Act 2016 (WA)*		
Balaenoptera borealis Sei whale	Vulnerable Migratory	Endangered	Foraging, feeding or related behaviour likely to occur within area	None - No BIA defined
Balaenoptera musculus Blue whale	Endangered Migratory	Endangered	Foraging, feeding or related behaviour known to occur within area	Yes – Refer to **Table 7-3**
Balaenoptera physalus Fin whale	Vulnerable Migratory	Endangered	Foraging, feeding or related behaviour likely to occur within area	None - No BIA defined
Eubalaena australis Southern right whale	Endangered Migratory	Vulnerable	Breeding known to occur within area	Yes – Refer to **Table 7-3**
Megaptera novaeangliae Humpback whale	Vulnerable Migratory	Specially Protected (special conservation interest)	Breeding known to occur within area	Yes – Refer to **Table 7-3**
Physeter macrocephalus Sperm whale	Migratory	Vulnerable	Foraging, feeding or related behaviour known to occur within area	Yes – Refer to **Table 7-3**
Balaenoptera bonaerensis Antarctic minke whale	Migratory	-	Species or species habitat likely to occur within area	None - No BIA defined
Balaenoptera edeni Bryde's whale	Migratory	-	Species or species habitat likely to occur within area	None - No BIA defined

Scientific Name **Common Name**	**Conservation Status** ***Environmental Protection and Biodiversity Conservation Act 1999 (Cwth)***	 *Biodiversity Conservation Act 2016 (WA)*	**Likelihood of occurrence in area of interest**	**Biologically important area in area of interest**
Caperea marginata Pygmy right whale	Migratory	-	Foraging, feeding or related behaviour likely to occur within area	None - No BIA defined
Orcinus orca Killer whale	Migratory	-	Species or species habitat may occur within area	None - No BIA defined
Sousa chinensis Indo-Pacific humpback dolphin	Migratory	-	Breeding known to occur within area	Yes – Refer to **Table 7-3**
Tursiops aduncus Spotted bottlenose dolphin (Arafura/ Timor Sea Populations)	Migratory	-	Species or species habitat likely to occur within area	Yes – Refer to **Table 7-3**
Orcaella brevirostris Irrawaddy dolphin (Australian snubfin dolphin)	Migratory	-	Species or species habitat known to occur within area	Yes – Refer to **Table 7-3**
Lagenorhynchus obscurus Dusky dolphin	Migratory	-	Species or species habitat likely to occur within area	None - No BIA defined
Neophoca cinerea Australian sea lion	Vulnerable	Vulnerable	Breeding known to occur within area	Yes – Refer to **Table 7-3**
Dugong dugon Dugong	Migratory	Specially protected (species otherwise in need of special protection)	Breeding known to occur within area	Yes – Refer to **Table 7-3**

In addition, the New Zealand fur-seal ***(Arctocephalus forsteri)***, has been identified as a species of relevance to the area of interest. The New-Zealand fur seal is listed as a protected species under WA Biodiversity Act 2016, but not listed as threatened under the EPBC Act.

7.1 Threatened & Migratory Species

7.1.1 Sei Whale

Sei whales have a worldwide, oceanic distribution, ranging from polar to tropical waters. Sei whales tend to be found further offshore than other species of large whales (Bannister *et al*. 1996).

Sei whales move between Australian waters and Antarctic feeding areas however they are only infrequently recorded in Australian waters (Bannister *et al*. 1996) and their movements and distribution in Australian waters is not well known (DoEE 2017a). There are no known mating or calving areas in Australian waters (Parker 1978 in DoEE 2017a). The National Conservation Values Atlas currently record no BIAs for this species (DoEE 2017b). Surveys of the Bonney Upwelling (outside of the area of interest) between 2000 and 2003 recorded sightings of sei whales feeding during summer and autumn, indicating that this is potentially an important feeding ground (DoEE 2017b).

7.1.2 Blue Whale

Two subspecies of blue whale are recorded in Australian waters; the southern (or true) blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*Balaenoptera musculus brevicauda*). Southern blue whales are believed to occur in waters south of 60°S and pygmy blue whales occur in waters north of 55°S (i.e. not in the Antarctic) (DEWHA 2008). By this definition all blue whales in waters from Busselton to the Northern Territory border are assumed to be pygmy blue whales, and are discussed below.

Pygmy blue whales have a southern hemisphere distribution, migrating from tropical water breeding grounds in winter to temperate and polar water feeding grounds in summer (Bannister *et al*. 1996, Double *et al*. 2014). The Western Australian migration path takes pygmy blue whales down the Western Australian coast to coastal upwelling areas along southern Australia (Gill 2002) and south at least as far as the Antarctic convergence zone (Gedamke *et al*. 2007).

Tagging surveys have shown pygmy blue whales migrating northward relatively near to the Australian coastline (100 km) until reaching North West Cape after which they travelled offshore (240 km) to Indonesia. Passive acoustic data documented pygmy blue whales migrating along the Western Australian shelf break (Woodside 2012).

The northern migration passes the Perth Canyon from January to May and north bound animals have been detected off Exmouth and the Montebello Islands between April and August (Double *et al*. 2012, McCauley & Jenner 2010). During the southern migration, pygmy blue whales pass south of the Montebello Islands and Exmouth from October to the end of January, peaking in late November to early December (Double *et al*. 2012).

Recognised feeding areas of significance to this species, located within the area of interest include Ningaloo Reef and Perth Canyon (DEH 2005a). The Ningaloo Reef area has the capacity to offer feeding opportunities to pygmy blue whales through unique biophysical conditions able to support large biomasses of marine species (Double *et al*. 2014). Surface lunge feeding of pygmy blue whales has been observed at North West Cape and Ningaloo Reef in June (C. Jenner & M-N Jenner, unpublished data, 2001 in Double *et al*. 2014).

Breeding areas have not yet been identified, however, it is likely that pygmy blue whales calve in tropical areas of high localised production such as deep offshore waters of the Banda and Molucca Seas in Indonesia (Double *et al*. 2014, DoEE 2017b). There are no known breeding areas of significance to blue whales in waters from Busselton to the Northern Territory border.

The BIAs for blue whale and pygmy blue whale are detailed in **Table 7-3** and depicted in **Figure 7-1** and **Figure 7-2.**

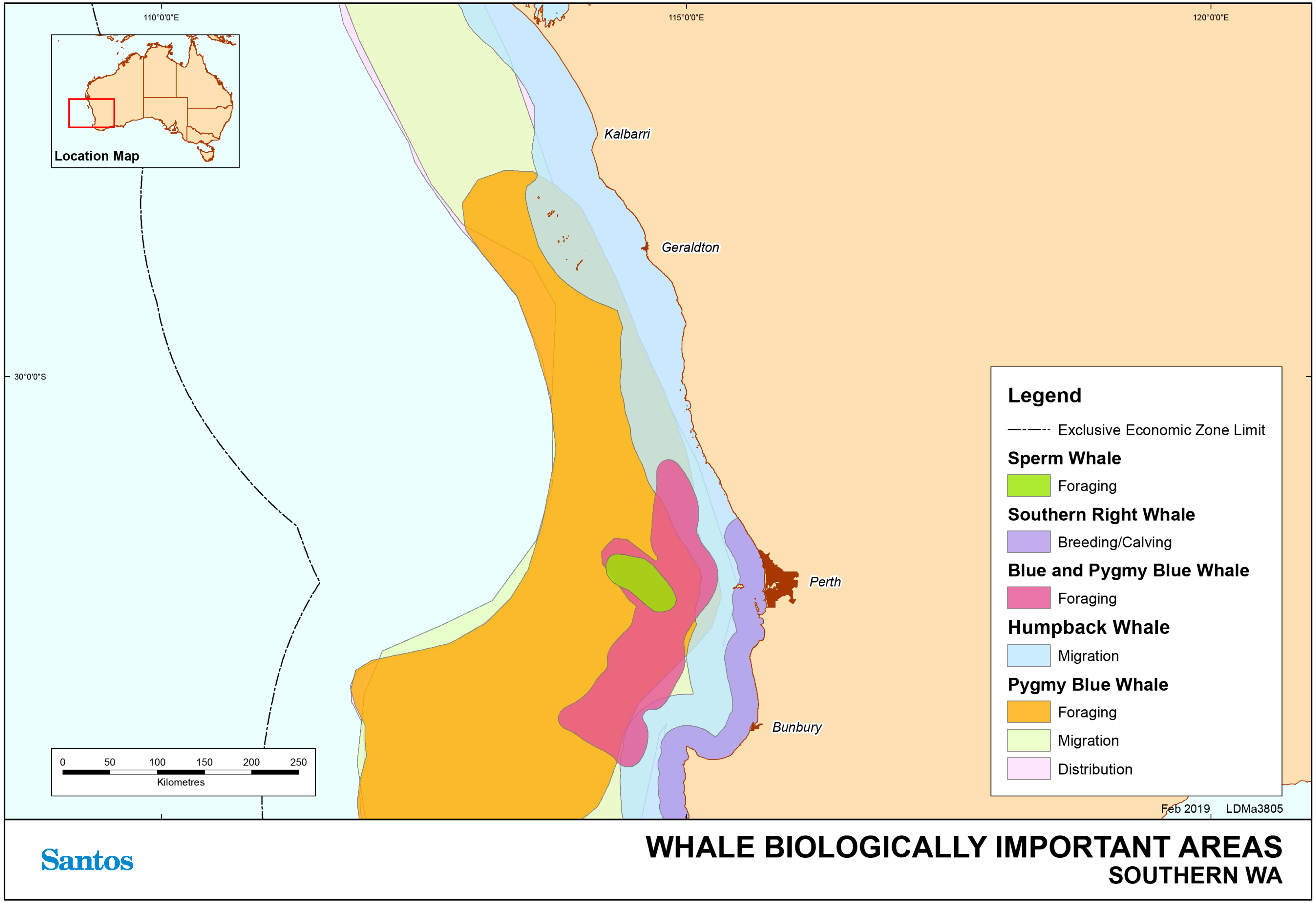

Figure 7-1: Biologically important areas – whales – Southern WA

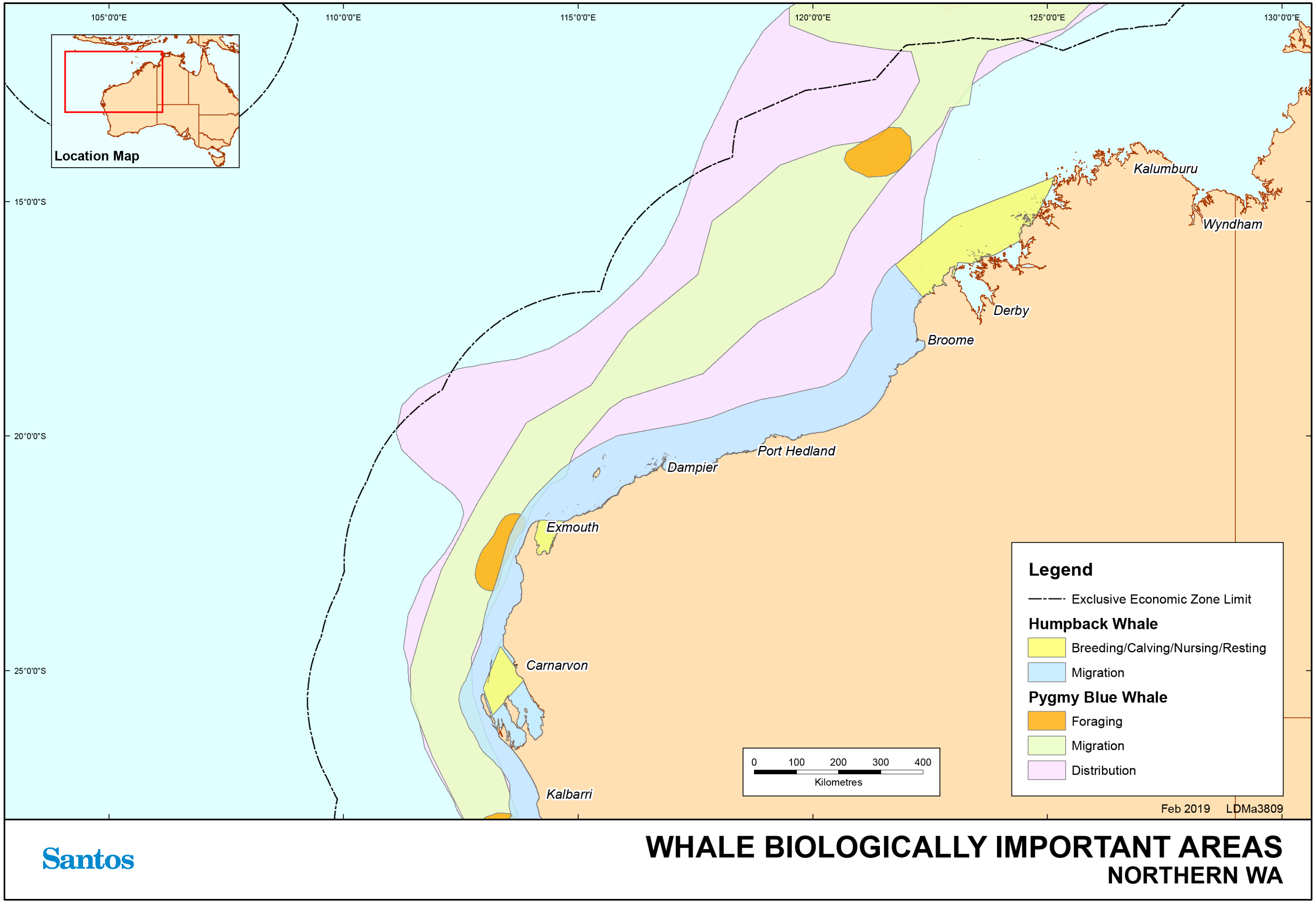

Figure 7-2: Biologically important areas – whales – Northern WA

7.1.3 Fin Whale

Fin whales have a worldwide distribution generally in deeper waters, with oceanic migrations between warm water breeding grounds and cold water feeding grounds.

The fin whale distribution in Australia is not clear due to the sparsity of sightings. Information is known primarily from stranding events and whaling records. According to the Species Profile and Threats database (DoEE 2017a); fin whales are thought to be present from Exmouth, along the southern coastline, to southern Queensland.

Migration paths are uncertain but are not thought to follow Australian coastlines (Bannister *et al*. 1996). There is insufficient data to prescribe migration times for fin whales. During summer and autumn this species has been recorded acoustically at the Rottnest Trench.

There are no known mating or calving areas in Australian waters (DoEE 2017a) and no BIAs for the fin whale are currently identified by the National Conservation Values Atlas (DoEE 2017b).

7.1.4 Southern Right Whale

The southern right whale is present in the southern hemisphere between approximately 30° and 60°S. The species feeds in the Southern Ocean in summer, moving close to shore in winter.

In Australian waters, southern right whales range from Perth, along the southern coastline, to Sydney. Sightings have been recorded as far north as Exmouth although these are rare (Bannister *et al*. 1996).

BIAs including calving and aggregation areas are recorded for this species along the southern coastline of Australia (DoEE 2017b). Details on the BIA for southern right whale are provided in **Table 7-3** and depicted in **Figure 7-1**.

7.1.5 Humpback Whale

Humpback whales have a worldwide distribution, migrating along coastal waters from polar feeding grounds to subtropical breeding grounds. Geographic populations are distinct and at least six southern hemisphere populations are thought to exist based on Antarctic feeding distribution and the location of breeding grounds on either side of each continent (Bannister *et al*. 1996). The population of humpback whales migrating along the Western Australian coastline was recently estimated to be greater than 33,000 whales and likely increasing at exceptionally high growth rates between 10–12% (Hedley *et al*. 2011, Salgado Kent *et al*. 2012).

The west coast Australian humpback whale population migrates from Southern Polar Ocean ‘summer’ feeding grounds to their northern tropical ‘winter’ calving/ breeding grounds in coastal waters of the Kimberley. The northern migration tends to follow deeper waters of the continental shelf, whilst the southward migration concentrates whales closer to the mainland (Jenner *et al*. 2001). Recent satellite tagging of southbound humpback whales indicate that whales generally migrated close to the coastline, within a few tens of kilometres of shore and in a corridor frequently less than 100 km (Double *et al*. 2010). Aerial surveys and noise logger recordings undertaken for Chevron’s Wheatstone Project indicated that the main distribution of humpback whales were sighted at an average distance of 50 km from the mainland during the northern migration and 35 km during the southbound migration (RPS 2010a).

The precise timing of the migration varies between years by up to six weeks, influenced by water temperature, sea ice distribution, predation risk, prey abundance and the location of feeding grounds (DEWR 2007).

Peak northward migration across the North West Shelf is identified as from late July to early August, and peak southward migration from late August to early September (DotE 2015c). Data collected between 1995 and 1997 by the Centre for Whale Research indicates that the period for peak northern migration into the calving grounds in the Kimberley is mid to late July. The peak for southern migration is in the first half of September (Jenner *et al* 2001). Actual timing of annual migration may vary by as much as three (3) weeks from year to year due to food availability in the Antarctic (DMP, 2003).

Details on the BIA for humpback whales are provided in **Table 7-3** and depicted in **Figure 7-1** and **Figure 7-2**.

7.1.6 Sperm Whale

Sperm whales typically occur in WA along the southern coastline between Cape Leeuwin and Esperance (Bannister et al. 1996). Sperm whales are distributed worldwide in deep waters (greater than 200 m) off continental shelves and sometimes near shelf edges, averaging 20 to 30 nautical miles offshore (Bannister et al. 1996). The sperm whale is known to migrate northwards in winter and southwards in summer, however, detailed information on the distribution of sperm whales is not available for the timing of migrations. Sperm whales have been recorded in deep water off the North West Cape on the west coast of Western Australia (RPS 2010b), and appear to occasionally venture into shallower waters in other areas (RPS 2010b). Details on the BIA for sperm whales are provided in **Table 7-3** and are shown in **Figure 7-1.**

7.1.7 Antarctic Minke Whale

The Antarctic minke whale is distributed throughout the Southern Hemisphere from 55°S to the Antarctic ice edge during the austral summer and has been recorded in all Australian States (Bannister et al. 1996; Perrin & Brownell 2002). Detailed information on timing and location of migrations and breading grounds on the west coast of Australia is largely unknown. However, it is believed that the Antarctic minke whale migrates up the WA coast to approximately 20°S during Australian winter to feed and possibly breed (Bannister *et al.* 1996).

7.1.8 Bryde's Whale

The Bryde's whale is found all year round in tropic and temperate waters (Kato 2002). Two forms are recognised: inshore and offshore Bryde's whales. It appears that the inshore form is restricted to the 200 m depth isobar whilst the offshore form is found in deeper waters of 500-1,000 m (DoEE 2017c). Both forms are expected to be found in zones of upwelling where they feed on shrimp like crustaceans (Bannister *et al.* 1996). Little is known about the population abundance of Bryde's whale, the location of exact breeding and calving grounds and large-scale migration patterns (DoEE 2017c). It is however, suggested that the offshore form migrates seasonally, heading towards warmer tropical waters during the winter.

7.1.9 Pygmy Right Whale

The pygmy right whale is considered the most elusive baleen whale and as a result very little is known about the whale's distribution in Australian waters. Records of the pygmy right whale in Australian waters are distributed between 32°S and 47°S and are restricted in the west by the Leeuwin current (Kemper 2002). It is possible that the pygmy right whale will be encountered in the southern extent of the area of interest, particularly in coastal areas of upwelling (Kemper 2002).

7.1.10 Killer Whale

The killer whale has a widespread global distribution and has been recorded in waters of all Australian states/territories (Bannister *et al.* 1996). Whilst more commonly found in cold, deeper waters, killer whales have been observed along the continental slope, shelf and shallow coastal areas of WA. Killer whales are known to make seasonal movements and are most likely to follow the migratory routes of their prey.

7.1.11 Indo-Pacific Humpback Dolphin

The Indo-pacific humpback dolphin is typically found in water less than 20 m deep, but has been recorded in waters up to 40 m deep. This species is generally found in association with river mouths, mangroves, tidal channels and inshore reefs (DoEE 2016a). This species of dolphin is known to have resident groups that forage, feed, breed and calve in the state waters of Roebuck Bay, Dampier Peninsula, King Sound north, Talbot Bay, Anjo Peninsula, Vansittart Bay, Napier Broome Bay and Deception Bay (DoEE 2016a).

The Indo-Pacific humpback dolphin BIA in the area of interest is detailed in **Table 7-3** and shown on **Figure 7-3**.

7.1.12 Spotted Bottlenose Dolphin (Indo-Pacific bottlenose dolphin)

The spotted bottlenose dolphin (*Tursiops aduncus*) (Arafura / Timor Sea populations) is generally considered to be a warm water subspecies of the spotted bottlenose dolphin, occurring in shallow (often <10 m deep) inshore waters (Bannister et al., 1996; Hale et al., 2000). The known distribution of the spotted bottlenose dolphin extends from Shark Bay north to the western edge of the Gulf of Carpentaria in Australia (DoEE 2016b). The spotted bottlenose dolphin BIA in the area of interest is detailed in **Table 7-3** and shown on **Figure 7-3**.

7.1.13 Irrawaddy Dolphin (Australian Snubfin Dolphin)

The Irrawaddy dolphin, also known as the snubfin dolphin (*Orcaella brevirostris*) is known to occur within the waters off northern Australia, extending north from Broome in Western Australia to the Brisbane River in Queensland (DoEE 2016c). Surveys have indicated that the species is typically found in protected shallow nearshore waters, generally less than 20 m deep, adjacent to river and creek mouths close to seagrass beds (DoEE 2016c). The snubfin dolphin was not recorded during any of the aerial surveys undertaken along the Dampier Peninsula coastline in the vicinity of James Price Point but were observed in Roebuck Bay from vessels on several occasions (RPS, 2010b). Based on the extensive survey effort and amenable conditions within the James Price Point coastal area during the survey, it is concluded that this species is seldom found outside of shallow and sheltered bays and inlets (DSD 2010). The Irrawaddy dolphin BIA in the area of interest is detailed in **Table 7-3** and shown on **Figure 7-3.**

7.1.14 Dusky Dolphin

The dusky dolphin's distribution is strongly linked to colder waters. In Australia, the dusky dolphin has been sighted in southern Australia from Western Australia to Tasmania. It is presumed to be primarily an inshore species but has been known to move further offshore, possibly due to its desire for colder waters (Gill *et al.* 2000). Dusky dolphins are expected to be limited in their distribution along the WA coastline due to the presence of the southward-flowing warm water of the Leeuwin Current.

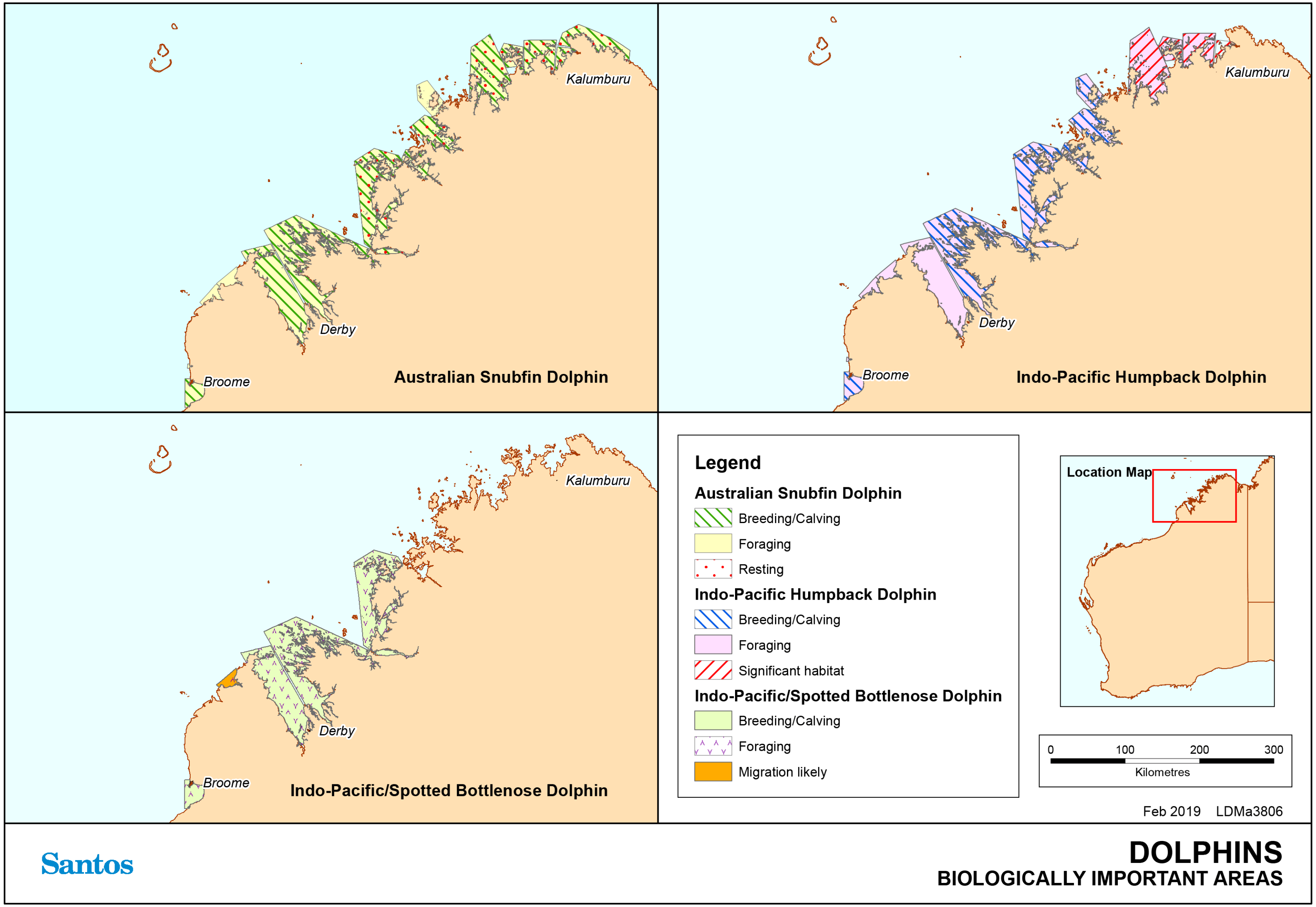

Figure 7-3: Biologically important areas – dolphins

7.1.15 Australian Sea Lion

The Australian sea lion is endemic to Australia. Breeding colonies are found only in South Australian and Western Australian waters. There are currently 76 known Australian sea lion pupping locations along the coast and offshore islands between the Houtman Abrolhos Islands in Western Australia to the Pages Islands in South Australia (DSEWPaC 2013). The species has also been recorded at Shark Bay (DoE 2014a).

BIAs for foraging, haul-out and breeding sites identified by the National Conservation Values Atlas are located south of the waters from Busselton to the Northern Territory border (DoEE 2017b). Male Australian sea lions have been recorded foraging in areas up to 60 km away from their birth colonies, with potentially larger dispersal ranges up to 180 km (Hamer *et al*. 2011). However, female Australian sea lions have restricted home ranges, with high rates of natal site fidelity and limited gene flow with other regions (Campbell 2005). The Australian sea lion BIA in the area of interest is outlined in **Table 7-3** and is depicted in **Figure 7-4.**

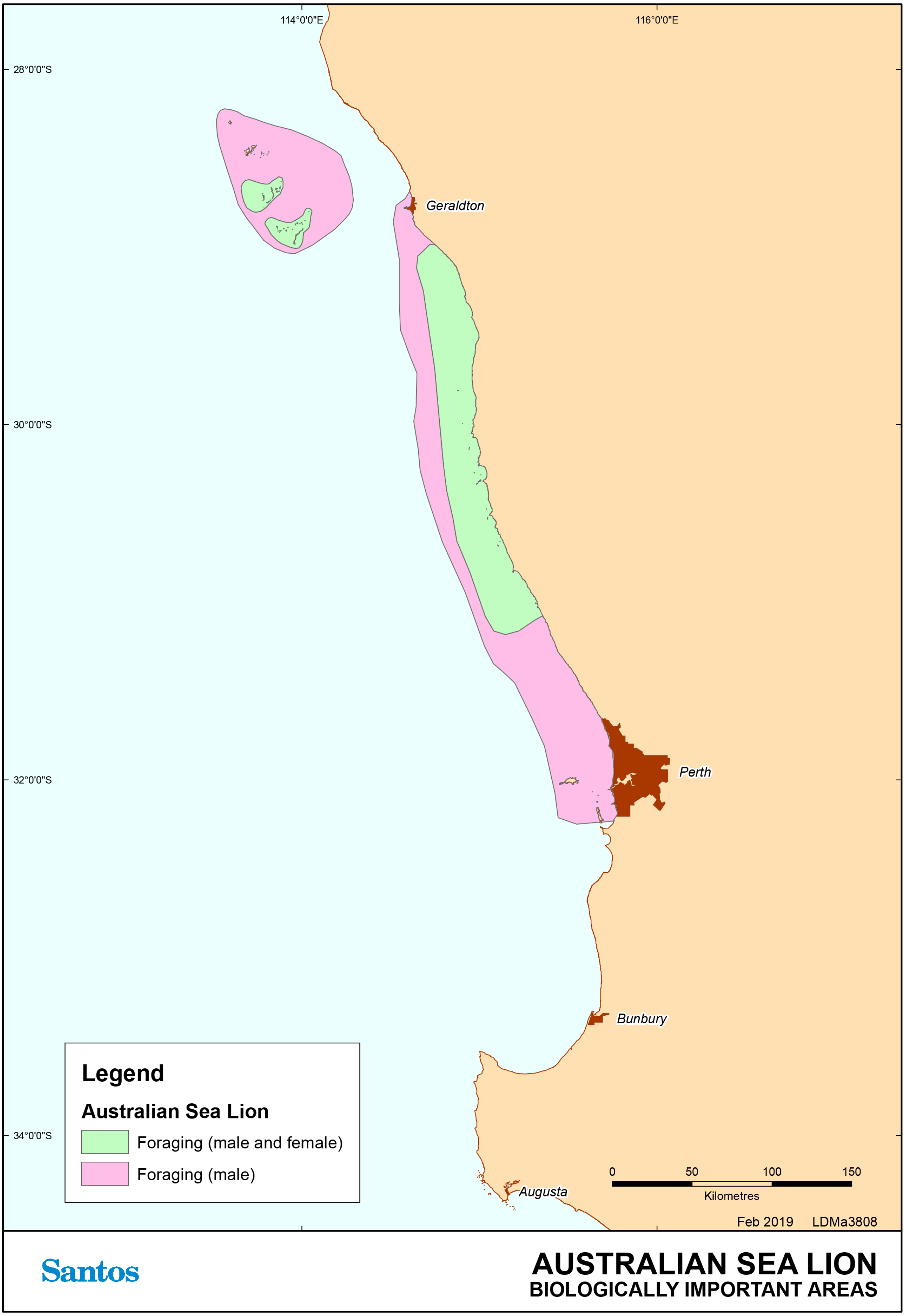

Figure 7-4: Biologically important areas – Australian sea lion

7.1.16 Dugongs

Dugongs (*Dugong dugon*) are large herbivorous marine mammals (up to 3 metres) that feed off seagrass and generally inhabit coastal areas. Key populations along the WA coast are principally located at: Shark Bay (the largest resident population in Australia), Ningaloo Marine Park and Exmouth Gulf, the Pilbara coast and offshore areas including Montebello/Barrow/Lowendal Islands, and further north at Eighty Mile Beach and off the Kimberley Coast, particularly Roebuck Bay and Dampier Peninsula (Marsh *et al*. 2002; DSEWPaC 2012). Populations are also present at Ashmore Reef. Dugong distribution and movement is based on the abundance, size and species of seagrass meadow. Dugongs can migrate hundreds of kilometres between seagrass habitat. The dugong BIAs in the area of interest are detailed in **Table 7-3** and shown in **Figure 7-5**.

7.1.17 New Zealand fur-seal, long-nosed fur-seal

The New Zealand fur-seal, long-nosed fur seal (Arctocephalus forsteri) is a specially protected species (Other Specially Protected) under the Biodiversity Conservation Act 2016.

The New Zealand fur seal is found in Ngari Capes Marine Park (two colonies) (and along other parts of Australia's southern coast).[5]

[5] Identified as a relevant species through review of Biodiversity Conservation Act 2016 listed species for marine species without an EBPC Act listing.

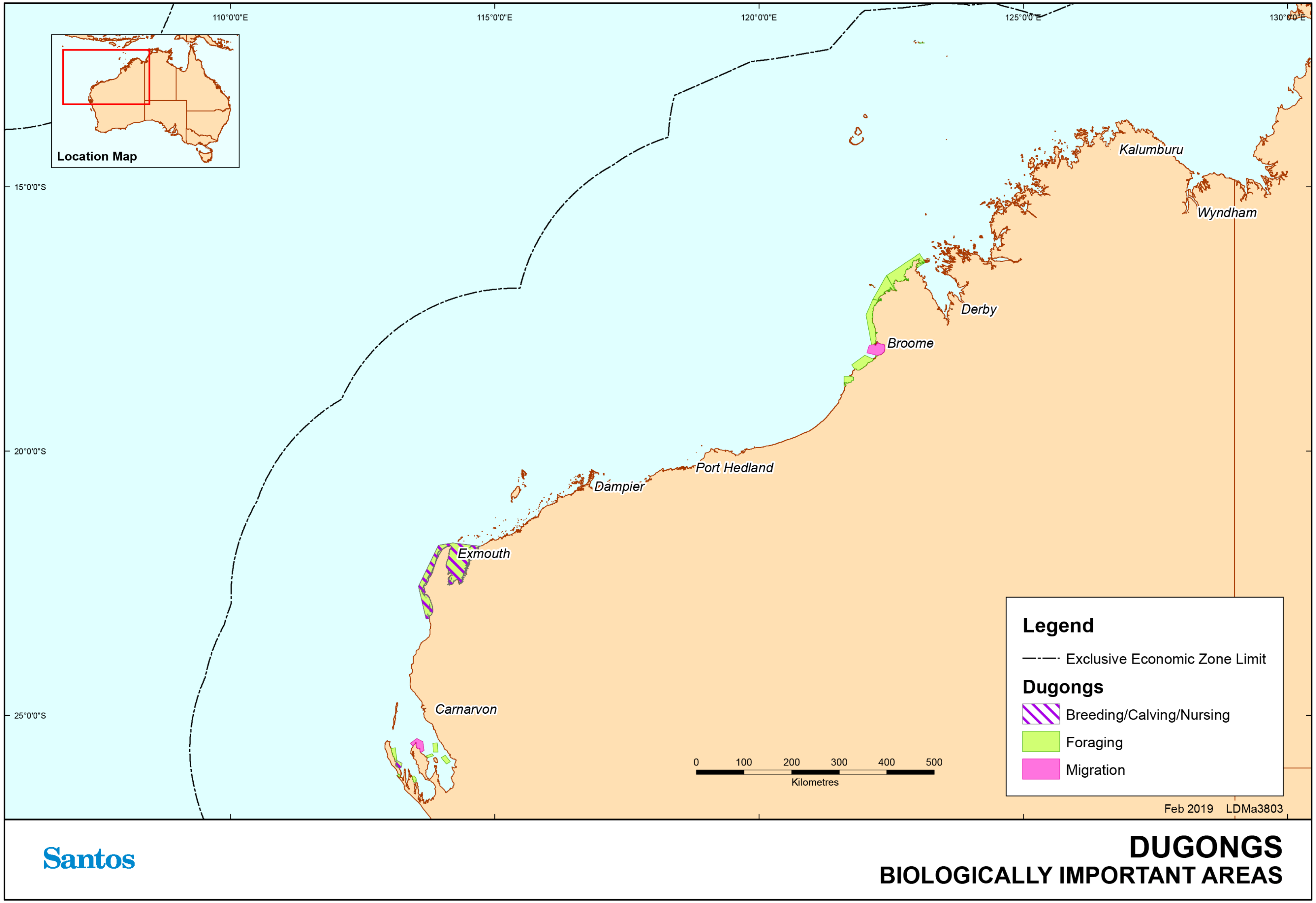

Figure 7-5: Biologically important areas – dugongs

Table 7-2: Summary of information for marine mammals listed as threatened under the EPBC Act

Aspect	Sei whale	Blue whale	Fin whale	Southern right whale	Humpback whale	Australian sea lion
Species expected in area	Unknown	Yes	Unknown	Unlikely, southern distribution	Yes	Unlikely, southern distribution
Migration depth (m)	Unknown, prefers offshore waters	500- 1,000	Unknown	n/a	Up to 100	n/a
Migration Seasonality	Unknown	Apr to Aug (north), Oct to Jan (south)	Unknown	n/a	Jun to Nov	n/a

7.2 Biologically Important Areas / Critical Habitat – Marine Mammals

Table 7-3 below provides an overview of BIAs in the area of interest for marine mammals

The DoEE may also make recovery plans for threated fauna listed under the EPBC Act. The EPBC Act requires that 'habitat critical to the survival of the listed threatened species' is identified in recovery plans, relevant recovery plans are listed in **Section 13.2**[6].

In addition, both the EPBC Act and WA Biodiversity Conservation Act 2016 and associated regulations (2018) provide for the listing of critical habitat - habitat 'critical to the survival of the threatened species'. To date no critical habitat in WA has been listed under either Act.

Table 7-3: Biologically important areas – marine mammals

Species	Scientific name	Aggregation area and use	Biologically important areas within area of interest
Blue and pygmy blue whales	*Balaenoptera musculus*	Migration – along the continental shelf edge off the WA coastline, extending offshore near Scott Reef and into Indonesian waters Foraging – along Ningaloo reef, around Scott Reef, around the Perth canyon	Blue and pygmy blue whale - Head of the Perth Canyon Outer continental shelf from Cape Naturaliste to south of Jurien Bay Outer Perth Canyon Pygmy blue whale - Augusta to Derby. Tend to pass along the shelf edge at depths of 500 m to 1000 m; appear close to coast in the Exmouth-Montebello Islands area on southern migration. From Mandurah to south of Cape Naturaliste, seaward to the 50 metre depth contour Indonesia- Banda SeaNingaloo Perth Canyon Scott Reef
Southern right whale	*Eubalena australis*	Breeding/calving – along the south west and southern coastline of WA/SA	Bunbury area, WA Camac Island/Fremantle, WA Coast Cape Naturaliste to Cape Leeuwin Coast Perth region to Cape Naturaliste Geographe Bay, WA Perth to Kangaroo Island
Humpback whale	*Megaptera novaeangliae*	Breeding/calving/nursing/resting – Campden Sound, Exmouth Gulf, Shark Bay Migration - northern migration deeper waters of the continental shelf, southward migration – along the WA mainland	Cape Leeuwin to Houtman Abrolhos Cape Naturaliste Cape Naturaliste to Cape Leeuwin Exmouth Gulf Flinders Bay Geographe Bay Houtman Abrolhos Islands Kimberley/Coastal North Lacepede Island, Camden Sound North of Houtman Abrolhos

[6] Further background information on BIA and identification of critical habitat in recovery plans is provided in Section 5.4

Species	Scientific name	Aggregation area and use	Biologically important areas within area of interest
			Shark Bay The migration corridor extends from the coast to out to approximately 100 km off shore in the Kimberley region extending south to North West Cape. From North West Cape to south of shark Bay the migration corridor is reduced to approximately 50 km. West coast - Lancelin to Kalbarri West coast- Bunbury to Lancelin including Rottnest Island
Sperm whale	*Physeter macrocephalus*	Foraging - west end of Perth Canyon	Western end of Perth canyon
Indo-Pacific humpback dolphin	*Sousa chinensis*	Breeding, calving, foraging – Kimberley coastal waters and islands Significant habitat – unknown behavior – Bougainville Peninsula Significant habitat - Vansittart Bay, Anjo Peninsula	Admiralty Gulf & Parry Harbour Bougainville Peninsula Camden Sound Area - Walcott Inlet, Doubtful Bay, Deception Bay, Augustus Island (Kuri Bay) Carnot & Beagle bay King Sound North and Yampi Sound and Talbot Bay Fjord area near Horizontal Falls King Sound Southern Sector Maret & Biggee Is. Pender bay Port Nelson, York Sound, Prince Frderick Harbour Prince Regent River Roebuck Bay Vansittart Bay, Anjo Peninsula Willie Creek
Indo-Pacific/spotted bottlenose dolphin	*Tursiops aduncus*	Breeding, calving, foraging – Kimberley coastal waters and islands Migration – Pender Bay	Camden Sound Area - Walcott Inlet, Doubtful Bay, Deception Bay, Augustus Island (Kuri Bay) King Sound North and Yampi Sound and Talbot Bay Fjord area near Horizontal Falls King Sound Southern Sector Pender bay Roebuck Bay
Irrawaddy dolphin (Australian snubfin dolphin)	*Orcella heinsohni*	Breeding, calving, foraging, resting– Kimberley coastal waters and islands	Admiralty Gulf & Parry Harbour Bougainville Peninsula Camden Sound Area - Walcott Inlet, Doubtful Bay, Deception Bay, Augustus Island (Kuri Bay) Cape Londonderry & King George River Carnot & Beagle bay King Sound North and Yampi Sound and Talbot Bay Fjord area near Horizontal Falls King Sound Southern Sector Maret & Biggee Is.

Species	Scientific name	Aggregation area and use	Biologically important areas within area of interest
			Ord River Pender bay Port Nelson, York Sound, Prince Frderick Harbour Prince Regent River Roebuck Bay Vansittart Bay, Anjo Peninsula Willie Creek
Australian sea lion	*Neophoca cinerea*	Foraging – male and female – Houtman Abrolhos Island, mid-west coast (more restricted spatial extent than males) Foraging – males Houtman Abrolhos Island, mid-west coast down to Perth Breeding – Buller Island, North Fisherman Island, Beagle Island, Albrolhos Island Haul Out Sites – North Cervantes Island, Sandland Island, Albrolhos Island	Houtman Abrolhos Islands Mid-west coast, includes Beagle Island, Fisherman Island, Jurien Bay, Cervantes and Buller Colonies
Dugong	*Dugong dugon*	Foraging –Dampier Peninsula, Roebuck Bay, Shark Bay, Exmouth and Ningaloo coastline Migration – Roebuck Bay Breeding/calving/nursing – Exmouth and the Ningaloo coastline	Ashmore Reef - Far West Ashmore Reef - South (located on sea reef side only, not interior) Between Peron Peninsula & Faure Island, Shark Bay Dirk Hartog Island, Shark Bay East of Faure Island, Shark Bay Exmouth Gulf Kimberley coast, Dampier Peninsula Middle Island, Kimberley coast North East Peron Peninsula, Shark Bay North of Faure Island, Shark Bay Pilbara and Kimberley coast near Dampier Peninsula Pilbara and Kimberley coast near James Price Point Roebuck Bay, Broome South Passage, Shark Bay Useless Loop, Shark Bay

8. Birds

Marine waters and coastal habitat in the area of interest contain key habitats that are important to birds, including offshore islands, sandy beaches, tidal flats, mangroves and coastal and pelagic waters. These habitats support a variety of birds which utilise the area in different ways and at different times of the year (DSEWPaC 2012a). Birds can be broadly grouped according to their preferred foraging habitat as coastal/ terrestrial birds, seabirds and shorebirds.

Coastal or terrestrial species inhabit the offshore islands and coastal areas of the mainland throughout the year. These species are either primarily terrestrial, or they may forage in coastal waters. Resident coastal and terrestrial species include osprey (*Pandion haliaetus*), white-bellied sea eagle (*Haliaeetus leucogaster*), silver gull (*Larus novaehollandiae*) and eastern reef egret (*Egreta sacra*) (DEWHA 2008).

Seabirds include those species whose primary habitat and food source is derived from pelagic waters. These species spend the majority of their lives at sea, ranging over large distances to forage over the open ocean. Seabirds present in the area include terns, noddies, petrels, shearwaters, tropicbirds, frigatebirds boobies and albatrosses (DEWHA 2008).

Shorebirds, including waders, inhabit the intertidal zone and adjacent areas. Some shorebird species, including oystercatchers are resident (Surman & Nicholson 2013). Other shorebirds are migratory and include species that utilise the East Asian–Australasian Flyway, a migratory pathway for millions of migratory shorebirds that travel from Northern Hemisphere breeding grounds to Southern Hemisphere resting and foraging areas. Shorebirds that regularly migrate through the area include the *Scolopacidae* (curlews, sandpipers etc.) and *Charadriidae* (plovers and lapwings) families.

Surveys in the area by Santos WA and other agencies have built a picture of diverse avifauna. A summary of research is discussed below, followed by information on threatened and migratory birds. Wetlands of international importance are discussed in **Section 9.2**.

8.1 Regional Surveys

8.1.1 Abrolhos Islands

The Abrolhos Islands are one of the most significant seabird nesting areas in the eastern Indian Ocean with over two million birds breed on the islands and small rocky atolls in the Abrolhos (DoF 2012). The mixture of species is unique, as subtropical and tropical species, and littoral and oceanic foragers, share the breeding islands. A total of 95 bird species have been recorded as residents or visitors to the Abrolhos Islands. Of these 35 species are known to breed at the Abrolhos (DoF, 2012):

- Common noddy (rookery – Pelseart Island): The Abrolhos supports 80 per cent of the Australian breeding population of the common noddy (Anous stolidus) with up to 250,000 common noddies breed at Pelsaert Island. These birds lay their eggs in spring, but the actual month can vary, depending on their food supply and the weather conditions existing in offshore waters (DoF 2012);
- Caspian tern (rookeries – Leo Island, West Wallabi Island and Pelsaert Island): Unlike other more social terns, Caspian terns (Hydroprogne caspia) are usually solitary nesters. There are less than 150 of these breeding at the Abrolhos, across 22 islands (DoF 2012);
- Wedge-tailed shearwaters (rookeries): The Abrolhos are the most important breeding sites in Australia for the wedge tailed shearwater (Ardenna pacifica), with between 500,000 and a million of these birds breeding there every year, predominantly on West Wallabi Island. The wedge-tailed shearwater breeding colonies at the Abrolhos are the largest in Australia (DoF 2012);
- Bridled tern (rookeries – Gun Island, Leo Island, Pelsaert Island, Little North Island, Fisherman Islands, Beagle Islands and Penguin Island): Bridled terns (Onychoprion anaethetus) breed on 90 islands throughout the Abrolhos. These birds fly north for the winter, through Indonesia to waters around the Phillippines. There are approximately 4,000 bridled terns who return to the Abrolhos around October every

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year to lay their eggs. Bridled terns nest on more islands in the Abrolhos than any other bird species (DoF, 2012);

- Osprey (nesting area – Pelseart Island): Up to 100 eastern ospreys (Pandion cristatus) nest at a number of sites throughout all three island groups at the Abrolhos, including nesting platforms made from converted rock lobster pots and stacked fishing equipment on jetties (DoF 2012);
- White-bellied sea eagle (nesting area – West Wallabi Island): At the Abrolhos, there are up to 50 breeding white-breasted sea eagles (Haliaeetus leucogaster), spread across all three island groups (DoF 2012);
- Australian lesser noddy (feeding area and rookeries Morley Island, Wooded Island and Pelseart Island): In Australia the Australian lesser noddy is only known to breed in this area and is known to forage between the islands and the continental shelf edge; and
- Other areas rookeries identified for both the wedge-tailed shearwater and bridled tern within the south west area include Lancelin Island, Rottnest Island and Safety Bay.

8.1.2 North West Cape

Avifauna surveys of the North West Cape have recorded 144 bird species, one third of which are seabirds and shorebirds (resident and migratory) (May *et al*. 1983). Approximately 33 species of seabirds and shorebirds are found in the Ningaloo Marine Park with the main breeding areas at Mangrove Bay, Mangrove Point, Point Maud, the Mildura wreck site and Fraser Island (CALM & MPRA 2005a).

8.1.3 Murion Islands and Exmouth Gulf Islands

Murion Islands and Exmouth Gulf Islands are generally lacking in published bird observations data. Early indications from surveys commissioned by Santos WA in 2013/14 indicate that South and North Murion Islands are regionally significant in terms of wedge-tailed shearwater (*Puffinus pacificus*) nesting, whilst Bessiers and Fly islands are also significant (Surman pers comm. 2013). Nine coastal/terrestrial species and 21 shorebirds were identified on the Murion and Exmouth Gulf Islands during the first of these surveys and seven bird species were recorded nesting (Surman 2013).

8.1.4 Dampier Archipelago/Cape Preston Region

The Dampier Archipelago/Cape Preston region is a nesting area for at least 16 species of seabirds. Many of the islands and rocks in the area are known breeding grounds for birds, including wedge-tailed shearwaters (*Puffinus pacificus*), Caspian terns (*Sterna caspia*), bridled terns (*Sterna anaethetus*) and roseate terns (*Sterna dougallii*). Small islands and islets such as Goodwyn Island, Keast Island and Nelson Rocks provide important undisturbed nesting and refuge sites and Keast Island provides one of the few nesting sites for pelicans in WA (CALM & MPRA 2005b).

8.1.5 Barrow Island and Lowendal Island Group

Barrow Island and surrounding islands have a diverse avifauna comprising at least 110 species, including 11 resident land birds, eight resident seabirds, 17 seabirds, 22 species of migratory waders, six resident shorebirds and 43 irregular visitors (Surman 2003). The avifauna of Barrow Island is thus poor in terms of land birds and waterfowl compared to mainland areas of the Pilbara, but rich in migratory waders and seabirds. Compared to other nearby offshore islands, Barrow Island has substantially more migratory waders but fewer breeding seabirds (Surman 2003).

The Lowendal Island Group has a diverse avifauna comprising 89 recorded species (Dinara Pty Ltd. 1991, Burbidge *et al*. 2000). Six species of resident land birds and six species of raptors have been recorded at the Lowendal Islands (Surman & Nicholson 2012). Up to fourteen seabird species have been observed at any one time during annual surveys of the Lowendal Islands between 2004 and 2012. Surveys at the Montebello Islands have recorded 70 bird species. This includes 12 species of seabirds and 14 species of migratory shorebirds (Burbidge *et al*. 2000).

8.1.6 Varanus, Airlie, Serrurier, Bridled, Abutilon, Beacon and Parakeelya Islands

Wedge-tailed shearwaters have been identified to nest on Varanus, Airlie, Serrurier and Bridled Islands (Astron 2017a). Breeding participation on the islands appears to be largely influenced by pre-breeding oceanographic conditions (Astron 2017a). Monitoring in 2016/17 was undertaken by Santos WA and demonstrated the colony sizes for wedgetailed shearwaters to be within or above previously reported ranges (Astron 2017a). This is informed though monitoring that has been undertaken under the Integrated Shearwater Monitoring Program (ISMP), established in 1994.

In 2016/17, areas of potential wedge-tailed shearwater nesting habitat were recorded on Varanus Island (5.53 ha) and Airlie Island (12.47 ha) and surrounding islands of Bridled (2.94 ha), Serrurier (130.89 ha), Abutilon (2.02 ha) and Parakeelya (1.66 ha) (Astron 2017a). The number of wedge-tailed shearwater breeding pairs was also estimated for each of Varanus (1,492 +/- 702), Airlie (600 +/- 124), Bridled (1,039 +/- 342), Serrurier (23,240 +/- 4,341), Abutilon (317 +/- 210) and Parakeelya (172 +/- 138) islands (Astron 2017a).

Other seabird species utilising Abutilon, Beacon, Bridled and Parakeelya islands for nesting include bridled terns, silver gulls, crested terns and lesser crested terns. Monitoring for these seabirds in 2016/17 was also completed by Santos WA , with monitoring results concluded to support previous trends for all species. Bridled terns mainly utilise Abutilon, Bridled and Parakeelya islands for breeding, with smaller numbers noted on Beacon and Varanus Islands. The bridled terns have not been recorded on Airlie Island and only in very small numbers on Varanus Island (Astron 2017b).

Silver gull numbers appear to be growing across the region (2010/2011). However, reasons for this are unknown but considered possibly to be due to greater prey availability or immigration from the mainland (Astron 2017b). Silver gulls have been found to utilise Bridled, Parakeelya, Abutilon and Beacon islands longer term for breeding. Silver gulls have not been identified to nest on Varanus island and were only recorded nesting on Airlie island for the first time in 2016/17 since monitoring commencement in 2004/05 (Astron 2017b).

The crested tern and lesser crested tern is noted as nomadic breeders that appear to use a consistent subset of islands for breeding. In 2016/17, Beacon Island was the favourable nesting site for the crested tern and lesser crested tern (Astron 2017b). Surveys in the vicinity of Port Hedland (Bennelongia 2011) recorded 23 species of migratory shorebird between 2002 and 2011. Terrestrial/coastal and seabird species were not targeted. A total of 4,248 migratory shorebirds of 18 species were observed during the field survey in April 2011.

8.2 Threatened Species

A Protected Matters search of the area of interest identified forty-five bird species (**Appendix A**) listed under the EPBC Act as threatened.

An examination of the species profile and threats database (DoEE 2017a) and The Action Plan for Australian Birds (Garnet 2011) showed that some listed bird species are not expected to occur in significant numbers in the marine and coastal environments in the area of interest due to their terrestrial or southern distributions. Hence, these species are not discussed further.

EPBC Act threatened species expected to occur in the area are listed in **Table 8-1** along with their WA conservation status (as applicable), and discussed below. BIAs for birds are detailed in **Table 8-5** and depicted in **Figure 8-1** and **Figure 8-2**.

Table 8-1: Birds listed as threatened under the EPBC Act

Scientific Name **Common Name**	**Conservation Status** *Biodiversity Conservation Act 2016*	**Environmental Protection and Biodiversity Conservation Act 1999**	**Likelihood of occurrence in area of interest**	**Biologically important area in area of interest**
Shorebirds				
Calidris canutus Red knot	Endangered	Endangered	Species or species habitat known to occur within area	None - No BIA defined
Calidris ferruginea Curlew sandpiper	Critically endangered	Critically endangered	Species or species habitat known to occur within area	None - No BIA defined
Calidris tenuirostris Great knot	Critically endangered	Critically endangered	Roosting known to occur within area	None - No BIA defined
Charadrius leschenaultia Greater sand plover	Specially protected (migratory)	Vulnerable	Roosting known to occur within area	None - No BIA defined
Charadrius mongolus Lesser sand plover	Endangered	Endangered	Roosting known to occur within area	None - No BIA defined
Limosa lapponica baueri Western Alaskan bar-tailed godwit	Vulnerable	Vulnerable	Species or species habitat known to occur within area	None - No BIA defined
Limosa lapponica menzbieri Northern Siberian bar-tailed godwit	Critically endangered	Critically endangered	Species or species habitat known to occur within area	None - No BIA defined
Numenius madagascariensis Eastern curlew	Critically endangered	Critically endangered	Species or species habitat known to occur within area	None - No BIA defined
Botaurus poiciloptilus Australasian bittern	Endangered	Endangered	Species or species habitat known to occur within area	None - No BIA defined
Rostratula australis Australian painted snipe	Endangered	Endangered	Species or species habitat may occur within area	None - No BIA defined
Seabirds				
Anous tenuirostris melanops Australian lesser noddy	Endangered	Vulnerable	Breeding known to occur within area	Yes – refer to **Table 8-5**
Pachyptila tutur subantarctica Fairy piron (southern)	-	Vulnerable	Species or species habitat known to occur within area	None - No BIA defined
Diomedea epomophora Southern royal albatross	Specially protected (migratory)	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	None - No BIA defined

Scientific Name **Common Name**	Conservation Status		Likelihood of occurrence in area of interest	Biologically important area in area of interest
	Biodiversity Conservation Act 2016	**Environmental Protection and Biodiversity Conservation Act 1999**		
Diomedea sanfordi Northern royal albatross	Endangered	Endangered	Foraging, feeding or related behaviour likely to occur within area	None - No BIA defined
Diomedea amsterdamensis Amsterdam albatross	Critically endangered	Endangered	Species or species habitat may occur within area	None - No BIA defined
Phoebetria fusca Sooty Albatross	Endangered	Vulnerable	Species or species habitat may occur within area	None - No BIA defined
Diomedea dabbenea Tristan albatross	Critically endangered	Endangered	Species or species habitat may occur within area	None - No BIA defined
Diomedea exulans Wandering albatross	Specially protected (migratory)	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	None - BIA not found in area of interest
Fregata andrewsi Christmas island frigatebird	Specially protected (migratory)	Endangered	Foraging, feeding or related behaviour known to occur within area	None - No BIA defined
Macronectes giganteus Southern giant petrel	Specially protected (migratory)	Endangered	Species or species habitat may occur within area	None - BIA not found in area of interest
Macronectes halli Northern giant petrel	Specially protected (migratory)	Vulnerable	Species or species habitat may occur within area	None - BIA not found in area of interest
Papasula abbotti Abbott's booby	-	Endangered	Species or species habitat likely to occur within area	None - No BIA defined
Pterodroma mollis Soft-plumaged petrel	-	Vulnerable	Foraging, feeding or related behaviour known to occur within area	Yes – refer to **Table 8-5**
Halobaena caerulea Blue Petrel	-	Vulnerable	Species or species habitat may occur within area	None - No BIA defined
Sternula nereis Australian fairy tern	Vulnerable	Vulnerable	Breeding known to occur within area	Yes – refer to **Table 8-5**
Thalassarche carteri Indian yellow-nosed albatross	Specially protected (migratory)	Vulnerable	Foraging, feeding or related behaviour may occur within area	Yes – refer to **Table 8-5**
Thalassarche cauta Shy albatross	Endangered	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	None - BIA not found in area of interest

Scientific Name Common Name	Conservation Status		Likelihood of occurrence in area of interest	Biologically important area in area of interest
	Biodiversity Conservation Act 2016	Environmental Protection and Biodiversity Conservation Act 1999		
Thalassarche cauta steadi White-capped albatross	Specially protected (migratory)	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	None - BIA not found in area of interest
Thalassarche melanophris Black-browed albatross	Endangered	Vulnerable	Species or species habitat may occur within area	None - BIA not found in area of interest
Thalassarche impavida Campbell albatross	Specially protected (migratory)	Vulnerable	Species or species habitat may occur within area	None - BIA not found in area of interest
Phaethon lepturus fulvus Christmas Island white-tailed tropicbird	-	Endangered	Species or species habitat may occur within area	None - No BIA defined

8.2.1 Shorebirds

Red Knot (New Siberian Islands and north-eastern Siberia)

The red knot is a migratory shorebird and the species includes five subspecies, including two found in Australia, Calidris canutus piersmai and Calidris canutus rogersi. The red knot breeds in Siberia and spends the non-breeding season in Australia and New Zealand. Non breeding season is spent on tidal mudflats or sandflats where they feed on intertidal invertebrates, especially shellfish (Garnet et al. 2011).

Curlew Sandpiper

This species is a migratory shorebird that breeds in north Siberia and spends the non-breeding season from western Africa to Australia (Bamford et al. 2008). The curlew sandpiper occurs around coastal Australia and preferred habitats include coastal brackish lagoons, tidal mud and sand flats, estuaries, saltmarshes and less often inland. Their diet is mainly comprised of polychaete worms, molluscs and crustaceans (Higgins & Davies 1996 in Garnet et al. 2011).

Great Knot

The great knot is a migratory shorebird with a global distribution, breeding in north-east Siberia and spending the non-breeding season along coasts from Arabia to Australia. Non breeding birds migrate to inlets, bays, harbours, estuaries and lagoons with large intertidal mud and sand flats where they feed on bivalves, gastropods, crustaceans and other invertebrates (Higgins & Davies 1996 in Garnet et al. 2011).

Greater Sand Plover and Lesser Sand Plover

The greater sand plover and lesser sand plover are cogeners that breed in China, Mongolia and Russia. The greater sand plover spends the non-breeding season along coasts from Japan through southeast Asia to Australasia, while the lesser sand plover spends the non-breeding season along coasts from Taiwan to Australasia (Banford *et al*. 2008). Non breeding birds occur along all Australian coasts, especially in the north for the greater sand plover (DoEE 2017a) and in the east for the lesser sand plover (DoEE 2017a).

Non breeding birds forage on beaches, salt-marshes, coastal bays and estuaries, and feed on marine invertebrates including molluscs, worms, crustaceans and insects (Marchant & Higgins 1993 in Garnet *et al*. 2011).

Bar-tailed Godwit (Western Alaskan and Northern Siberian Subspecies)

Two subspecies of the bar-tailed godwit exist, as determined by their breeding locations in Siberia and Alaska (Bamford *et al*. 2008). Non-breeding birds migrate to the coasts of Australia. The western Alaskan subspecies occurs especially on the north and east coasts of Australia whilst the northern Siberian subspecies occurs especially along the coasts of north Western Australia (DoEE 2017b).

Non breeding birds are found on muddy coastlines, estuaries, inlets, mangrove-fringed lagoons and sheltered bays, feeding on annelids, bivalves and crustaceans (Higgins and Davies 1996 in Garnet *et al*. 2011).

Eastern Curlew

The eastern curlew is a migratory shorebird that breeds in Siberia, Kamchatka and Mongolia and migrates to coastal East Asia and Australia. The South Korean Yellow Sea is an important staging post for this species. Non breeding birds occur around coastal Australia, are more common in the north and have disappeared or become much rarer at many sites along the south coast (Garnet 2011).

Non breeding birds are present at estuaries, mangroves, saltmarshes and intertidal flats, particularly those with extensive seagrass (Zosteraceae), where they feed on marine invertebrates, especially crabs and small molluscs (Higgins & Davies 1996 in Garnet 2011).

Australian Painted Snipe

The Australian painted snipe has been recorded at wetlands in all states of Australia (DoE 2014g). The Australian painted snipe generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. They also use inundated or waterlogged grassland or saltmarsh, dams, rice crops, sewage farms and bore drains. Typical sites include those with rank emergent tussocks of grass, sedges, rushes or reeds, or samphire; often with scattered clumps of lignum Muehlenbeckia or canegrass or sometimes tea-tree (*Melaleuca*). The Australian painted snipe sometimes utilises areas that are lined with trees, or that have some scattered fallen or washed-up timber (DoE 2014g).

Australasian Bittern

The Australasian bittern is found in coastal and sub-coastal areas of south-eastern and south-western mainland Australia and the eastern marshes of Tasmania (Birdlife Australia 2017). The specie lives predominantly in reedbeds and other water vegetation. Feeding on other small animals, insects, snails and spiders the bittern forages at night. Breeding occurs during summer from October to January.

8.2.2 Seabirds

Australian Lesser Noddy

This species is usually found only around its breeding islands in the Houtman Abrolhos Islands in Western Australia (Storr *et al*. 1986). The Australian lesser noddy occupies coral-limestone islands that are densely fringed with white mangrove *Avicennia marina*, and it occasionally occurs on shingle or sandy beaches (Higgins & Davies 1996 in DoEE 2017a). This species is thought to be sedentary or resident, staying near to its breeding islands in the non-breeding season. It may leave nesting islands for short periods during the non-breeding season, and probably forages widely (Higgins & Davies 1996 in DoEE 2017a).

Breeding apparently occurs only on Morley, Wooded and Pelsaert Islands at the Houtman Abrolhos Islands (Higgins and Davies 1996 in DoE 2014b). Mangrove stands support approximately 68,000 breeding pairs spread over the three islands (Surman & Nicholson 2006). Breeding may also occur on Ashmore Reef (Stokes & Hinchey 1990). The breeding season extends from mid-August to early April (Higgins & Davies 1996 in DoE 2014b).

The National Conservation Values Atlas identifies BIAs for this species in the area of the Houtman Abrolhos islands (**Table 8-5**). The National Recovery Plan for Ten Species of Seabirds 2005-2010 (DEH 2005) states that Ashmore Island could possibly be important habitat, however the Species Group Report Card – Seabirds (DSEWPaC 2012b) states that the entire Australian population of this species breeds in the South-west Marine Region, south of Busselton.

Albatrosses

A Protected Matters search of the waters in the area of interest (**Appendix A**) identified several albatross species that may occur in the area, comprised of the southern royal albatross, northern royal albatross, Amsterdam albatross, Tristan albatross, sooty albatross, wandering albatross, Indian yellow-nosed albatross, shy albatross, white-capped albatross, black-browed albatross and Campbell albatross. All these species predominantly occur in subantarctic to subtropical waters and breed on islands in the southern oceans (DoEE 2017a).

The National Conservation Values Atlas (DoEE 2017b) and the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016 (DSEWPaC 2011) do not identify any BIAs for these species in the area from Busselton to the Northern Territory border. However, a BIA for the Indian yellow-nosed albatross is identified for foraging north to Shark bay and extending east into Bass Strait.

Christmas Island Frigatebird

The Christmas Island frigatebird is a very large seabird. Breeding colonies of the Christmas Island frigatebird is currently confined to Christmas Island in the Indian Ocean (DoE 2014c). No breeding colonies have ever been found away from Christmas Island.

Southern Giant Petrel

The southern giant petrel is a highly migratory bird with a large natural range. This species occurs from Antarctic to subtropical waters and breeds on the Antarctic continent, peninsular and islands and on subantarctic islands and South America. Breeding occurs annually between August and March (DoEE 2017a).

The National Conservation Values Atlas (DoEE 2017b) and the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016 (DSEWPaC 2011) do not identify any BIAs for this species in the area from Busselton to the Northern Territory border.

Northern Giant Petrel

The northern giant petrel occupies the Antarctic Polar Front. In summer, it occurs predominantly in sub-Antarctic to Antarctic waters, usually between 40 and 64° The northern giant-petrel breeds on sub-Antarctic islands. Its breeding range extends into the Antarctic zone at South Georgia. It nests in coastal areas where vegetation or broken terrain offers shelter, on sea-facing slopes, headlands, in the lee of banks, under or against vegetation clumps, below cliffs or overhanging rocks, or in hollows. On Campbell Island, it nests on the edge of the coastal plateau. Tussock-grass is widespread at many breeding sites. Its nests are built in secluded, coastal sites, sheltered by heavy vegetation. On Antipodes Island, it nests under *Senecio antipoda* (DoE 2014d).

The National Conservation Values Atlas (DoEE 2017b) does not identify any BIAs for this species in area spanning SW WA to the Northern Territory border.

Soft-Plumaged Petrel

The soft-plumaged petrel is generally found over temperate and subantarctic waters in the South Atlantic, Southern Indian and western South Pacific Oceans. The species breeds colonially on islands in the southern oceans. Breeding occurs from August to May (Marchant & Higgins 1990 in DoEE 2017a).

A BIA for this species is identified for foraging in seas north to 21°30’S off of WA.

Blue Petrel

The blue petrel is marine species of the Sub Antarctic and Antarctic seas. In summer, it occurs mainly over waters of -2 to 2° C in surface temperature, but it also ranges south to the edge of the pack-ice and north to approximately 30° south, or further north over cool currents (DoE 2014e). In the Antarctic, it generally avoids the pack-ice, and only occasionally approaches the edge of the ice. Given the location of the area of interest, this species is unlikely to occur.

The National Conservation Values Atlas (DoEE 2017b) does not identify any BIAs for this species in area spanning SW WA to the Northern Territory border.

Abbott’s Booby

Currently, Abbott's booby is only known to breed on Christmas Island and to forage in the waters surrounding the island (DoE 2014f). Within Christmas Island, most nests are found in the tall plateau forest on the central and western areas of the island, and in the upper terrace forest of the northern coast.

The National Conservation Values Atlas (DoEE 2017b) does not identify any BIAs for this species in area spanning SW WA to the Northern Territory border.

Australian Fairy Tern

The fairy tern is distributed in a large geographic range between Australia, New Zealand and New Caledonia. Three subspecies have been identified, one of which is found in Australia. The Australian fairy tern occurs along the coasts of Victoria, Tasmania, South Australia and Western Australia; occurring as far north as the Dampier Archipelago (DoEE 2017a). The subspecies has been found in embayments of a variety of habitats including offshore, estuarine or lacustrine islands, wetlands and mainland coastline (Higgins & Davies 1996 in DoE 2014b, Lindsey 1986).

Australian fairy terns nest on sheltered sandy beaches, spits and banks above the high tide line and below vegetation. The Australian fairy tern breeds from August to February depending on the location of the breeding colony (Higgins & Davies 1996 in DoEE 2017a). They generally nest in small colonies of up to 100 birds, although larger colonies of more than 1400 pairs have been reported in Western Australia (Hill *et al*. 1988).

The National Conservation Values Atlas (DoEE 2017b) identifies the vicinity of the lower north-west coast (north to Dampier Archipelago) and west coast (south to Peel inlet) as BIAs for foraging. Biologically important breeding areas were also identified scattered along the coast between Shark Bay and the Pilbara (**Table 8-5**).

Christmas Island White-tailed Tropicbird

The Christmas Island white-tailed tropicbird is endemic to Christmas Island and leaves the island to forage in the warm waters of the Indian Ocean (Garnett 2011). The white-tailed tropicbird roots at sea; only incubating or brooding adults remain on nests on the island at night (Stokes 1988).

The National Conservation Values Atlas (DoEE 2017b) does not identify any BIAs for this species within the area of interest.

Fairy Piron (southern)

The fairy piron is distributed off the cold-water coasts of Antarctica and southern Australia and New Zealand. The southern subspecies is known to breed on Macquarie Island, Langdon Point, Davis Point and Bishop and Clerk islands (Garnett & Crowley 2000). It is estimated that the population of the fairy piron (southern) is a little over 50 pairs (Brothers 1984).

The National Conservation Values Atlas (DoEE 2017b) does not identify any BIAs for this species within the area of interest.

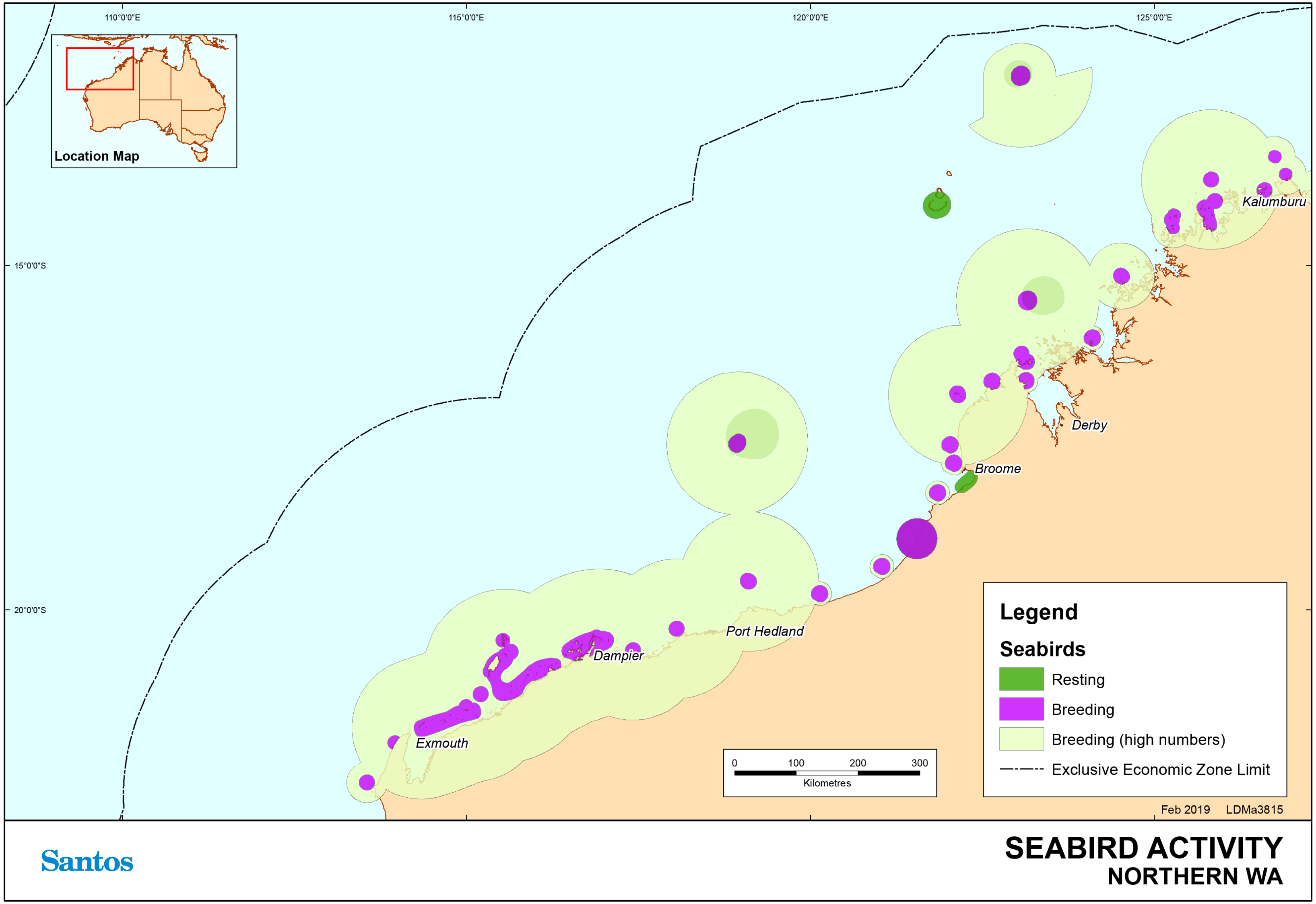

Figure 8-1: Biological important areas – birds – Northern WA

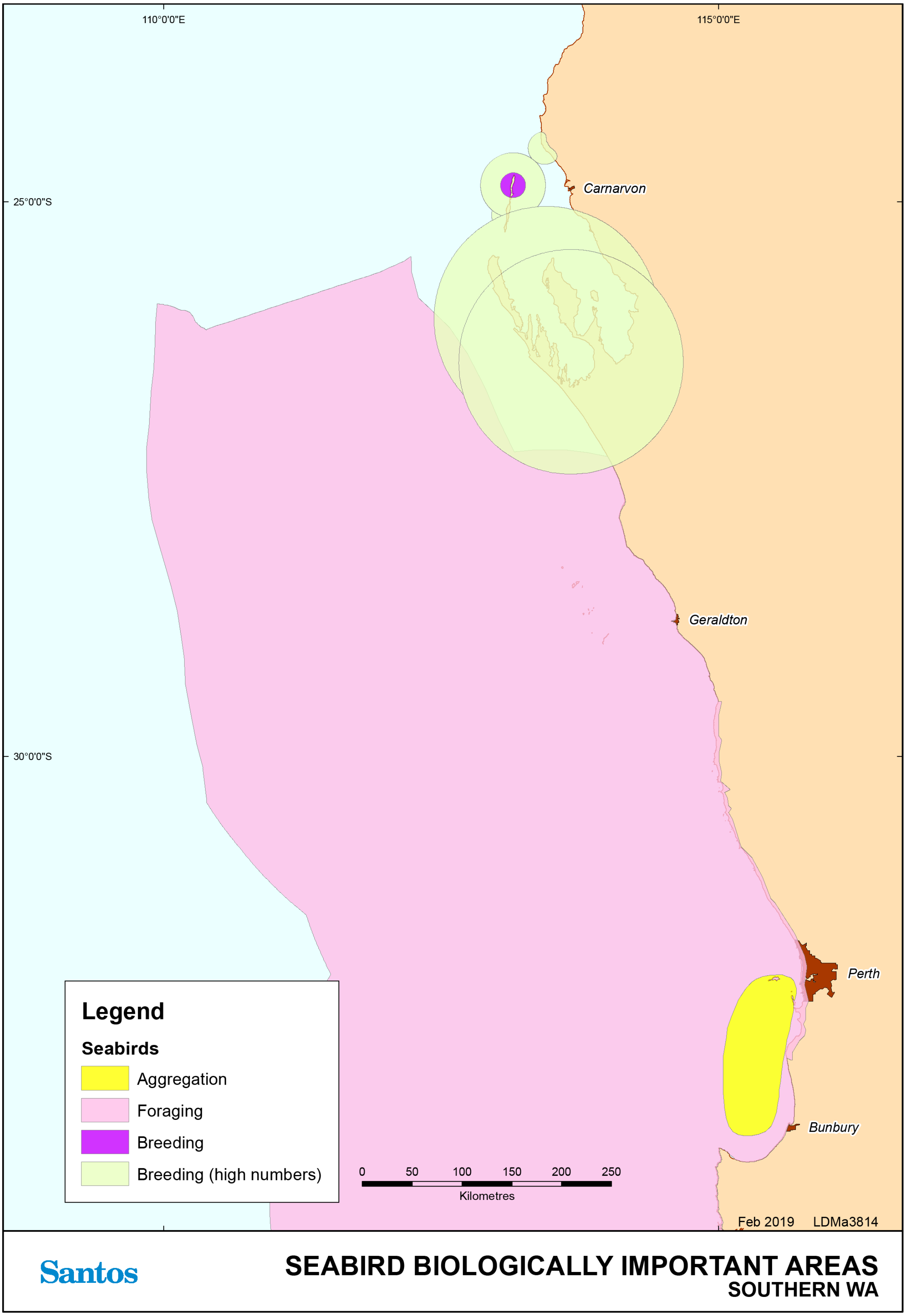

Figure 8-2: Biologically important areas – birds – Southern WA

Santos

Table 8-2: Summary of information for birds listed as threatened under the EPBC Act that may be in the area of interest.

Species	Species Expected in Area of Interest	Breeding in the Area /Seasonality	Foraging
Shorebirds			
Red knot	Yes	No	Intertidal invertebrates
Curlew sandpiper	Yes	No	Polychaete worms, molluscs and crustaceans taken from shorelines
Great knot	Yes	No	bivalves, gastropods, crustaceans and other invertebrates taken from shorelines
Greater sand plover/lesser sand plover	Yes	No	marine invertebrates taken from shorelines
Bar-tailed godwit	Yes	No	annelids, bivalves and crustaceans taken from shorelines
Eastern curlew	Yes	No	marine invertebrates associated with seagrass
Australasian bittern	Yes	No	other small animals, insects, snails and spiders
Australian painted snipe	Yes	No	Seeds and small invertebrates
Seabirds			
Australian lesser noddy	May forage from Kalbarri to Shark Bay	No	Small fish taken from marine and coastal waters (DoE 2014b)
Albatross spp.	Low densities	No	Cephalopods, fish and crustaceans taken from marine and coastal waters.
Southern & Northern giant petrel	Low densities	No	Scavenges penguin, seal and whale carcasses. Hunts live birds, penguin chicks' cephalopods and krill. Marine and coastal waters (DoE 2014b)
Soft-plumaged petrel	Low densities	No	Cephalopods, fish and crustaceans taken from marine and coastal waters (DoE 2014b)
Australian fairy tern	Yes	Yes Aug to Feb	Bait fish taken from coastal waters
Fairy piron (southern)	Very low densities	No	Small pelagic crustaceans, small fish and squid
Christmas Island frigatebird	Low densities	No	Planktonic crustaceans, fish and squid
Abbott's booby	Low densities	No	Fish and squid
Blue petrel	Low densities	No	Crustaceans, small fish and squid
Christmas Island white-tailed tropicbird	Very low densities	No	Squid and flying fish

8.3 Migratory Species

Australia is signatory to three international treaties with China, Japan and the Republic of Korea to safeguard migratory bird species, predominantly shorebirds. To facilitate observance of the three agreements, 36 species of migratory shorebirds have been listed as specially protected under both the Commonwealth EPBC Act and the WA *Biodiversity Conservation Act 2016.*

Three internationally recognised areas that support shorebird migrations are protected as wetlands of international importance; Ashmore Reef, Eighty-mile Beach and Roebuck Bay. These wetlands are discussed further in **Section 9.2**.

The EPBC Act policy statement 3.21 sets out criteria for determining the significance of sites to migratory shorebirds based on the number of migratory species and the proportion of a species population that is supported by the site (DEWHA 2009). Site significance can be difficult to assess, particularly for ephemeral inland wetlands. These areas may be used rarely, depending weather conditions, but still provide important habitat for migratory shorebird species.

Migratory shorebirds require a particular conservation approach due to their migration patterns that take them across international boundaries (Bamford *et al*. 2008). These species and their habitats are sensitive to threats due to their high site fidelity, tendency to aggregate, high energy demands and the need for habitat networks containing both roosting and foraging sites (DEWHA 2009). Migratory shorebirds are known to use networks of connected sites (also known as site complexes). They move within these networks depending on the time of day, availability of resources and environmental conditions at the site (DEWHA 2009).

The types of habitat used by migratory shorebirds in Australia vary across the species identified in the PMST search. Migratory shorebirds use both coastal and inland habitats that most commonly include:

+ Coastal habitats: coastal wetlands, estuaries, mudflats, rocky inlets, reefs and sandy beaches, sometimes supporting mangroves; and
+ Inland habitats: inland wetlands, floodplains and grassland areas, often with ephemeral water sources (DEWHA 2009).

Feeding guilds provide an explanation for much of the shorebird distribution pattern in the north Western Australia. For example, Rogers (1999) classified shorebirds (and others) in Roebuck Bay as belonging to seven guilds on the basis of prey choice and foraging method. In order of abundance; these are summarised in **Table** 8-3.

Table 8-3: Feeding guilds based on prey choice and foraging method (Rogers 1999) adapted from DEC (2003) and Bennelongia (2008)

Feeding Habitat	Feeding Guild	Species
Sea edge	tactile hunters of macrobenthos	Great knot, red knot, bar-tailed godwit, black-tailed godwit, Asian dowitcher
Along sandy sea edges or near tidal creeks	tactile hunters of microbenthos	Curlew sandpiper, red-necked stint, broad-billed sandpiper, marsh sandpiper, sharp-tailed sandpiper
Reefs or mangrove fringes	visual hunters of slow surface-dwelling prey	Common sandpiper, sooty oystercatcher, pied oystercatcher, silver gull, ruddy turnstone
Sandier western parts of Roebuck Bay, often near-shore	visual hunters of small fast prey	Grey plover, red-capped plover, greater sand plover, lesser sand plover, grey-tailed tattler, terek sandpiper
Soft mudflats in N.E. Roebuck Bay	visual hunters of fast large prey	Eastern curlew, whimbrel, greenshank, striated heron and black-necked stork
Soft mudflats in N.E. Roebuck Bay	kleptoparasites	Gull-billed tern (robs large crabs from whimbrels)

Creek-lines in eastern Roebuck Bay	pelagic hunters of nekton (animals of the pelagic zone) and neuston (animals that live on the surface film)	Black-winged stilt, red-necked avocet, reef egret, little egret, great white egret, white-faced heron, royal spoonbill

The Wildlife Conservation Plan (DoE, 2015) for Migratory Shorebirds provides a framework to guide the conservation of migratory shorebirds and their habitat in Australia and, in recognition of their migratory habits, outlines national activities to support their appreciation and conservation throughout the East Asian-Australasian Flyway (EAAF).

The following migratory shorebird species are subject to the Wildlife Conservation Plan 2015.

Table 8-4: Birds subject to the Wildlife Conservation Plan 2015.

Migratory Species	DoEE SPRAT information on distribution within the Area of Interest
Common Sandpiper	WA distribution • Roebuck Bay • Nuytsland Nature Reserve
Sharp-Tailed Sandpiper	They are widespread from Cape Arid to Carnarvon, around coastal and subcoastal plains of Pilbara Region to south-west and east Kimberley Division (Higgins & Davies 1996).
Oriental Practincole	Internationally important site • Eighty Mile Beach (2.88m birds). The species occurs at numerous and widespread sites in northern Australia, especially near the Pilbara and Kimberley coasts of northern Western Australia.
Oriental Plover	Internationally important marine sites • Eighty Mile Beach (~60,000 birds). • Roebuck Bay (Approximately 8500 birds)
Fork-tailed swift	In Western Australia, there are sparsely scattered records of the Fork-tailed Swift along the south coast, ranging from near the Eyre Bird Observatory and west to Denmark. They are widespread in coastal and subcoastal areas between Augusta and Carnarvon, including some on nearshore and offshore islands. They are scattered along the coast from south-west Pilbara to the north and east Kimberley region, near Wyndham. There are sparsely scattered inland records, especially in the Wheatbelt, from Lake Annean and Wittenoom. They are found in the north and north-west Gascoyne Region, north through much of the Pilbara Region, and the south and east Kimberley (Higgins 1999).
Streaked Shearwater	Exmouth Gulf to the north.

Shorebird migration patterns are seasonal and vary according to species (DSEWPaC 2012). Generally, shorebirds migrate to northern Australia in August to November. Many birds remain in northern Australia but others disperse southwards (Bennelongia 2011). Migratory shorebird numbers on northern beaches peak in November then again in March as the majority of birds begin their return to the northern hemisphere between March and May. Most migratory shorebirds don't breed in Australia and juvenile birds may spend several years in Australia before reaching maturity and returning north to breed (DEWHA 2009).

8.4 Biologically Important Areas / Critical Habitat – Birds

Table 8-5 below provides an overview of BIAs in the area of interest for birds. The DoEE may make recovery plans for threated fauna listed under the EPBC Act. The EPBC Act requires that 'habitat critical to the survival of the listed threatened species' is identified in recovery plans, relevant recovery plans are listed in **Section 13.2**[7].

[7] Further background information on BIA and identification of critical habitat in recovery plans is provided in Section 5.4

In addition, both the EPBC Act and WA Biodiversity Conservation Act 2016 and associated regulations (2018) provide for the listing of critical habitat - habitat 'critical to the survival of the threatened species'. To date no critical habitat in WA has been listed under either Act.

Table 8-5: Biologically important areas - birds

Species	Scientific name	Aggregation area and use	Specific geographic locations for species
Common noddy	*Anous stolidus*	Foraging	Around Houtman Abrolhos Around Lancelin Island
Australian lesser noddy	*Anous tenuirostris melanops*	Foraging - Houtman Abrolhos Islands	Houtman Abrolhos Islands
Flesh footed shearwater	*Ardenna carneipes*	Foraging, aggregation (pre-migration) - Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef	Foraging from Cape Naturaliste to Eyre, 1-150 km offshore. Pre departure zone in some years from Rottnest Island to Bunbury.
Wedge-tailed shearwater	*Ardenna pacifica*	Breeding, foraging – west coast from Ashmore Reef to Carnac I. Kimberley, Pilbara, Gascoyne coasts, Ashmore reef	Breeding (in hundreds of thousands) off west coast from Ashmore Reef (12º15'S) to Carnac I. (32º07'S), and ranging in western seas between 12º00'S and 33º20'S. Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef
Little penguin	*Eudyptula minor*	Foraging - Perth to Bunbury	Perth to Bunbury
Lesser frigatebird	*Fregata ariel*	Breeding, foraging – Kimberley and Pilbara coasts and islands also Ashmore Reef.	Kimberley and Pilbara coasts and islands also Ashmore Reef.
Greater frigatebird	*Fregata minor*	Breeding, foraging - Kimberley and Ashmore Reef	Kimberley and Ashmore Reef
Caspian tern	*Sterna caspia*	Foraging - mainly islands (as far offshore as Adele, Bedout, Trimouille and the Houtman Abrolhos)	In Western Australia found on most coasts, mainly islands (as far offshore as Adele, Bedout, Trimouille and the Houtman Abrolhos) and at Lake Argyle, Lake Gregory and Lake MacLeod; accidental elsewhere in the interior.
Pacific gull	*Larus pacificus*	Foraging –west coast and islands	West coast and islands from Point Quobba (24º30'S) south to Wedge I. (formerly south to Warnbro Sound and at Cape Naturaliste); casual further north (Point Cloates and Lake MacLeod).
Bridled tern	*Sterna anaethetus*	Foraging - West coast of Western Australia and around to Recherche Archipelago	West coast of Western Australia and around to Recherche Archipelago including offshore waters
Sooty tern	*Sterna fuscata*	Foraging – Timor sea	Timor Sea S to 14º30, off NW coast from Lacepede I SW to 117ºE inc Abrolhos, Fisherman & Lancelin Is, accidental on lower west coast to Hamelin Bay. Breeding visitor (late Aug - early May) Abrolhos &

Species	Scientific name	Aggregation area and use	Specific geographic locations for species
			Lancelin Is; casual winter (Nov - Apr) to Fisherman
White-tailed tropic bird	*Phaethon lepturus*	Breeding, foraging - Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef	Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef
Great-winged petrel	*Pterodroma macroptera*	Foraging - Offshore south of Shark Bay	Offshore south of Shark Bay, extending around south-west corner of WA and east past Kangaroo Island
Soft plumage petrel	*Pterodroma mollis*	Foraging - seas north to 21°30'S	In WA found in seas north to 21°30'S.
Little shearwater	*Puffinus assimilis*	Foraging - From Kalbarri to Eucla	From Kalbarri to Eucla including offshore waters
Roseate tern	*Sterna dougallii*	Breeding, foraging – Islands and coastline in the Kimberley, Pilbara and Gascoyne regions Resting – Eighty Mile Beach	Eighty Mile Beach (northern end) Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef Low Rocks and Stern Island in Admiralty Gulf North-east and North-west Twin Islets near the mouth of King sound North-western and west coasts and islands from Sir Graham Moore Is (13°50'S), south to Mandurah (32°32'S) and as far offshore as Ashmore Reef, Bedout I. and the Houtman Abrolhos.
Little tern	*Sternula albifrons*	Breeding, foraging, resting - Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef Resting - Roebuck Bay	Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef Roebuck Bay Ramsar site
Australian fairy tern	*Sternula nereis*	Foraging – Kimberley, Pilbara and Gascoyne coasts and islands	Found in the vicinity of lower north-west coast (north to Dampier Archipelago), west coast (south to Peel Inlet) and south coast (from Flinders Bay east to Israelite Bay), including islands (as far offshore as Trimouille I. and Houtman Abrolhos. Pilbara and Gascoyne coasts and islands
Brown Booby	*Sula leucogaster*	Breeding, foraging - Kimberley and northern Pilbara coasts and islands also Ashmore Reef.	Kimberley and northern Pilbara coasts and islands also Ashmore Reef.
Red-footed Booby	*Sula sula*	Breeding, foraging - north west Kimberley and Ashmore reef	North west Kimberley and Ashmore reef
Indian Yellow-nosed Albatross	*Thalassarche carteri*	Foraging - south-west marine region, north to Shark Bay and extending east into Bass Strait	Throughout offshore waters of south-west marine region, north to Shark Bay and extending east into Bass Strait

Species	Scientific name	Aggregation area and use	Specific geographic locations for species
Lesser crested tern	*Sterna bengalensis*	Breeding, foraging - Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef	Kimberley, Pilbara and Gascoyne coasts and islands including Ashmore Reef

9. Protected Areas

A number of areas in the area of interest are protected under state and federal legislation. Protected areas include World Heritage Areas (WHAs), Wetlands of International Importance (Ramsar), Wetlands of National Importance, National and Commonwealth Heritage Places, and terrestrial conservation reserves (National Parks, Nature Reserves and Conservation Parks) that bound marine waters. These areas are listed in **Table 9-1**, and shown in **Figure 9-1**, **Figure** 9-2 and **Figure 9-3**, and discussed below. Other protected areas include Key Ecological Features (discussed in **Section 10**) and State and Commonwealth Marine Parks/Reserves (discussed in **Section 11** and **Section 12**). A Protected Matters search of the area of interest (**Appendix A**) identified several protected areas which were deemed to be irrelevant to Santos WA's petroleum activities due to their terrestrial location (e.g. Forrestdale and Thomsons Lakes – Ramsar wetland).

The Register of the National Estate (RNE) provides a listing of more than 13,000 natural, historic and indigenous sites of significance. However, in 2012 all references to the RNE were removed from the EPBC Act and the *Australian Heritage Council Act 2003*.The RNE is now maintained on a non-statutory basis as a publicly available archive and educational resource. A protected matters search of the area from the South Australian border to the Northern Territory border listed 197 places on the RNE, although it is recognised that not all indigenous sites may be listed (**Appendix A**). The RNE places are not discussed further here but are listed in **Appendix A**.

Table 9-1: Summary of protected areas in waters within the area of interest

Area type	Title
World Heritage Area	Shark Bay
	The Ningaloo Coast
Wetland of International Importance (Ramsar)	Eighty Mile Beach
	Roebuck Bay
	Ashmore Reef National Nature Reserve
	Becher Point
	Peel-Yalgorup System
	Vasse-Wonnerup System
Wetlands of National Importance	Ashmore Reef
	Mermaid Reef
	Vasse-Wonnerup Wetland System
National Heritage Place	HMAS Sydney II and HSK Kormoran Shipwreck Sites
	Batavia Shipwreck Site and Survivor Camps Area 1629- Houtman Abrolhos
	The West Kimberley
	The Ningaloo Coast
	Shark Bay
Commonwealth Heritage Place	HMAS Sydney II and HSK Kormoral Shipwreck Sites
	Ningaloo Marine Area - Commonwealth Waters
	Mermaid Reef - Rowley Shoals
	Ashmore Reef National Nature Reserve
	Scott Reef and Surrounds – Commonwealth Area
	Garden Island

Area type	Title
Threatened Ecological Communities	Monsoon Vine Thickets on the ridge on the coastal sand dunes of Dampier Peninsula
	Roebuck Bay mudflats
Terrestrial Conservation Reserves e.g. national parks, nature reserves, and conservation parks.	Numerous bounding marine waters – refer to **Section 9.6**.

9.1 World Heritage Areas

There are two World Heritage Areas (WHAs) located in marine waters of WA, both of which occur in the waters from the South Australian border to the Northern Territory border: the Ningaloo Coast and Shark Bay (DEC 2012).

9.1.1 Shark Bay

Shark Bay was included on the World Heritage List in 1991 and is one of the few properties inscribed for all four outstanding natural universal values:

+ An outstanding example representing the major stages in the earth's evolutionary history;
+ An outstanding example representing significant ongoing ecological and biological processes;
+ An example of superlative natural phenomena; and
+ Containing important and significant habitats for in situ conservation of biological diversity.

Since 1997, an agreement established the joint management of the Shark Bay WHA by the Australian Commonwealth government and the Western Australian state government, with the operational responsibility by the Western Australian agencies (DEWHA 2008). This agreement also created a Community Consultative Committee and a Scientific Advisory Committee, both of which provide advice as required. The entire WHA encompasses islands and peninsulas, with an area of approximately 2.2 million hectares (70% of which is marine waters), and includes the following areas (UNESCO 2014):

+ Hamelin Pool Marine Nature Reserve;
+ Francois Peron National Park;
+ Shell Beach Conservation Park;
+ Monkey Mia Reserve;
+ Monkey Mia Conservation Park;
+ Zuytdorp Nature Reserve;
+ Bernier, Dorre and Koks Islands Nature Reserves;
+ Dirk Hartog Island National Park; and
+ Various pastoral leases.

The marine environment of the Shark Bay WHA is protected as a State Marine Reserve and is discussed further in **Section 11.1.3**.

9.1.2 The Ningaloo Coast

The Ningaloo Coast was included on the World Heritage List in 2011 and was inscribed for outstanding natural universal values as follows:

- An example of superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance;
- outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features; and
- the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

The Ningaloo Coast WHA includes (DEWHA 2010):

- Ningaloo Marine Park (Commonwealth waters);
- Ningaloo Marine Park (Western Australia state waters);
- Muiron Island Marine Management Area (including the Muiron Islands);
- Jurabi Coastal Park;
- Bundegi Coastal Park;
- Cape Range National Park; and
- Learmonth Air Weapons Range.

The Ningaloo Coast World Heritage Area (including the Murion Islands) is managed under a plan that is consistent with the World Heritage Convention and Australia's World Heritage management principles. World Heritage Management principles are set out in regulations and cover matters relevant to the preparation of management plans, the environmental assessment of actions that may affect the property and community consultation processes.

The Australian World Heritage management principles are outlined under Schedule 5 of the EPBC regulations (2000). The objective is to ensure that any likely impact of an action on the World Heritage values of the property should be considered. Any action should be consistent with the protection, conservation, presentation or transmission to future generations of the World Heritage values of the property.

The marine environment of the Ningaloo Coast WHA is protected as a State Marine Park, a Commonwealth Marine Park, and is discussed further in **Section 11.1.4** and **Section 12.3.4**, respectively.

9.2 Wetlands of International Importance (Ramsar)

There are nine wetlands of international importance (Ramsar wetlands) in waters from the South Australian border to the Northern Territory border; all were listed in 1990 with the exception of Becher Point which was listed in 2001 and the dales which was listed in 2002. The Ashmore Reef National Nature Reserve (listed in 2002) is also a Commonwealth Marine Park and is discussed further in **Section 12.3.12.**

9.2.1 Eighty Mile Beach

The Eighty Mile Beach Ramsar site comprises a 220 km beach between Port Hedland and Broome with extensive intertidal mudflats and Mandora Salt Marsh, located 40 km east (Hale & Butcher 2009) totalling 175,487 ha. Eighty Mile Beach is characterised by extensive mudflats supporting an abundance of macroinvertebrates which provide food for large numbers of shorebirds.

Eighty Mile Beach is one of the most important sites for migratory shorebirds in the East Asian Australasian Flyway, with 42 migratory shorebird species recorded at this location. It is estimated that 500,000 shorebirds use Eighty Mile Beach as a migration terminus annually (Hale and Butcher 2009), and more than 472,000 migratory waders have been counted on the mudflats during the September to November period. The location of Eighty Mile Beach makes it a primary staging area for many migratory shorebirds on their way to and from Alaska and eastern Siberia (Hale & Butcher 2009). Although many birds move further on their journey, others remain at the site for the non-breeding period.

Eighty-mile Beach supports more than one per cent of the flyway population (or one per cent of the Australian population for resident species) of 21 waterbirds, including 17 migratory species and four Australian residents. It is one of the most important sites in the world for the migration of Great Knot.

Eighty Mile Beach also supports a high diversity and abundance of wetland birds. A total of 97 wetland bird species have been recorded within the beach portion of the Ramsar site (Hale & Butcher 2009). This includes 42 species that are listed under international migratory agreements CAMBA (38), JAMBA (38) and ROKAMBA (32) as well as an additional 22 Australian species that are listed under the EPBC Act. In addition, there is a single record for Nordmann's Greenshank (*Tringa guttifer*) from the beach, which is listed as endangered under the IUCN Red List.

The Mandora Salt Marsh area contains an important and rare group of wetlands (Lake Walyarta and East Lake), including raised peat bogs, a series of small permanent mound springs and the most inland occurrence of mangroves in WA (Hale & Butcher 2009). A small number of tidal creeks dissect the beach, including Salt Creek which is fed partly from groundwater and has permanent surface water. The Mandora Salt Marsh lakes fill predominantly from rainfall and runoff in the wet season then dry back to clay beds. The mound springs likely come from water deep within the Broome sandstone aquifer rising through fractures in the rock, and resulting in permanent mostly freshwater surface water. Flatback turtles (*Natator depressus*), listed as vulnerable under the EPBC Act, regularly nest at scattered locations along Eighty Mile Beach.

Eighty Mile Beach is used for beach based recreation, including four-wheel driving, motorcycling, fishing and shell collecting. Mandora Salt Marsh is mainly used for cattle grazing. The site is traditionally part of Karajarri Country in the north, Nyangumarta Country in the south and Ngarla Country in the southern end of Eighty Mile Beach. The site has artefacts such as middens, pinka (large baler shells used to scoop and carry water for drinking), wilura (used for sharpening spear heads), axes, and flakes, and kurtanyanu and jungari (grinding stones).

9.2.2 Roebuck Bay

The Roebuck Bay Ramsar site is located at Roebuck Bay near Broome in northern WA totalling 34,119 ha. Roebuck Bay has a large tidal range which exposes around 160 km^2 of mudflat, covering most of the Ramsar site (DoE 2014c). Waters more than 6 m deep at low tide are excluded from the site (Bennelongia 2009). The eastern edge of the site is made up of microscale linear tidal creeks (DoE 2014c).

The intertidal mud and sand flats support a high abundance of bottom dwelling invertebrates (between 300—500 benthic invertebrate species), which are a key food source for waterbirds (Bennelongia 2009). The site is one of the most important migration stopover areas for shorebirds in Australia and globally. For many shorebirds, Roebuck Bay is the first Australian landfall they reach on the East Asian Australasian Flyway. The total numbers of waders using the site each year is estimated at over 300,000 (DoE 2014c). The northern beaches and Bush Point provide important high tide roost sites.

The site receives tidal seawater as well as fresh surface and groundwater, and the balance between the two influences the residual groundwater salinity and the distribution of plants and animals (DoE 2014c). Mangrove swamps line the eastern and southern edges of the site, and extend up into the linear tidal creeks (DoE 2014c). They are important nursery areas for marine fishes and crustaceans, particularly prawns.

Extensive seagrass beds occur in the bay, providing an important feeding ground for dugongs and loggerhead and green turtles (Bennelongia 2009). Flatback turtles nest in small numbers, while marine fish (including sawfish) regularly breed in the tidal creeks and mangroves. Dolphins also regularly use the site (DoE 2014c).

The site is used for recreational or tourism activities such as fishing, crabbing, sightseeing and bird watching. Broome Bird Observatory, a small reserve at the northern end of the site, engages in shorebird research and public education.

Roebuck Bay lies in the traditional estate of Indigenous people belonging to both Jukun and Yawuru groups. The site was an important area for seasonal meetings, exchanging gifts, arranging marriages and settling disputes. Numerous shellfish middens, marking former camping places, can still be seen along coastal cliffs and dunes. Indigenous people continue to make extensive use of Roebuck Bay's natural resources for activities such as gathering shellfish, fishing and hunting.

9.2.3 Ashmore Reef National Nature Reserve

In addition to being listed as a National Nature Reserve, Ashmore Reef has been designated a Ramsar Wetland of International Importance due to the importance of the islands in providing a resting place for migratory shorebirds and supporting large breeding colonies of seabirds (Hale and Butcher, 2013). The reserve provides a staging point for many migratory wading birds from October to November and March to April as part of the migration between Australia and the northern hemisphere (Commonwealth of Australia, 2002). Migratory shorebirds use the reserve's islands and sand cays as feeding and resting areas during their migration.

Ashmore is the largest of the atolls in the Timor Province bioregion. The three islands within the site are also the only vegetated islands in the bioregion. Each of the wetland types present are in near natural condition and the site has the largest seagrass coverage in the bioregion. The reserve supports 64 species of internationally and nationally threatened species. This includes 41 species of hard reef forming coral, eight fish, six reptiles (including endangered and critically endangered sea turtles and seasnakes), five sea cucumbers, two giant clams, one soft coral and the dugong.

Ashmore Reef plays a primary role in the maintenance of biodiversity in reef systems in the region. The Reserve supports 275 species of reef building coral, 13 species of sea cucumbers, and high numbers of mollusc species. There are over 760 fish species, 13 species of sea snake, 99 species of decapod crustacean and 47 species of waterbird listed as migratory under international treaties. It supports breeding of 20 species of waterbirds including the brown booby, lesser frigatebird, crested tern, bridled tern, sooty tern and common noddy. The Ramsar site is also important for feeding for green turtles, hawksbill turtle and loggerhead turtle and critical nesting and inter-nesting habitats for green and hawksbill turtles.

Ashmore Reef regularly supports more than 20,000 waterbirds and has been known to support more than 65,000 waterbirds. The Ramsar site regularly supports more than one per cent of at least six species of waterbird including the sooty tern, bar-tailed godwit, grey-tailed tattler, ruddy turnstone, sanderling and greater sand plover.

9.2.4 Becher Point

The Becher Point Wetlands Ramsar site is a system of about sixty small wetlands located near Rockingham in south-west Western Australia and covers 677 ha. The wetlands are made up of chains of small, linear ovoid or irregular shaped basins arranged in five groups, each roughly parallel to the coast and separated by sand ridges (DoE 2014l). The wetlands are an example of shrub swamps and seasonal marshes that have formed in an extensive sequence of inter-dunal depressions that have arisen from seaward advancement of the coastline over recent millennia.

The wetlands in the site are shallow and fill seasonally. Rainfall in winter and spring recharges the groundwater, which rise up to waterlog the wetland basins. The wetlands then dry out again for summer to autumn. When flooded the wetlands are mainly freshwater (DoE 2014l).

The wetlands support sedgelands, herblands, grasslands, open-shrublands and low open-forests. The sedgelands that occur within the linear wetland depressions of the Ramsar site are a nationally listed threatened ecological community. At least four species of amphibians and 21 species of reptiles have been recorded within the wetlands, as well as the Southern Brown Bandicoot (DoE 2014l).

9.2.5 Peel-Yalgorup System

The Peel-Yalgorup System located adjacent to the city of Mandurah in Western Australia, is a large and diverse system of shallow estuaries, coastal saline lakes and freshwater marshes. The site includes the Peel Inlet, Harvey Estuary, Lake McLarty, Lake Mealup and ten Yalgorup National Park wetlands and covers an area of 26, 530 ha (DoE 2014m). Lake Clifton, which is part of the wetlands is one of the few locations in the word where thrombolites occur in inland, hyposaline waters. Thrombalites are underwater rock-like structures that are formed by the activities of microbial communities.

The Peel-Yalgorup System Ramsar site is the most important area for waterbirds in south-western Australia, supporting in excess of 20,000 waterbirds annually (DoE 2014m). It also supports a wide variety of invertebrates and estuarine and marine fish.

9.2.6 Vasse-Wonnerup System

The Vasse-Wonnerup System Ramsar wetland is situated in the Perth Basin, south-western Western Australia and covers an area of 1115 ha. It is an extensive, shallow, nutrient-enriched wetland system of highly varied salinities. The site is located on a narrow, flat plain separated from the ocean by a narrow system of low dunes. The system is comprised of two former estuaries – the Vasse and Wonnerup lagoons (DoE 2014n).

The system supports tens of thousands of resident and migrant waterbirds of a wide variety of species. More than 33,000 waterbirds have been counted at the Vasse-Wonnerup System and more than 80 species have been recorded in the System including Red-necked Avocets and Black-winged Stilts, Wood Sandpiper, Sharp tailed Sandpiper, Long-toed Stint, Curlew Sandpiper and Common Greenshank (DoE 2014n).

9.3 Wetlands of National Importance

9.3.1 Ashmore Reef

See the Ashmore Reef National Nature Reserve (**Section 9.2.3**) and Ashmore Reef Marine Park (**Section 12.3.12**).

9.3.2 Mermaid Reef

See the Mermaid Reef Marine Park (**Section 12.3.9**).

9.3.3 Vasse-Wonnerup Wetland System

See the Vasse-Wonnerup Wetland System (**Section 9.2.6**).

9.4 National Heritage Places

Natural, historic and indigenous places that are of outstanding heritage value to the Australian nation are recorded as National Heritage Places. Eleven National Heritage Places are found in waters from the South Australian border to the Northern Territory border. Shark Bay and The Ningaloo Coast are listed as both World Heritage Areas and National Heritage Places, and are discussed in **Section 9.1**.

9.4.1 HMAS Sydney II and HSK Kormoran Shipwreck Sites

The naval battle fought in 1941 between the Australian warship HMAS Sydney II and the German commerce raider HSK Kormoran off the Western Australian coast during World War II was a defining event in Australia’s cultural history. The loss of HMAS Sydney II, along with its entire crew of 645 following the battle with HSK Kormoran, remains Australia’s worst naval disaster (DoE 2014d).

The shipwreck sites are comprised of two areas located approximately 290 km west-southwest of Carnarvon. The shipwrecks of the HMAS Sydney II and HSK Kormoran are located on the seabed approximately 22 km apart (DoE 2014d).

9.4.2 Batavia Shipwreck site

The Batavia was included on the National Heritage List in 2006. This shipwreck is the oldest of the known Verenigde Oost-Indische Compagnie (VOC) wrecks on the WA coast and has a unique place in Australian shipwrecks. Because of its relatively undisturbed nature the archaeological investigation of the wreck itself has revealed a range of objects of considerable value to the artefact specialist and historian. The recovered sections of the hull of the Bataviathat have been reconstructed in the Western Australian Maritime Museum and provides information on 17th century Dutch ship building techniques, while the remains of the cargo carried by the vessel have provided economic, and social evidence of the operation of the Dutch port at Batavia (now Jakarta) in the early 17th century (DoE 2014d).

9.4.3 The West Kimberley

The West Kimberley was included on the National Heritage List in 2011 and has numerous values which contribute to the significance of the property, including indigenous, historic, aesthetic, cultural and natural heritage values (DoE 2014d). Of these values, the most relevant to the marine environment is Roebuck Bay as a migratory hub for shorebirds. These values are discussed in **Section 9.2.2**. The area is characterised by a diversity of landscapes and biological richness found in its cliffs, headlands, sandy beaches, rivers, waterfalls and islands.

9.4.4 The Ningaloo Coast

See the Ningaloo Coast World Heritage Area (**Section 9.1.2**).

9.4.5 Shark Bay

See Shark Bay World Heritage Area (**Section 9.1.1**).

9.5 Commonwealth Heritage Places

The Commonwealth Heritage Places List comprises natural, indigenous and historic heritage places which are either entirely within a Commonwealth area, or outside the Australian jurisdiction and owned or leased by the Commonwealth or a Commonwealth Authority. Nine natural Commonwealth Heritage Places are found in or adjacent to the area of interest. Three of these places (Ashmore Reef, Mermaid Reef and the Ningaloo Marine Area – Commonwealth Waters) are found in Marine Parks and are discussed further in **Section 12**. The HMAS Sydney II and HSK Kormoran Shipwreck Sites is listed under both National and Commonwealth Heritage Lists and discussed in **Section 9.4.1**.

9.5.1 Scott Reef and Surrounds – Commonwealth Area

Scott Reef is a large, emergent shelf atoll located on the edge of the broad continental shelf, about 300 km from mainland north-western Australia. The listing comprises the areas of Scott Reef that are within Commonwealth waters to the 50 m BSL bathymetric contour. This includes North Reef, an annular reef, 16.3 km long and 14.4 km wide; and parts of the lagoon of South Reef, a crescent shaped reef 17 km across (DoE 2014d).

The place is regionally significant both because of its high representation of species not found in coastal waters off Western Australia and for the unusual nature of its fauna which has affinities with the oceanic reef habitats of the Indo-West Pacific as well as the reefs of the Indonesian region (DoE 2014d).

9.5.2 Mermaid Reef – Rowley Shoals

See the Mermaid Reef Marine Park (**Section 12.3.9**).

9.5.3 Ningaloo Marine Area – Commonwealth Waters

See the Ningaloo Coast World Heritage Area (**Section 9.1.2**).

9.5.4 Ashmore Reef National Nature Reserve

See the Ashmore Reef Marine Park (**Section 12.3.12**).

9.5.5 Garden Island

Garden Island is located to the south of Perth, 5 km northwest of Rockingham. It was registered in 2004 based on vaeioua fauna, geological, European and Aboriginal heritage and vegetation values. It was the original first site occupied by Governors Stirling's Party in 1829, with prior use by Aborigines and the French (being called Ile de Buache by the French in 1801). The island is virtually free from widespread feral animal colonisation, providing important habitat for various species that have reduced on the mainland. The island provides breeding habitat for bridled tern (*Sterna anaethetus*), rainbow bee-eaters (*Merops ornatus*) and osprey (*Pandion haliaetus*), which nest on the rocks surrounding the island. Important feeding habitat for the Sanderling (*Calidris alba*) is provided by sandy beaches on the west coast of the island.

The island provides nesting habitat on beaches for the breeding migrant fairy tern (*Sterna nereis*), which requires undisturbed nesting periods. The mature relatively undisturbed heath, scrub and low forest communities unburnt since the 1920's in the northern section of the island are especially important as a reference site for natural history. The least disturbed examples of calcaronite reef structures dune and tamate landscapes in the metropolitan region are present on the western side of the island (DoEE 2016b).

9.6 Coastal Terrestrial Conservations Reserves – bound by marine waters

Conservation reserves are created under the Land Administration Act 1997, and once reserved and set aside for conservation purposes are regulated under the Conservation and Land Management Act (CALM) 1984. Most conservation reserves in WA are vested in (owned) by the WA Conservation and Parks Commission, an independent statutory body established by the CALM Act 1984, and most are managed by the Department of Biodiversity Parks Conservation and Attractions – Parks and Wildlife Service.

In WA there are three main types of terrestrial conservation reserves with legislative protection:

+ Nature reserves – established for wildlife and landscape conservation; scientific study; and preservation of features of archaeological, historic or scientific interest
+ National parks – as above but also to be used for enjoyment by the public. Have national or international significance
+ Conservation parks – as above but have local or regional significance.

Nature reserves can have an extra classification applied to them and become 'A class' reserves, which generally require an Act of Parliament to alter.

There are numerous terrestrial conservation reserves located adjacent to the coast in the area of interest. The oceanward boundary of the reserves varies. In some cases, the reserves extend to the low water mark, i.e. including the inter-tidal zone (particularly applicable to older gazetted reserves and terrestrial reserves not surrounded by a marine reserve). While in other cases, the terrestrial reserves extend to the high-water mark e.g. Lowendal Islands Nature Reserve (particularly applicable to terrestrial reserves adjacent to more recently gazetted marine parks). In other cases, the seaward boundary of the reserves is not defined. Management plans also contain the caveat for further consideration of the most appropriate tenure for intertidal areas and management arrangements.

Further information on coastal terrestrial reserves is provided below in **Section 9.6.1** (national parks) and **Section 9.6.2** (nature reserves and conservations parks).

9.6.1 Coastal National Parks

Protected coastal national parks managed under the CALM Act 1984 in the area of interest are listed in **Table 9-2**. The table also includes: any applicable management plan; whether the park includes the inter-tidal area; and the name of any adjacent state marine reserve. All National Parks are WA Class A reserves and IUCN Class 2.

Table 9-2: Coastal National Parks – coastal boundary in relation to inter-tidal zone

National Park	IBRA Bioregion[8]	Management Plan	Includes inter-tidal zone	Adjacent Marine Management Park (see Section 11)
Reserves of Northern WA (see Figure 9-4)				
Lawley River		-	No [9]	Kimberley Marine Park

[8] The Interim Biogeograhic Regionalisation for Australia (IBRA) classifies Australia's landscapes into large geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information (DoEE 2012).

Mitchell River	Northern Kimberley	-		
Prince Regent	Northern Kimberley	-		
Reserves of North-West WA (see Figure 9-5)				
Murujuja	Pilbara	Murujuga National Park management plan 78 (DEC 2013)	Yes [10]	-
Cape Range	Carnarvon	Cape Range National Park Management Plan (DEC 2010)	No	Ningaloo Marine Park
Reserves of Southern WA – (see Figure 9-6)				
Francois Peron	Carnarvon	Shark Bay Terrestrial Reserves and Proposed Reserve Additions Management Plan (2012)	No	Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve
Dirk Hartog	Yalgoo	Shark Bay Terrestrial Reserves and Proposed Reserve Additions Management Plan (2012)	Yes – intertidal zone on western side of Dirk Hartog is included (as no marine park on western side of island)	Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve
Kalbarri	Geraldton Sandplains	Kalbarri National Park Management Plan (DPAW 2015)	Yes [10]	-
Namburg	Geraldton Sandplains	Namburg National Park Management Plan (1998)	Yes	-
Yalgorup	Swan Coastal Plain	Yalgorup National Park Management Plan (CALM 1995)	Yes [10]	-
Leeuwin - Naturaliste	Warren	Leeuwin-Naturaliste Capes Area Parks and Reserves Management Plan (DPAW 2015)	No	Ngari Capes Marine Park

9.6.2 Coastal Nature Reserves and Conservation Parks

Protected coastal nature reserves and conservation parks managed under the CALM Act 1984 in the area of interest are listed in **Table 9-3** and shown in **Figure 9-4**, **Figure 9-5** and **Figure 9-6** for the north, north-west and south of WA respectively. The table also includes: reserve class; IUCN classification; any applicable management plan; whether the reserve includes the inter-tidal area; and the name of any adjacent state marine reserve (may also describe inter-tidal areas values).

The CALM Act does not require management plans to be in place for conservation reserves at all time, instead they are required to be made as is reasonably practicable regarding resources. This means some conservation reserves do not have a management plan, or do not have a recent management plan.

Table 9-3: Nature Reserves (NR) and Conservation Parks (CP) in area of interest

Reserve Name and Type	Reserve Class (WA)	IUCN	Management Plan	Includes inter-tidal zone	Adjacent Marine Park (see Section 11)
Reserves of Northern WA (see Figure 9-4)					
Ord River NR	-	1a	-	No [9]	North Kimberley Marine Park
Pelican Island NR	-	1a			
Leseur Island NR	A	1a			
Low Rocks NR	A	1a			
Browse Island NR	A	1a	-	Yes [10]	-
Scott Reef	-	1a	-	Yes [10]	-
Adele Island NR	A	1a	-	Yes [10]	-
Tanner Island NR	A	1a	-	Yes [10]	-
Lacepede Islands NR		1a	-	Yes [10]	-
Colomb Point NR	A	1a	-	Yes [10]	-
Yawaru Birragun CP; Yawuru Northern Intertidal Area	- & A	2 & 6	Yawaru Birragun Conservation Park Management Plan (DPAW 2016). *Yawuru Intertidal Area management plan is not yet available*.	Yes	-
Jinmarnkur CP	C	-	Parks and reserves of the south-west Kimberley and north-west Pilbara Draft Management Plan (DPAE 2016). *Covers 80 Milebeach coastal reserves*.	No	Eighty Mile Beach Marine Park
Jinmarnkur Kulja NR	A	-			
Kujungurru Warrarn NR	A	1a			
Kujungurru Warrarn CP	C	-			
Unamed	A	-			
Jarrkunpungu NR	A				
Bedout Island NR	A	1a	-	Yes [10]	-
North Turtle Island NR	A	1a	-	Yes [10]	-
Reserves of North-West WA (see Figure 9-5)					
Unnamed (Dampier Archipelago) NR	A	1a	Dampier Achipelago Management Plan (CALM 1990). *Covers 25 of the islands*	Yes	-
Unamed NR		1a	-	Yes [10]	-
North Sandy Island NR	A	1a	-	Yes [10]	-

[9] Inferred as adjacent marine park boundary is the high water mark and dual tenure cannot exist.

[10] Conservatively inferred as no adjacent marine park

Reserve Name and Type	Reserve Class (WA)	IUCN	Management Plan	Includes inter-tidal zone	Adjacent Marine Park (see Section 11)
Montebello Islands CP	A	2	-	Partially [11]	Montebello Islands Marine Park
Lowendal Island NR		1a	-	No	Barrow Island Marine Management Area and Marine Park. Lowendal Island NR only partially bounded
Barrow Island NR	A	1a	Barrow Island Group Nature Reserves (DPAW 2015)	Yes	
Boodie, Double and Middle Islands NR	-	1a		Yes	
Great Sandy Island NR	B	1a	-	Yes	Barrow Island Marine Management Area
Weld Island NR	-	1a	-	Yes [10]	-
Little Rocky Island NR	A	1a	-	Yes [10]	-
Airlie Island NR	-	1a	-	Yes [10]	-
Thevenard Island Nature	-	1a	-	Yes [10]	-
Bessieres Island NR Reserve	A	1a	-	Yes [10]	-
Serruier Island NR	-	1a	-	Yes [10]	-
Round Island NR	-	1a	-	Yes [10]	-
Locker Island	A	1a	-	Yes [10]	-
Rocky Island NR	-	1a	-	Yes [10]	-
Gnardaroo Island NR	A	1a	-	Yes [10]	-
Victor Island NR	-	1a	-	Yes [10]	-
Y Island NR	-	1a	-	Yes [10]	-
Tent Island NR	-	1a	-	Yes [10]	-
Burnside and Simpson Island NR	-	1a	-	Yes [10]	-
Whalebone Island NR		1a	-	Yes [10]	-
Whitmore, Roberts, Doole Islands & Sandalwood Landing NR	-	1a	-	Yes [10]	-
Muiron Islands NR	-	1a	Jarabi and Bundegi Coastal Parks and Muiron Islands (CALM 1999)	No [9]	Murion Islands Marine Management Area
OneTree Point NR	A	1a	-	Yes [10]	
Reserves of Southern WA – (see Figure 9-6)					
Koks Island NR	A	1a		Yes [10]	-

[11] Reserve R42197 includes the inter-tidal zone and reserve R42196 does not.

Reserve Name and Type	Reserve Class (WA)	IUCN	Management Plan	Includes inter-tidal zone	Adjacent Marine Park (see Section 11)
Bernier And Dorre Islands NR	A	4	Shark Bay Terrestrial Reserves and Proposed Reserve Additions Management Plan (DPAW 2012)		
Shell Beach CP	-	3		No	Shark Bay Marine Park
Freycinet, Double Islands Etc NR	A	1a	-		Shark Bay Marine Park
Zuytdorp NR	-	1a		Yes [10]	-
Beekeepers NR	-	1a	-	Yes [10]	-
Beagle Islands NR	A	1a	Turquoise Coast Nature Reserve Management Plan (CALM 2004).	Yes	-
Lipfert, Milligan, etc Islands NR	A	1a			-
Fisherman Islands NR	A	1a	*Covers chain of approximately 40 protected islands lying between Lancelin and Dongara.*		Jurien Bay Marine Park: extends from Greenhead south to Wedge Island
Sandland Islands NR	A	1a			
Boullanger, Whitlock, Favourite, Tern and Osprey Islands NR	A	1a			
Escape Island NR	A	1a			
Essex Rocks NR	A	1a			
Outer Rocks NR	A	1a			
Ronsard Rocks NR	A	1a			
Cervantes Islands NR	A	1a			
Buller, Whittell and Green Islands NR	A	1a			
Wedge Island NR	A	1a			
Lancelin and Edwards Islands NR	A	1a			-
Southern Beekeeper's NR	-	1a	Namburg National Park Management Plan (CALM 1998)	No	-
Wanagarren NR	-	1a		Yes	
Nilgen NR	-	1a		Yes	
Unnamed CP (R 49994) west of Wilbinga	-	2		Yes [10]	-
Unnamed CR (R 42469) at Woodman Point	-	-	Woodman Park Regional Park Management Plan (DEC 2010)	No	-
Unnamed CP at Woodman Point (R 49220)	-	2		No	-
Carnac Island	A	1a	Carnac Island Nature Reserve Management Plan (CALM 2003)	Yes	-
Penguin Island CP	A	3		No	

Reserve Name and Type	Reserve Class (WA)	IUCN	Management Plan	Includes inter-tidal zone	Adjacent Marine Park (see Section 11)
Shoalwater Islands NR	A	1a	Shoalwater Islands Management Plan (CALM 2002)	Yes	Shoalwater Islands Marine Park
Port Kennedy Scientific Park	A	1a	Rockingham Lakes Regional Park (DEC 2015)	No	-
Leschenault Peninsula CP	A	2	Leschenault Peninsula Management Plan (CALM 1998)	Yes	-
Sugar Loaf Rock NR	A	1a	Leeuwin-Naturaliste Capes Area Parks and Reserves Management Plan (DPAW 2015)	Yes	Ngari Capes Marine Park
Hamelin Island NR	A	1a		Yes	
Seal Island NR	A	1a		Yes	
St Alouarn Island NR	A	1a		Yes	
Flinders Bay NR	A	1a		Yes	

Further information is provided below in relation to Varanus Island and Airlie Island Nature Reserves. Santos WA's Varanus Island Processing Hub and Airlie Island (operations ceased) co-exist with the reserves.

Lowendal Islands Nature Reserve - Varanus Island

Varanus Island is part of the Lowendal Islands group, a Nature Reserve (Class C). The Lowendal Islands comprise more than 40 limestone islands, islets and rocky stacks. There is not currently a DBCA Management Plan covering the Lowendal Islands Nature Reserve. Varanus Island is the largest island in the Lowendal Islands and is approximately 2.5 km long and 600m wide at its widest point. Its highest point is approximately 30m above sea level.

Described ecological conservation values of marine relevance include: Wedge-tailed Shearwater nesting (see Section **8.1.6**); Loggerhead and Hawksbill Turtle nesting (see Section 6.1.1 and Section **6.1.3**), Flatback Turtle nesting (Section 6.1.4). The Lowendal Islands are described as particularly important for tern breeding (DEC 2002), further information on terns is provided in **Section 8.2.1**.

Airlie Island Nature Reserve

Airlie Island Nature Reserve is an ungazetted 'C' class nature (Reserve identifier: 40323, Crown Lease 1901/100) located on Airlie Island. Airlie Island is a small sand cay (26 Ha) located 35 km NNE of Onslow. It is part of the Pilbara Inshore Islands chain. A management plan for the nature reserves of the Pilbara Inshore Islands is currently under development (DBCA 2019) i.e. there is not currently a DBCA Management Plan covering Airlie Island Nature Reserve.

Described ecological conservation values of marine relevance include: a Wedge-tailed Shearwater nesting (see Section **8.1.6**); Silver Gull nesting (see Section **8.1.6**) and low levels of Green Turtle and Hawksbill Turtle nesting (see Section **6.1.2** and **6.1.3**).

9.7 Threatened Ecological Communities

An ecological community is a naturally occurring group of plants, animals and other organisms interacting in a unique habitat. Ecological communities are listed under the EPBC Act as threatened if the community is at risk of extinction.

Similarly, ecological communities can be listed under the WA Biodiversity Conservation Act (2016) as threatened if facing a risk of becoming a collapsed ecological community. To date no ecological communities are listed as threatened under the WA Act, however several ecological communities are currently endorsed by the WA Minister of Environment as Threatened Ecological Communities (TECs) through the previous non-statutory process.

TEC of relevance (likely to exist in marine water inter-tidal areas) in the area of interest are listed in **Table** 9-1 and further described below.

Table 9-4: Relevant TEC in the marine area of interest

Species	**Conservation Status**		
	Environment Protection and Biodiversity Conservation Act 1999	***Biodiversity Conservation Act 2016***	**Otherwise endorsed by the WA Minister for Environment**
Monsoon Vine Thicket on the Ridge on the Coastal Sand Dunes of Dampier	Endangered	-	Vulnerable
Roebuck Bay mudflats	-	-	Vulnerable

9.7.1 Monsoon Vine Thicket on the Ridge on the Coastal Sand Dunes of Dampier

Monsoon vine thicket occurs as semi - deciduous and evergreen vine thicket communities on and behind landward slopes of coastal sand dunes on the Damiper Peninsula in the Kimberley Region. This community is closely associated with coastal dunes elsewhere on the Dampier Peninsula and is listed as Endangered under the EPBC Act (Government of Western Australia, 2010; DoEE, 2016b). The community is also endorsed by the WA Minister for Environment as a threatened ecological community (non-statutory process).

9.7.2 Roebuck Bay Mudflats

Roebuck Bay mudflats (Kimberley region) have been endorsed by the WA Minister for Environment as a threatened ecological community (non-statutory process). The TEC is not listed under the EPBC Act.

Roebuck Bay mudflats (Kimberley region) are described as a 'species rich faunal community of the intertidal mudflats of Roebuck Bay' in the Kimberley region. Classed as Vulnerable (B). Roebuck Bay is a tropical marine embayment with extensive, biologically diverse, intertidal mudflats.

Roebuck Bay is protected as a designated RAMSAR Wetland of International Importance (**Section 9.2.2**) and Marine Park (see **Section 11.1.17** and **12.3.10**).

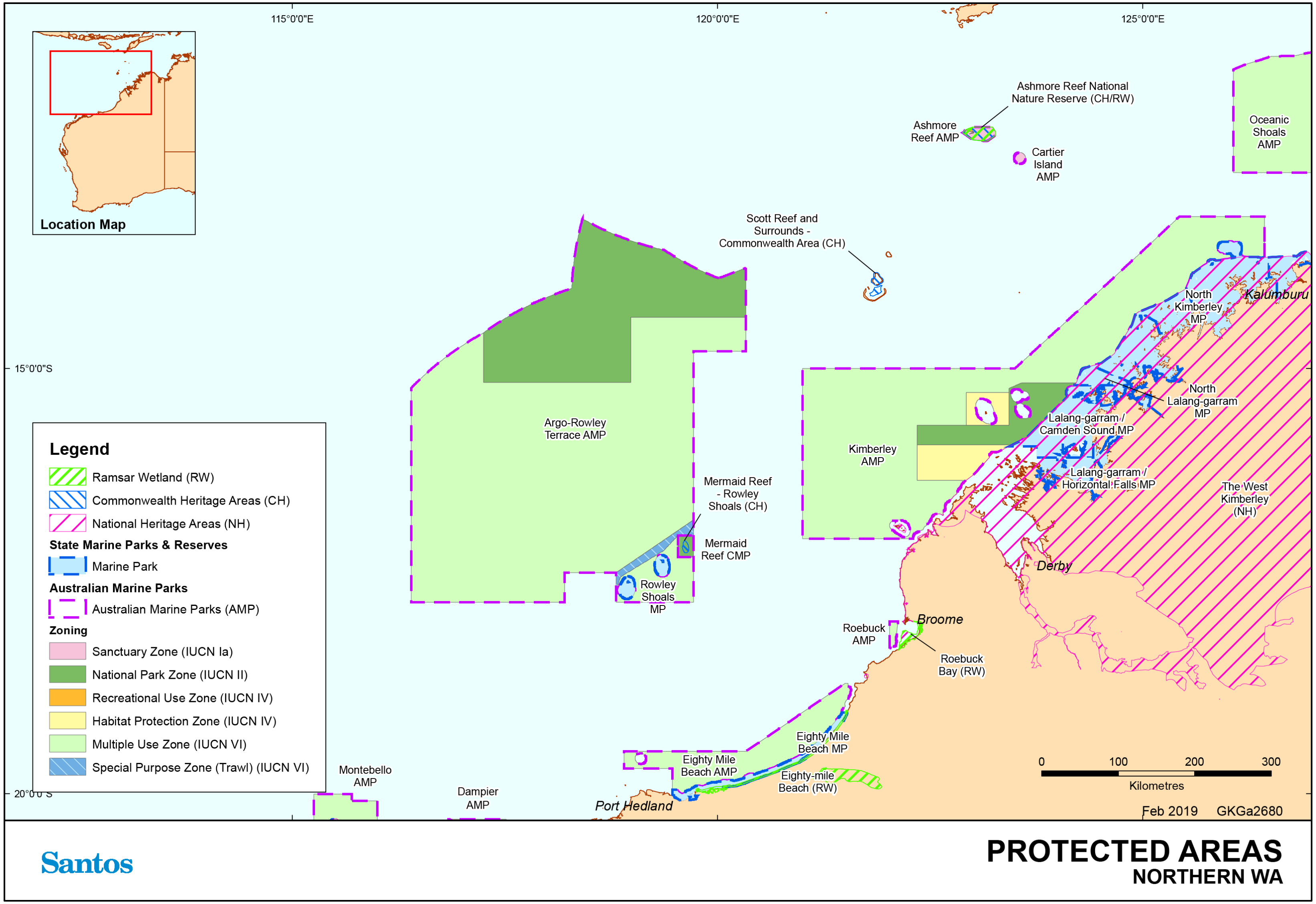

Figure 9-1: Protected areas Northern WA

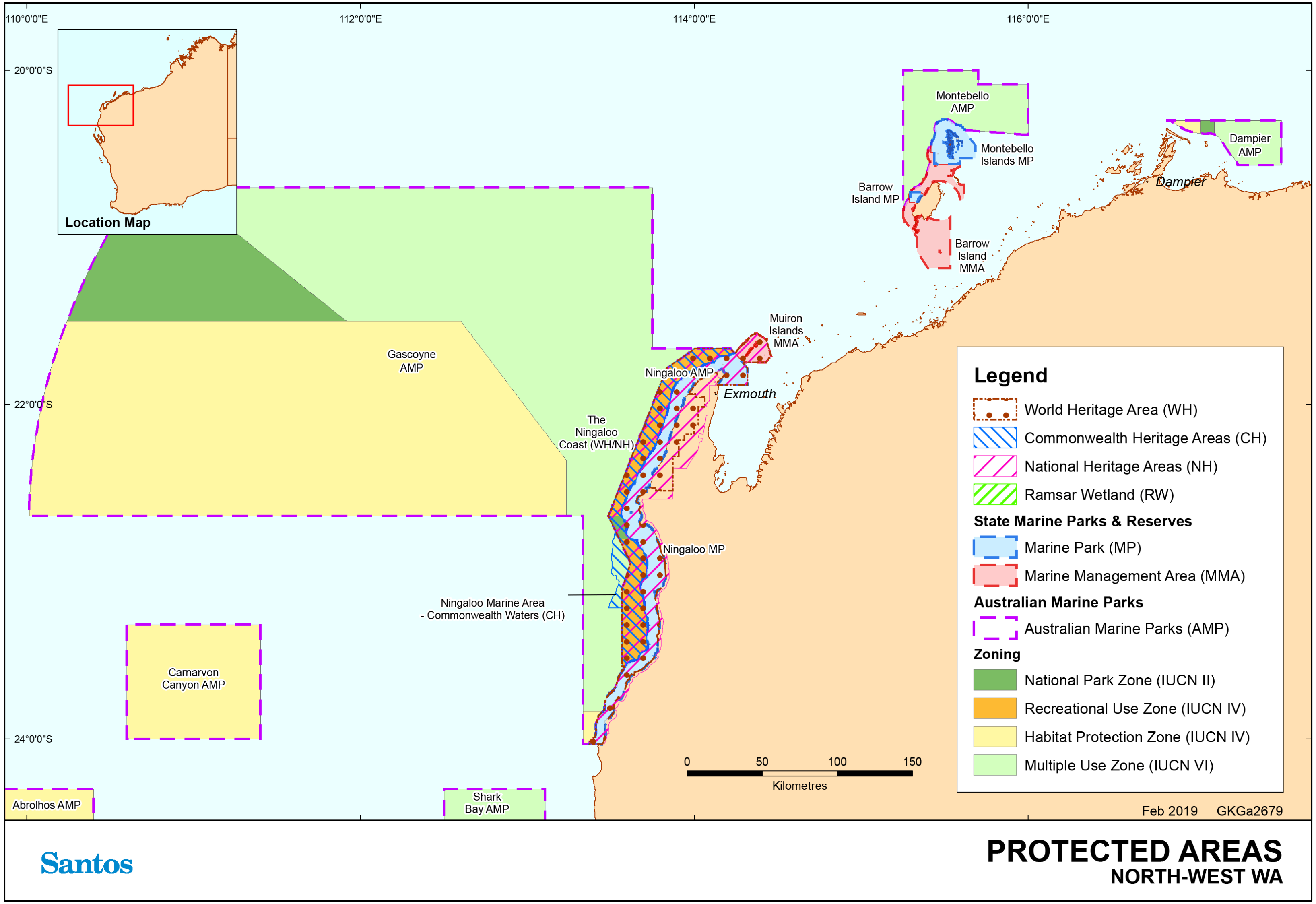

Figure 9-2: Protected areas in North-West WA

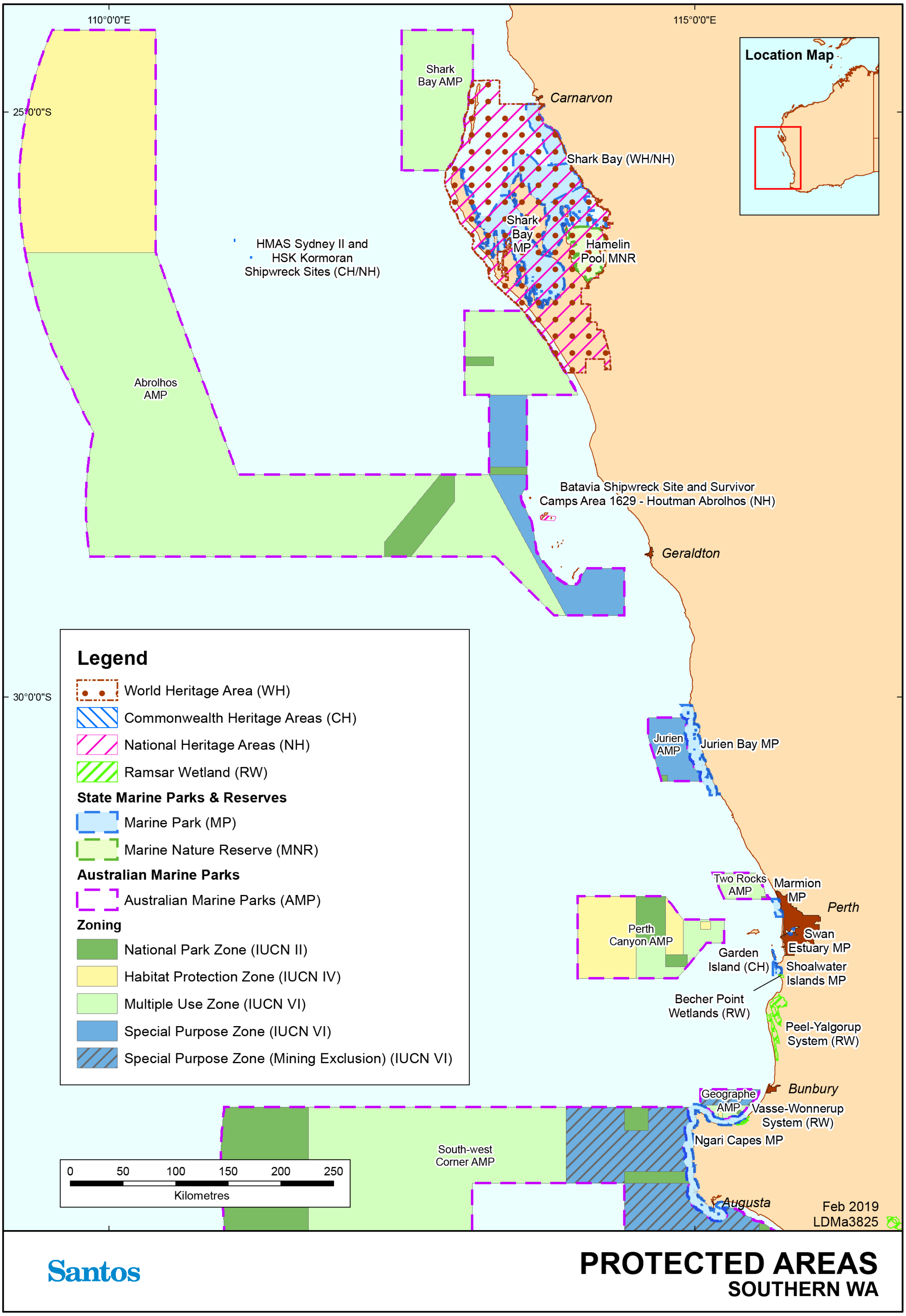

Figure 9-3: Protected areas in Southern WA

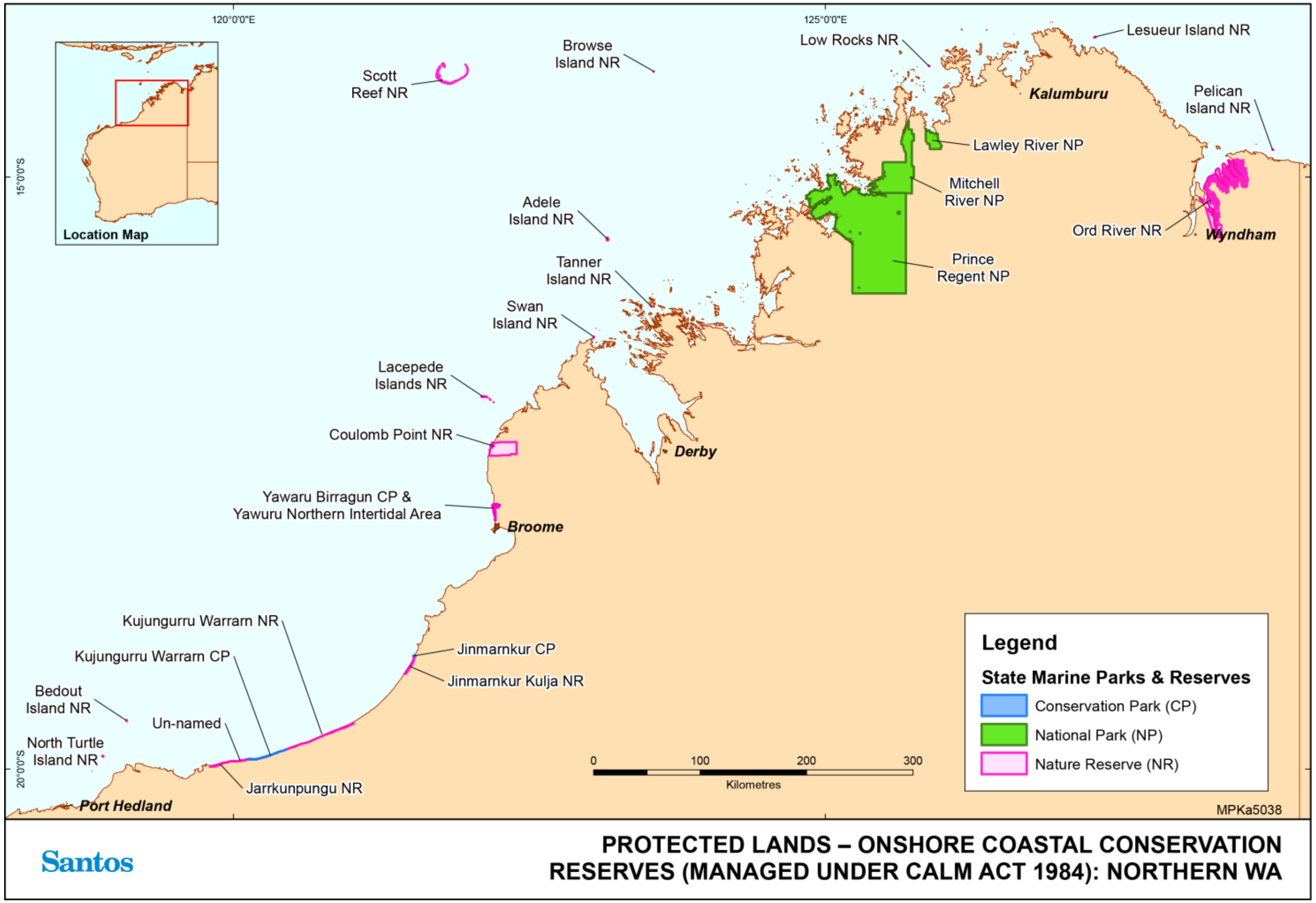

Figure 9-4: Protected Lands (CALM Act 1984) – terrestrial conservation reserves bounding marine waters in northern WA[12]

[12] Yawaru Minyirr Buru Conservation Reserve (adjacent to Roebuck Bay) not shown as exact spatial extent unavailable, however the adjacent inter-tidal waters are managed under adjacent Roebuck Bay Marine Park (described in **Section 11.1.17**).

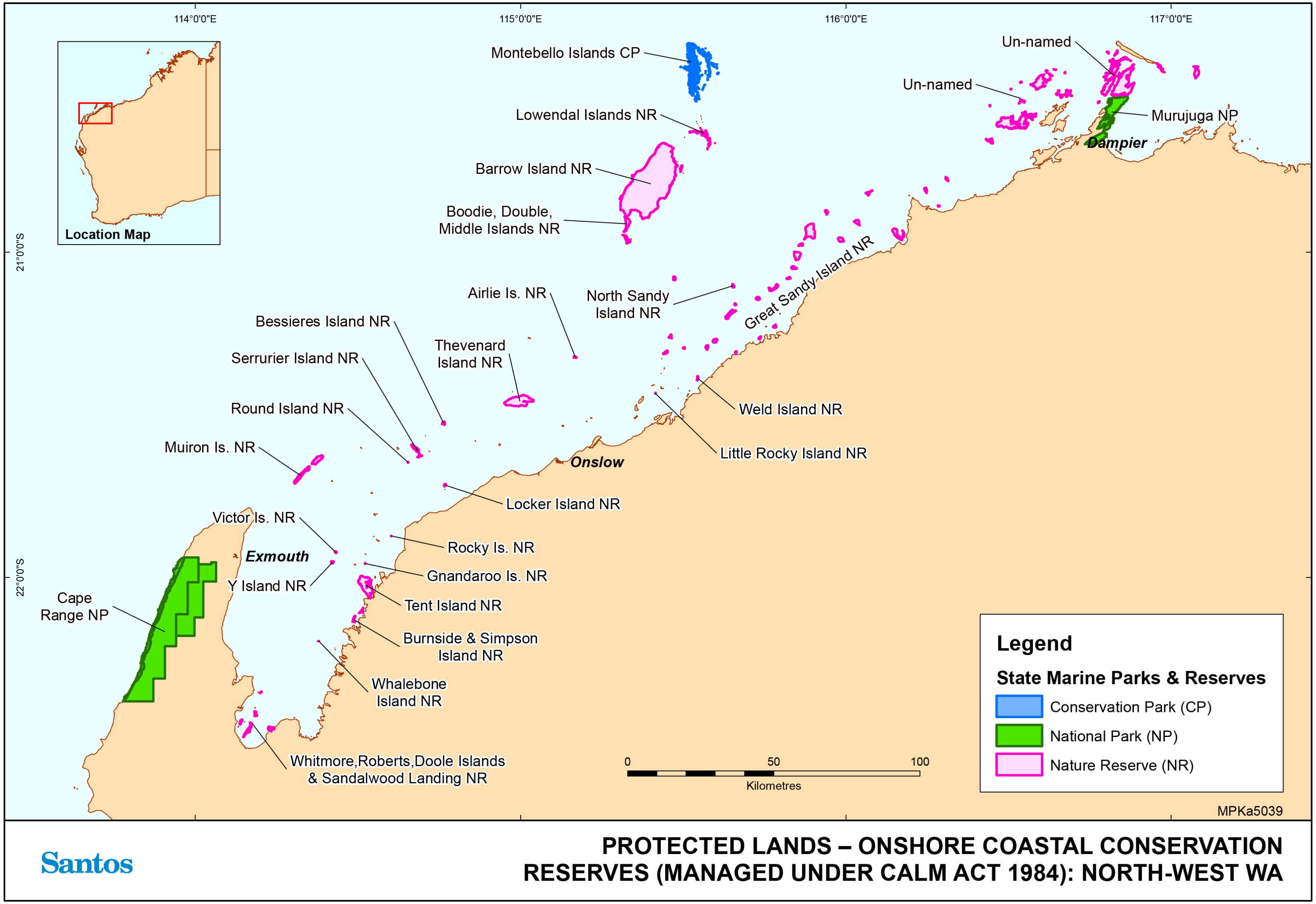

Figure 9-5: Protected Lands (CALM Act 1984) – terrestrial conservation reserves bounding marine waters in North-West WA

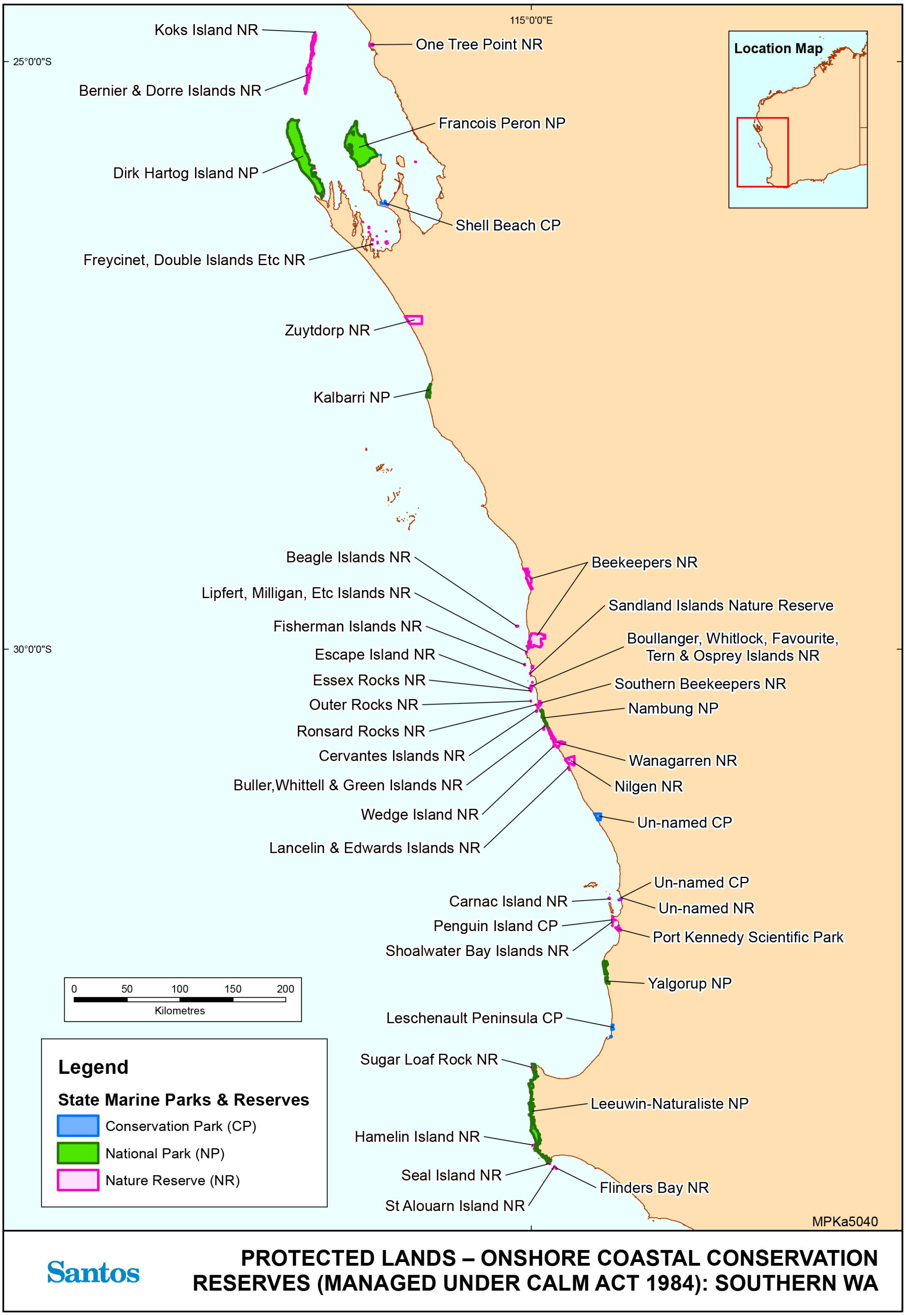

Figure 9-6: Protected Lands (CALM Act 1984) – terrestrial conservation reserves bounding marine waters in Southern WA[13]

[13] Rottnest Islands Conservation Park Conservation Park is not shown (managed under Rottnest Island Authority Act 1987).

9.8 International

There are fifty-three National Parks in Indonesia, six are World Heritage Sites, nine are part of the World Network of Biosphere Reserves and five are wetlands of international importance under the Ramsar convention. A total of nine parks are largely marine (ADB 2014). Of these protected areas only the Laut Sawu Marine National Park (including the Tirosa Batek Marine Area and the Sumba Strait Marine Area) intersects with the area of interest.

The Laut Sawu Marine National Park located within the Lesser Sunda Ecoregion in the Savu Sea and covers a reported 35,211 km^2 (Protected Planet 2017). It was established in 2009 and has an IUCN Category II status (Protected Planet 2017). The marine park area is a known migration route for several cetacean species, including the blue whale and sperm whale. Other cetacean species such as pygmy killer whales, melon-head whale, short-finned pilot whales and numerous dolphin species (including Risso's dolphin, Fraser's dolphin, common dolphin, bottlenose dolphin and spinner dolphin) are known to frequent the marine park area. Several species of marine turtle, including the green turtle, hawksbill turtle and leatherback turtle have also been recorded in the marine park area.

The marine park area covers a range of habitats and species diversity, including:

+ 532 corals species which include 11 endemic and sub endemic species;
+ 350 reef fish species;
+ fifteen mangrove species are recorded that represented 9 families of mangrove;
+ ten seagrass species;
+ deep-water habitats such as seamounts, deep-water canyons, straits (migratory corridors);
+ large persistent pelagic habitats;
+ main migratory corridors and habitats for 14 whale species, 7 dolphin's species, and dugong; and
+ habitats for 5 sea turtles species (green, leatherback, olive ridley, loggerhead, and flat back) as well as for large marine fauna such as sharks, napoleon, parrotfish and groupers (Savu Sea National Marine Conservation Area undated).

10. Key Ecological Features

10.1 Introduction

Key ecological features are elements of the Commonwealth marine environment that are considered to be of regional importance for either a region's biodiversity or its ecosystem function and integrity. Key ecological features meet one or more of the following criteria (DSEWPaC 2012):

- A species, group of species or a community with a regionally important ecological role;
- A species, group of species or a community that is nationally or regionally important for biodiversity;
- An area or habitat that is nationally or regionally important for:
  - Enhanced or high biological productivity;
  - Aggregations of marine life; or
  - Biodiversity and/or endemism
- A unique seafloor feature with ecological properties of regional significance.

Twenty-one key ecological features of the Commonwealth waters in the area of interest (covering the North Marine Region, the North-west Marine Region and the South-West Marine Region) have been identified in the protected matters search (**Figure** 10-1 and **Figure 10-2**) and are discussed in this section.

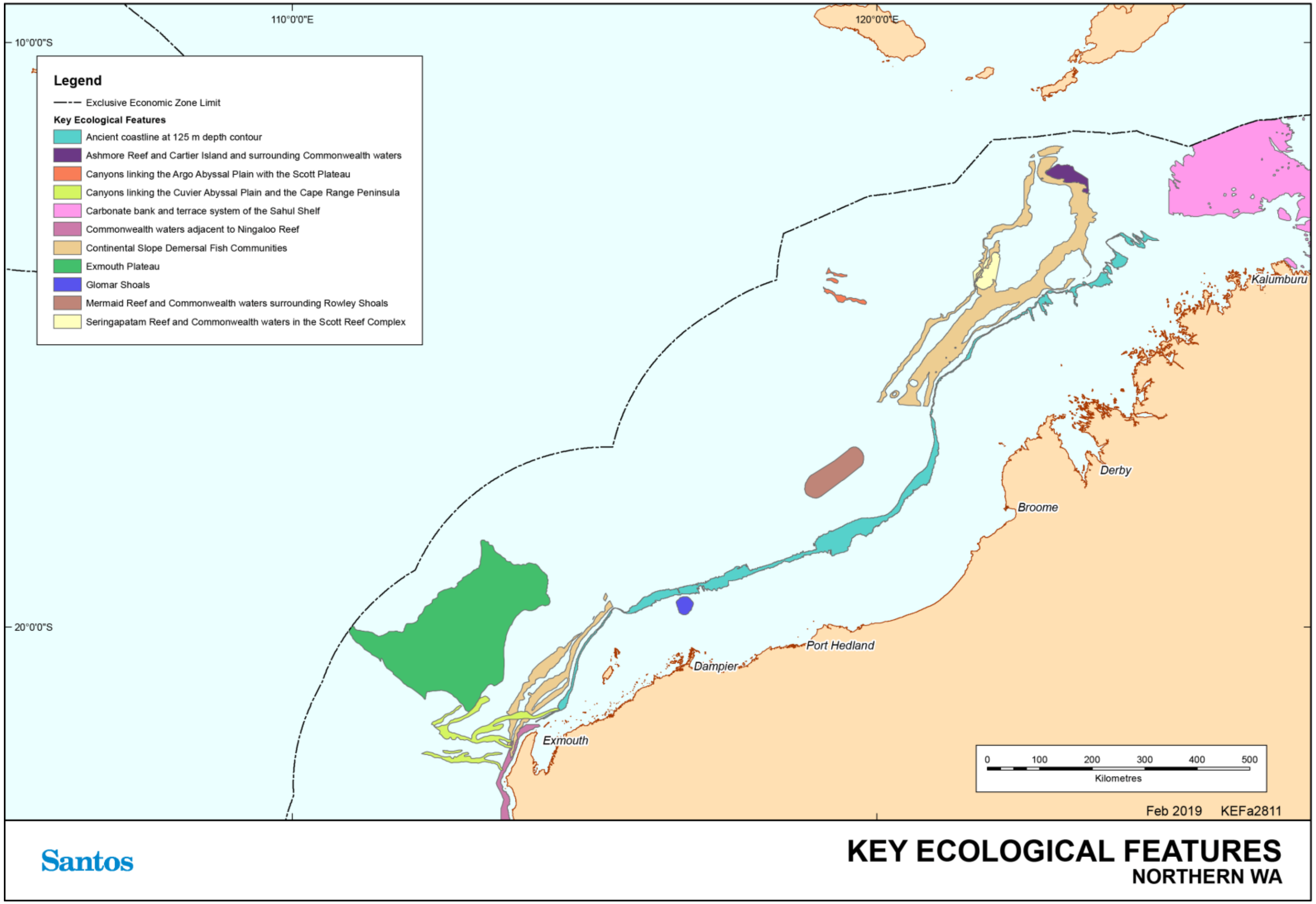

Figure 10-1: Key ecological features of Northern WA

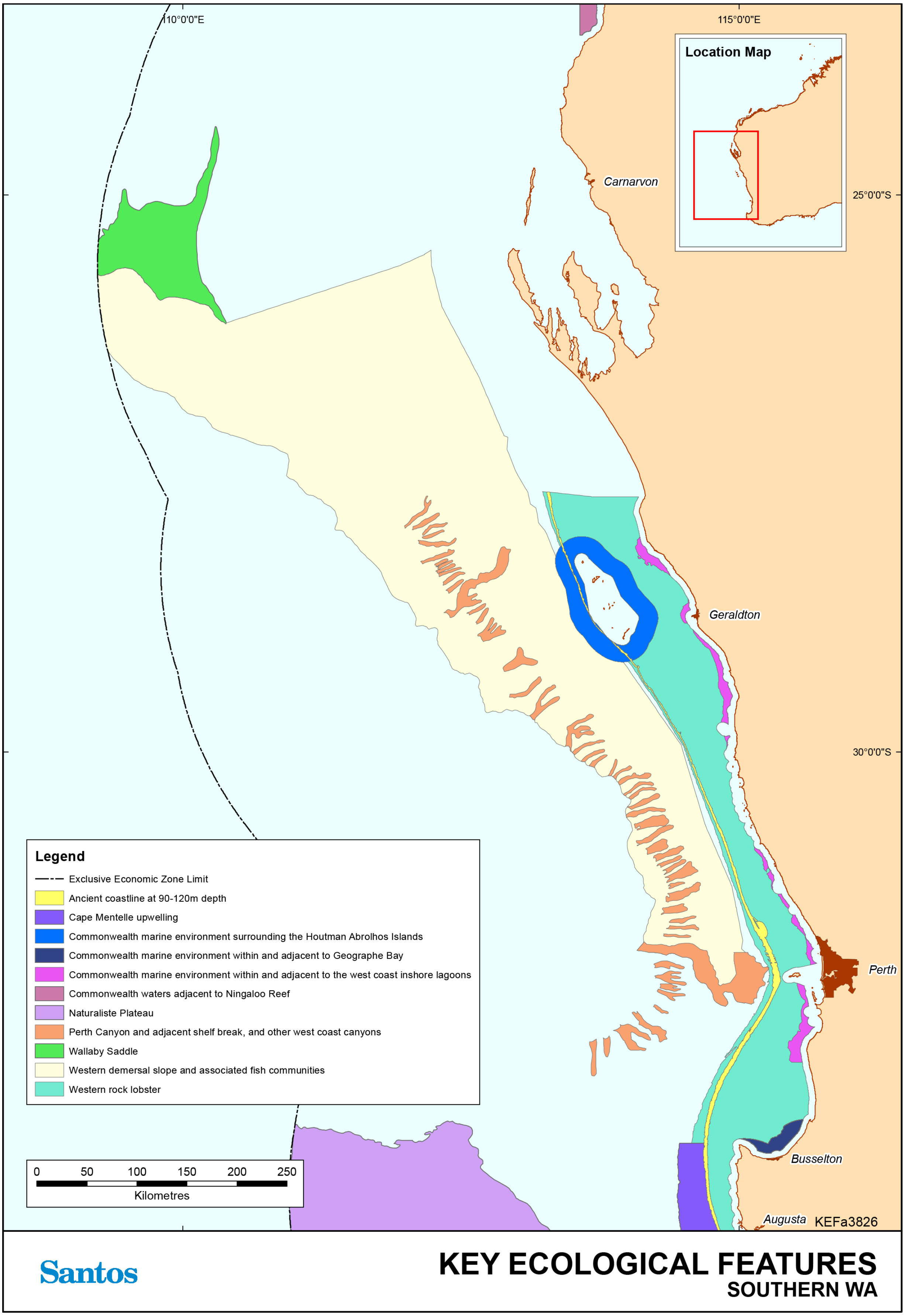

Figure 10-2: Key ecological features of Southern WA

10.1.1 Commonwealth Marine Environment Surrounding the Houtman Abrolhos Islands (and Adjacent Shelf Break)

The Commonwealth marine environment surrounding the Houtman Abrolhos Islands (and adjacent shelf break) is defined as a KEF for its high levels of biodiversity and endemism in benthic and pelagic habitats. The Houtman Abrolhos Islands and surrounding reefs support a unique mix of temperate and tropical species, resulting from the southward transport of species by the Leeuwin Current over thousands of years. The reefs are composed of 184 known species of corals that support about 400 known species of demersal fish, 492 known species of molluscs, 110 known species of sponges, 172 known species of echinoderms and 234 known species of benthic algae (DEWHA 2008a). The Houtman Abrolhos Islands are the largest seabird breeding station in the eastern Indian Ocean (DSEWPaC 2012). They support more than one million pairs of breeding seabirds. The Houtman Abrolhos Islands and surround waters are also BIAs for Australian sea lions for foraging and breeding (DEWHA 2010).

10.1.2 Perth Canyon and Adjacent Shelf Break, and other West-Coast Canyons

The Perth Canyon is defined as a KEF for its high biological productivity and aggregations of marine life and unique seafloor features with ecological properties of regional significance. The Perth Canyon is the largest known undersea canyon in Australian waters. In the Perth Canyon, interactions between the Leeuwin Current and the VCanyon topography induce clockwise-rotating eddies that transport nutrients upwards in the water column from greater depths (DoEE 2017a). Due to the Canyon's depth and Leeuwin Current's barrier effect, this remains a subsurface upwelling which supports ecological complexity that is typically absent from canyon systems in other areas (Pattiaratchi 2007). This nutrient-rich cold-water habitat attracts feeding aggregations of deep-diving mammals, such as pygmy blue whales and large predatory fish that feed on aggregations of small fish, krill and squid (DSEWPaC 2012). The Perth Canyon also marks the southern boundary for numerous tropical species groups on the shelf, including sponges, corals, decapods and xanthid crabs (DoEE 2017).

10.1.3 Commonwealth Marine Environment within and adjacent to the West-Coast Inshore Lagoons

The Commonwealth marine environment within and adjacent to the west-coast inshore lagoons is defined as a KEF for its high productivity and aggregations of marine life. These lagoons are important for benthic productivity, including macroalgae and seagrass communities, and breeding and nursery aggregations for many temperate and tropical marine species. They are important areas for the recruitment of commercially and recreationally important fishery species. Extensive schools of migratory fish visit the area annually, including herring, garfish, tailor and Australian salmon (DSEWPaC 2012).

10.1.4 Commonwealth Marine Environment within and Adjacent to Geographe Bay

The Commonwealth marine environment within and adjacent to Geographe Bay is defined as a KEF for its high productivity and aggregations of marine life and high levels of biodiversity and endemism. Geographe Bay is known for its extensive beds of tropical and temperate seagrass that account for about 80 % of benthic primary production in the area (DEH 2006). This habitat supports a diversity of species, many of them not found anywhere else (DSEWPaC 2012). The bay provides important nursery habitat for many species, including juvenile dusky whaler sharks. It is also an important resting area for migrating for humpback whales (McCauley *et al.* 2000).

10.1.5 Cape Mentelle Upwelling

The Cape Mentelle upwelling is defined as a KEF for its high productivity and aggregation soft marine life. The Cape Mentelle upwelling draws relatively nutrient-rich water from the base of the Leeuwin Current, up the continental slope and onto the inner continental shelf, where it results in phytoplankton blooms at the surface. The phytoplankton blooms provide the basis for an extended food chain characterised by feeding aggregations of small pelagic fish, larger predatory fish, seabirds, dolphins and sharks (DSEWPaC 2012). The Cape Mentelle upwelling has a disproportionate influence on the overall-nutrient poor nature of the region's water.

10.1.6 Naturaliste Plateau

The Naturaliste Plateau is defined as a KEF for its unique seafloor feature with ecological properties of regional significance. The Naturaliste Plateau is Australia's deepest temperate marginal plateau and occurs an area where numerous water bodies and currents converge. It is also the only seafloor feature in the region that interacts with the subtropical convergence front (DoEE 2017b). Although there is very little known about the marine life of the plateau, it is speculated that the combination of its structural complexity, mixed water dynamics and relative isolation indicate that it supports deep-water communities with high species diversity and endemism (DEWHA 2008a; DSEWPaC 2012). The Plateau acts as an underwater 'biogeographical island' on the edge of the abyssal plain, providing habitat for fauna unique to these depths (Richardson et al. 2005). The Plateau is also within a deep eddy field that is thought to be associated with high productivity and aggregations of marine life (Pattiaratchi 2007). Proximity to the nearby subtropical convergence front is thought to have a significant influence on the biodiversity of the Plateau (DEWHA 2008a).

10.1.7 Western Demersal Slope and associated Fish Communities

The Western Demersal Slope and associated Fish Communities, also known as the Demersal Slope and associated Fish Communities of the Central Western Province, is defined as a key ecological community for its high levels of biodiversity and endemism. The western demersal slope provides important habitat for demersal fish communities, with a high level of diversity and endemism. A diverse assemblage of demersal fish species below a depth of 400 m is dominated by relatively small benthic species such as grenadiers, dogfish and cucumber fish. Unlike other slope fish communities in Australia, many of these species display unique physical adaptations to feed on the sea floor (such as a mouth position adapted to bottom feeding), and many do not appear to migrate vertically in their daily feeding habits (DSEWPaC 2012). Scientists have described 480 species of demersal fish that inhabit the slope, and 31 of these are considered endemic (DoEE 2017c).

10.1.8 Western Rock Lobster

The western Rock Lobster KEF is defined due to its presumed ecological role on the West Coast Continental Shelf. This species is the dominant large benthic invertebrate in the region. The lobster plays an important trophic role in many of the inshore ecosystems of the South-west Marine Region. Western rock lobsters are an important part of the food web on the inner shelf, particularly as juveniles as they are preyed upon by octopus, cuttlefish, baldchin groper, dhufish, pink snapper, wirrah cod and breaksea cod (DEWHA 2008a, DSEWPaC 2012). The high biomass of western rock lobsters and their vulnerability to predation suggest that they are an important trophic pathway for a range of inshore species that prey upon juvenile lobsters (DEWHA 2008a).

10.1.9 Wallaby Saddle

The Wallaby Saddle is defined as a KEF for its high productivity and aggregations of marine life. The Wallaby Saddle is an abyssal geomorphic feature located on the upper continental slope at a depth of 4,000–4,700 m (DSEWPaC 2012). The feature connects the north-west margin of the Wallaby Plateau with the margin of the Carnarvon Terrace (Falkner *et al*. 2009 in DSEWPaC 2012). The Wallaby Saddle is situated within the Indian Ocean water mass and is thus differentiated from systems to the north that are dominated by transitional fronts or the Indonesian Throughflow (DSEWPaC 2012). Little is known about the Wallaby Saddle; however, the area is considered one of enhanced productivity and low habitat diversity (Brewer *et al*. 2007). The Wallaby Saddle is associated with historical aggregations of sperm whales (DEWHA 2008b).

10.1.10 Commonwealth Waters Adjacent to Ningaloo Reef

The Commonwealth Waters adjacent to Ningaloo Reef KEF is defined for high productivity and aggregations of marine life. The Ningaloo Reef extends almost 300 km along the Cape Range Peninsula to the Red Bluff and is globally significant as the only extensive coral reef in the world that fringes the west coast of a continent. Commonwealth waters adjacent to the reef are thought to support the rich aggregations of marine species at Ningaloo Reef through upwellings associated with canyons on the adjacent continental slope and interactions between the Ningaloo and Leeuwin currents (Brewer *et al*. 2007, DEWHA 2008c, DSEWPaC 2012). The narrow continental shelf (10 km at its narrowest) means that the nutrients channelled to the surface via canyons are immediately available to reef species. Terrestrial nutrient input is low, hence this deep-water source is a major source of nutrients for Ningaloo Reef and therefore very important in maintaining this system (DEWHA 2008b).

The reef is known to support an extremely abundant array of marine species including over 200 species of coral and more than 460 species of reef fish, as well as molluscs, crustaceans and other reef plants and animals (DEWHA 2008b). Marine turtles, dugongs and dolphins frequently visit the reef lagoon. The Commonwealth waters around Ningaloo include areas of potentially high and unique sponge biodiversity (DEWHA 2008b). Upwellings on the seaward side support aggregations such as whale sharks and manta rays (these waters are the main known aggregation area for whale sharks in Australian waters). Humpback whales are seasonal visitors to the outer reef edge and seasnakes, sharks, large predatory fish and seabirds also utilise the reef and surrounding waters.

The Ningaloo Marine Park includes this Key Ecological Feature and is discussed in **Section 12.3.4**.

10.1.11 Canyons Linking the Cuvier Abyssal Plain with the Cape Range Peninsula

The Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula are defined as a key ecological feature as they are unique seafloor features with ecological properties of regional significance.

Cape Range Peninsula and the Cuvier Abyssal Plain are linked by canyons, the largest of which are the Cape Range Canyon and Cloates Canyon. These two canyons are located along the southerly edge of Exmouth Plateau adjacent to Ningaloo Reef and are unique due to their close proximity to the North West Cape (DSEWPaC 2012). The Leeuwin Current interacts with the heads of the canyons to produce eddies resulting in delivery of higher nutrient, cool waters from the Antarctic intermediate water mass to the shelf (Brewer *et al*. 2007). Strong internal tides also create upwelling at the canyon heads (Brewer *et al*. 2007). Thus the canyons, the Exmouth Plateau and the Commonwealth waters adjacent to Ningaloo Reef interact to create the conditions for enhanced productivity seen in this region (Sleeman *et al*. 2007 in DSEWPaC 2012). The canyons are also repositories for particulate matter deposited from the shelf and sides of the canyons and serve as conduits for organic matter between the surface, shelf and abyssal plains (DSEWPaC 2012).

The soft bottom habitats within the canyons themselves are likely to support important assemblages of epibenthic species. Biological productivity at the head of Cape Range Canyon in particular, is known to support species aggregations, including whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds. The canyons are thought to be significant contributors to the biodiversity of the adjacent Ningaloo Reef, as they channel deep water nutrients up to the reef, stimulating primary productivity (DEWHA 2008b).

10.1.12 Exmouth Plateau

The Exmouth Plateau is defined as a KEF as it is a unique seafloor feature with ecological properties of regional significance. The Exmouth Plateau covers an area of 49,310 km^2 and is located approximately 150 km northwest of Exmouth. The plateau ranges in water depths from 800 to 4,000 m (Heap & Harris 2008 in DSEWPaC 2012). The plateau's surface is rough and undulating at 800–1,000 m depth. The northern margin is steep and intersected by large canyons (e.g. Montebello and Swan canyons) with relief greater than 50 m. The western margin is moderately steep and smooth and the southern margin is gently sloping and virtually free of canyons (Falkner *et al*. 2009 in DSEWPaC 2012).

The Exmouth Plateau is a regionally and nationally unique tropical deep sea plateau. It that may serve an important ecological role by acting as a topographic obstacle that modifies the flow of deep waters that generate internal tides, causing upwelling of deeper water nutrients closer to the surface (Brewer *et al.* 2007). Sediments on the plateau suggest that biological communities include scavengers, benthic filter feeders and epifauna. Whaling records from the 19th century suggest that the Exmouth Plateau may have supported large populations of sperm whales (Bannister *et al*. 2007). Fauna in the pelagic waters above the plateau are likely to include small pelagic species and nekton (Brewer *et al.* 2007).

10.1.13 Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals

Mermaid Reef and Commonwealth waters surrounding Rowley Shoals is defined as a KEFFF for its enhanced productivity and high species richness. The Rowley Shoals are a group of three atoll reefs—Clerke, Imperieuse and Mermaid reefs—located about 300 km north-west of Broome. Mermaid Reef lies 29 km north of Clerke and Imperieuse reefs and is totally submerged at high tide. Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals are regionally important in supporting high species richness, higher productivity and aggregations of marine life associated with the adjoining reefs themselves (Done et al. 1994). Rowley shoals contain 214 coral species and approximately 530 species of fishes (Gilmour et al. 2007), 264 species of molluscs and 82 species of echinoderms (Done et al. 1994; Gilmour et al. 2007). Both coral communities and fish assemblages differ from similar habitats in eastern Australia (Done et al. 1994).

Mermaid Reef falls under Commonwealth jurisdiction and forms the Mermaid Reef Commonwealth Marine Park. Clerke and Imperieuse reefs constitute the Rowley Shoals Marine Park, which falls under Western Australian Government jurisdiction (EA 2000). The Rowley Shoals are discussed with the Commonwealth and State Marine Park (**Sections 11.1.9** and **12.3.9**).

10.1.14 Glomar Shoals

The Glomar Shoals are a submerged feature situated at a depth of 33–77 m, approximately 150 km north of Dampier on the Rowley Shelf (Falkner *et al*. 2009 in DSEWPaC 2012). They consist of a high percentage of marine-derived sediments with high carbonate content and gravels of weathered coralline algae and shells (McLoughlin & Young 1985 in DSEWPaC 2012). The area's higher concentrations of coarse material compared to surrounding areas are indicative of a high energy environment subject to strong seafloor currents (Falkner *et al*. 2009 in DSEWPaC 2012).

Biological communities found at the Glomar Shoals have not been comprehensively studied, however the shoals are known to be an important area for a number of commercial and recreational fish species such as rankin cod, brown striped snapper, red emperor, crimson snapper, bream and yellow-spotted triggerfish. Catch rates at the Glomar Shoals are high, indicating that the area is a region of high productivity (Falkner *et al*. 2009, Fletcher & Santoro 2009 in DSEWPaC 2012). It is unclear if the removal of non-target species due to the commercial fishing over the shoals is having an impact on its value (DSEWPaC 2012).

The Glomar Shoals are regionally important for their potentially high biological diversity and localised productivity. Biological data specific to the Glomar Shoals is limited, however the fish of the shoals are probably a subset of reef-dependent species and anecdotal evidence suggests they are particularly abundant (DSEWPaC 2012).

10.1.15 Ancient Coastline at 125 m Depth Contour

The shelf of the North-west Marine Region contains several terraces and steps which reflect changes in sea level that occurred over the last 100,000 years. The most prominent of these features occurs at a depth of 125m as an escarpment along the North West Shelf and Sahul Shelf (DSEWPaC 2012). Where the ancient submerged coastline provides areas of hard substrate it may contribute to higher biological diversity. Little detailed knowledge is available, but the hard substrate of the escarpment is likely to support sponges, crinoids, molluscs, echinoderms (DSEWPaC 2012). It is understood that changes in topography at these depths are critical points for the generation of internal waves (Holloway *et al.* 2001 cited in DEWHA 2008b), playing a minor role in aiding localised upwelling or at least regional mixing associated with the seasonal changes in currents and winds. It is also believed that this prominent floor feature could be important as a migratory pathway for cetaceans and pelagic species such as the whale shark and humpback whale, as they move north and south between feeding and breeding grounds (DEWHA 2008b).

Parts of the ancient coastline are thought to provide biologically important habitats in areas otherwise dominated by soft sediments. The topographic complexity of these escarpments may also facilitate vertical mixing of the water column providing a relatively nutrient-rich environment for species present on the escarpment (DSEWPaC 2012). This enhanced productivity could potentially be attracting baitfish, which in turn provide food for the migratory species. The pressures of potential concern on the biodiversity value of this feature generally include ocean acidification as a result of climate change (DoEE 2017).

10.1.16 Ancient Coastline at 90-120 m Depth

This coastline is found in the South-west Marine Region and contains several terraces and steps reflecting a gradual increase in sea level across the shelf that occurred during the Holocene. Some of these features create escarpments of distinct elevation, creating topographic complexity through the exposure of rocky substrates. The most prominent of these occurs close to the middle of the continental shelf off the Great Australian Bight at a depth of 90-120 m, which provides a complex habitat for a number of species (DSEWPaC 2012c). The area has important conservation value due to its potential for high productivity, biodiversity and aggregations of marine life. Benthic biodiversity and productivity occur where the ancient coastline forms a prominent escarpment of exposed hard substrates, where it is dominated by sponge communities of significant biodiversity and structural complexity (DSEWPaC 2012c). These sponge communities have been recorded to contain sponges up to one metre across, which implies that some of the sponges in this region are likely to be many decades old (DSEWPC 2012c). It has been suggested that in certain places, the area may support some demersal fish species, travelling to the upper continental slope from across the continental shelf. The transportation of fine grained sediments off shelf occurs as a physical process down to depths of approximately 120 m, and influence the benthic invertebrate communities of the Great Australian Bight (DSEWPaC 2012c). Both species richness and biomass in the area, has been associated as declining with increasing depth and percentage of fines in sediment (Ward *et al.* 2006 cited in DSEWPaC 2012c).

10.1.17 Canyons Linking the Argo Abyssal Plain with Scott Plateau

The Scott Plateau connects with the Argo Abyssal Plain via a series of canyons, the largest of which are the Bowers and Oates canyons (DSEWPaC 2012). The canyons are believed to be up to 50 million years old and excavated during the evolution of the region through sediment and water movements (DEWHA 2008c). The canyons cut deeply into the south-west margin of the Scott Plateau and act as conduits for transport of sediments from an approximate depth of 2,000–3,000 m to depths of more than 5,500 m (DSEWPaC 2012). The water masses at these depths are deep Indian Ocean water on the Scott Plateau and Antarctic bottom water on the Argo Abyssal Plain. Both water masses are cold, dense and nutrient-rich (Lyne *et al*. 2006 in DSEWPaC 2012). The high productivity of the region is believed to be led by topographically induced water movements through the canyons and the action of internal waves in these canyons as well as around islands and reefs. The canyons are therefore thought to be linked to small and periodic upwellings that enhance this biological productivity (DEWHA 2008c).

The Canyons linking the Argo Abyssal Plain and Scott Plateau are likely to be important features due to their historical association with sperm whale aggregations (DSEWPaC 2012). Historical records of whaling in the Timor region indicate that the number of sperm whales was high in the region in the past. Though current numbers are unknown, it is possible that they congregate around the canyon heads adjacent to the Scott Plateau, encouraged by the high biological productivity, supporting stocks of their prey (DEWHA 2008c). There is anecdotal evidence that supports the idea that the Scott Plateau itself may be a breeding ground for sperm and beaked whales. It is also likely that important demersal communities occur in the canyons, as they do in the Scott Plateau supported by the localised upwelling, which in turn attract larger predatory fish, sharks and cetaceans (DEWHA 2008c).

10.1.18 Continental Slope Demersal Fish Communities

The Australian Continental Slope provides important habitat for demersal fish communities, characterised by high endemism and species diversity. Specifically, the continental slope between North West Cape and the Montebello Trough is the most diverse slope bioregion in Australia with more than 500 fish species, 76 of which are endemic (Last *et al*. 2005 in DSEWPaC 2012).

The Continental Slope consists of two distinct community types, associated with the upper and mid slope, 225 – 500 m and 750 – 1000 m respectively. The Timor Province and Northwest Transition bioregions are the second-richest areas for demersal fish across the entire continental slope (DSEWPaC 2012). The bacteria and fauna that is present in the system on the Continental Slope are the basis for the food web for demersal fish and higher order consumers in the system. Further information of this system has been poorly researched, though it has been suggested that it is a detritus-based system, where infauna and epifauna become prey for a range of teleost fish, molluscs and crustaceans (Brewer *et al.* 2007). The higher order consumers supported by this system are likely to be carnivorous fish, deep water sharks, large squid and toothed whales (Brewer *et al.* 2007). The pelagic production is known to be phytoplankton based, with hotspots located around oceanic reefs and islands (Brewer *et al.* 2007).

It is believed that the loss of the benthic habitat along this continental shelf region would likely lead to a decline in the species diversity and endemism that this feature is associated with (DoEE 2017e). The endemism of the region is not supported by large data sets and is scarce. It is consequently not well understood what interactions exist between the physical processes and trophic structures that lead to this high diversity of fish and the suggested presence of endemic species in the region (DoEE 2017e).

10.1.19 Seringapatam Reef and Commonwealth Waters in the Scott Reef Complex

Scott and Seringapatam reefs are emergent, oceanic reefs on the north-west continental slope (Falkner *et al*. 2009). The reefs are located approximately about 300 km from the Kimberley Coast and 23 km apart and as two of the few offshore reefs in the north-west region, they are an important biophysical environment in the region

Scott Reef consists of two separate reef formations: North Scott Reef and South Scott Reef. The KEF encompasses only the waters beyond the three nautical mile limit at South Scott Reef, but includes the reefs and surrounding waters at North Scott and Seringapatam reefs. The total area of this key feature is approximately 2418 square kilometres (DSEWPaC 2012b).

Seringapatam Reef is a large, emergent shelf atoll located on the edge of the broad continental shelf, about 300 km from mainland north-western Australia. Seringapatam Reef is situated about 23 km northeast of the nearest shelf atoll, Scott Reef. The listed area comprises the emergent reef, the enclosed lagoon and the surrounding oceanic waters extending to the 50 m BSL bathymetric contour (DoE 2014d). The coral reef communities at Seringapatam Reef display highly developed zonation influenced by the unique combination of oceanic conditions and extreme tidal ranges (4.6 m; DoE 2014d).

Similar to Scott Reef, Seringapatam Reef is regionally important for the biological diversity and high productivity. Studies at Seringapatam and Scott Reefs have recorded diverse fauna including corals (213 species in 56 genera); molluscs (279 species); decapod crustaceans (56 species); echinoderms (117 species) and fish (482 species) (Allen and Russell 1986, Berry and Morgan 1986, Marsh 1986, Veron 1986, Wells and Slack-Smith 1986, Hatcher 1988). The two reefs and the waters surrounding them often contain aggregations of humpback whales, other cetacean species, whale sharks and sea snakes (Donovan *et al.* 2008; Jenner *et al.* 2008; Woodside 2009, cited in DSEWPaC 2012b). Sandy Islet, located on South Scott Reef, during the summer months' hosts nesting green and hawksbill turtles, which also can be found foraging in the surrounding waters. The feature also provides foraging areas for numerous sea bird species, including the lesser frigatebird, wedged-tailed shearwater, brown booby and roseate tern.

Scott Reef is listed as Commonwealth Heritage Places and is discussed in **Section 9.5.1**.

10.1.20 Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters

Ashmore Reef and Cartier Island are emergent, oceanic reefs situated in the north-east Indian Ocean, approximately 350 km northwest of Australia's Kimberley coast, 115 km south of the Indonesian island of Roti and 45 km apart (EA 2002). Ashmore Reef and Cartier Island are both Australian Marine Parks and are discussed in **Section 12**. Ashmore Reef is the largest if the only three emergent reefs in the north-eastern Indian Ocean as well as being the only reef in the region with islands with vegetation. It also supports the highest number of coral species of any reef off the west Australian coast. The reef, islands and surrounding waters are areas of enhanced primary productivity and are considered significant for the feeding and breeding of birds as well as other marine life, providing seabirds and migratory birds with a habitat offshore (DSEWPaC 2012c). The enhanced productivity is driven by the localised upwelling and turbulent mixing in the surrounding Commonwealth waters. This supports the reef structure and the diverse ecology of benthic and pelagic fish species, and a range of primary and secondary consumers. Ashmore Reef is also biologically significant in that a small and genetically distinct population of dugongs, as well as a distinct green turtle population, can be found at the reef. The leaf-scaled seasnake is endemic to the region of the reefs of the Sahul Shelf, the

Ashmore Reef in particular. The two reefs contain a uniquely high diversity of sea snakes, of which the significant decline of the population at the Ashmore Reef is not yet fully understood (DSEWPaC 2012b).

10.1.21 Carbonate Bank and Terrace System of the Sahul Shelf

The Carbonate Banks and Terrace System of the Sahul Shelf are located in the western Joseph Bonaparte Gulf and to the north of Cape Bougainville and Cape Londonderry. The banks consist of a hard substrate and flat tops at depths of 150–300 m. Each bank occupies an area generally less than 10 km^2 and is separated from the next bank by narrow sinuous channels with depths up to 150 m. The origin of the banks is uncertain, though the area contains predictably high levels of productivity, in comparison to the generally low productivity of the region (DSEWPaC 2012).

The banks are foraging areas for loggerhead, olive ridley and flatback turtles and provide habitat for humpback whales, and green and freshwater sawfish (Donovan *et al*. 2008 in DSEWPaC 2012). The hard substrate of the banks is thought to support diverse organisms including sessile benthic invertebrates such as sponges, soft and hard corals, gorgonians, bryozoans, ascidians and associated reef fish and elasmobranchs (Brewer *et al*. 2007). Cetaceans, green and fresh sawfish are also likely to occur in the area, as well as possibly the Australian snubfin dolphin, a migratory species occurring mostly on the northern extent of the Sahul Shelf (DSEWPaC 2012).

According to DSEWPaC (2012) the carbonate banks and terrace system of the Sahul Shelf are regionally important because of their role in enhancing productivity relative to their surrounds. Little is known about the banks, terraces and associated channels but they are believed to be areas of enhanced productivity and biodiversity due to the upwellings of cold nutrient-rich water at the heads of the channels and the availability of hard substrate (Brewer *et al*. 2007).

11. State Marine Conservation Reserves

11.1 Introduction

Marine parks and reserves have been progressively established in Western Australia since 1987. The Conservation and Parks Commission (CPC) is the vesting authority for marine parks and reserves under the provisions of the Conservation and Land Management Act 1984. Parks and Wildlife, within the Department of Biodiversity, Conservation and Attractions (DBCA), is responsible for day to day management of the parks.

There are three categories of state marine conservation reserves: marine parks; marine management areas; and marine nature reserves.

Marine parks are created to protect natural features and aesthetic values while allowing recreational and commercial uses that do not compromise conservation values. There are currently sixteen marine parks within the area of interest (Refer **Figure 9-1**, **Figure 9-2** and **Figure 9-3**).

Marine parks are multiple-use reserves that cater for a wide range of activities. Within marine parks there may be four types of management zones: recreation zones: general use zones; no-take areas known as sanctuary zones; and special purpose zones.

Each marine park has a 'management plan' that contains strategies to protect the high value assets in the park, as well as permitted activities tables. These tables provide explicit regulatory management.

Sanctuary zones are 'no-take' areas created primarily for conservation and scientific research and are designed to protect a particular significant ecosystem or habitat. Low-impact tourism may be permitted, but no recreational or commercial fishing, aquaculture, pearling, petroleum drilling or production is allowed.

Marine management areas provide an integrated management structure over areas that have high conservation value and intensive multiple-use. There are two marine management areas within the area of interest (described below).

There is currently only one state marine nature reserve: Hamelin Pool Nature Reserve part of the Shark Bay World Heritage Area (**Section 9.1.1**)

11.1.1 Ngari Capes Marine Park

The Ngari Capes Marine Park is gazetted as a Class A Marine Park. The park is located off the southwest coast of Western Australia, approximately 250 km south of Perth, covering approximately 123,790 ha. The seaward boundary of the marine park is congruent with the seaward limit of Western Australian waters (three nautical miles from the territorial baseline). The north-eastern boundary in Geographe Bay is located near the intersection of the Shire of Busselton boundary with the coastline. The Shire of Busselton–Shire of Capel boundary is approximately 30 m north-east of the marine park boundary, while the south-eastern boundary in Flinders Bay is located at 115˚17’00” E. The marine park consists of four areas that are representative of the Leeuwin–Naturaliste marine bioregion: Geographe Bay; Cape Naturaliste to Cape Mentelle coast; the Cape Mentelle to Cape Leeuwin coast; and Flinders Bay. These areas show distinct differences in geomorphology, oceanography, habitats and flora and fauna.

The Ngari Capes Marine Park was identified as one of the most diverse temperate marine environments in Australia. Warm, tropical waters of the Leeuwin Current mix with the cool waters of the Capes Current, resulting in high finfish diversity, including tropical and temperate species (see fish in **Section 5.1.1**) and internationally significant seagrass diversity with seagrasses occurring at depths greater than 40 m (see seagrasses in **Section 3.2**). The marine park also surrounds a number of islands that are important seabird nesting habitat and pinniped haul-outs (places where seals and sea lions leave the water and come onto land), including Hamelin Island, Sugarloaf Rock and the Saint Alouarn Islands which include Flinders Island, Seal Island and Square Rock (DEC 2013). These islands are vested with the Conservation Commission as nature reserve and are managed by DBCA for the purpose of conservation. The marine park is also adjacent to the Leeuwin Naturaliste National Park which extends to the high water mark (DEC 2013).

The Ngari Capes marine park was also created for its high social values. The unique geographical location of this region exposes it to large, uninterrupted ocean swells and results in the South West capes area being recognised as one of the world's premier surfing regions. Many activities occurring in the region are marine based, including commercial and recreational fishing, swimming, surfing, diving, snorkelling, boating, and marine nature based tourism.

11.1.2 Jurien Bay Marine Park

The Jurien Bay Marine Park is located on the central west coast of Western Australia about 200 km north of Perth and covers an area of 82,375 ha. The marine park was gazetted on the 26 August 2003 as a Class A marine park.

The Jurien Bay region is dominated by five major marine habitat types: seagrass meadows; bare or sparsely vegetated mobile sand; shoreline and offshore intertidal reef platforms; subtidal limestone reefs; and reef pavement. Extensive seagrass meadows consisting of at least nine species of seagrass exist in the Jurien Bay Marine Park (DEC 2005). The densest and presumably the most productive seagrass meadows are between the Jurien Bay town site and Black Rock and these areas are dominated by *Posidonia sinuosa* and *Amphibolis* species. The marine flora and fauna of the Central West Coast region is a mixture of tropical and temperate species, the former carried south by the Leeuwin Current from tropical northern waters and the latter carried north by the Capes Current from the cool temperate waters of the south coast of Western Australia. The fauna is regarded as being predominantly temperate; however, a survey by CALM indicated that tropical species comprise a significant proportion (35%) of the marine fauna found in the region (DEC 2005)

11.1.3 Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve

The Shark Bay Marine Reserves comprise the Shark Bay Marine Park and the Hamelin Pool Marine Nature Reserve. The Shark Bay Marine Park was gazetted on 30 November 1990 as A Class Marine Park Reserve No. 7 and vested in the National Park and Nature Conservation Authority (NPNCA) under the CALM Act. The marine park encompasses an area of 748,725 ha (CALM 1996).

The Bay is located near the northern limit of a transition region between temperate and tropical marine fauna. Of the 323 fish species recorded from Shark Bay, 83% are tropical species with 11% warm temperate and 6% cool temperate species. Similarly, of the 218 species of bivalves recorded in Shark Bay, 75% have a tropical range and 10% a southern Australian range, with 15% being endemic to the west coast (CALM 1996).

Key features of Shark Bay Marine Park include (CALM 1996, DSEWPaC 2013):

+ 12 species of seagrass making it one of the most diverse seagrass assemblages in the world;
+ Seagrass that covers over 4,000 km2 of the bay. The 1,030 km2 Wooramel Seagrass Bank is the largest structure of its type in the world;
+ An estimated population of about 11,000 dugongs, one of the largest populations in the world;
+ Humpback and southern right whales use the bay as a migratory staging post;
+ Bottlenose dolphins occur in the bay, and green turtle and loggerhead turtle nest on the beaches;
+ Large numbers of sharks including whaler, tiger shark and hammerhead are present as well as an abundant population of rays, including the manta ray;
+ Hamelin Pool in Shark Bay contains the most diverse and abundant examples of stromatolite forms in the world, representative of life-forms which lived some 3,500 million years ago; and
+ Shark Bay Marine Park does not cover Bernier and Dorre Islands and only coastal waters inshore of Dirk Hartog Island (east of eastern shoreline).

Shark Bay was included on the World Heritage List in 1991 primarily on the basis of three natural features: vast seagrass beds; dugong population; and stromatolites (microbial colonies that form hard, dome-shaped deposits and are among the oldest forms of life on Earth) (DSEWPaC 2013; see **Section 9.1**).

There is no zoning within the Hamelin Pool Marine Nature Reserve. This area is a 'look but don't take' area managed solely for the conservation of globally outstanding marine life. Hamelin Pool is one of only two known places in the world with living examples of marine stromatolites (DEC 2010). The shores of Hamelin Pool are also important for the formation of extensive marine algal mats formed by microbial algae. If damaged, the mats and stromatolites can take many hundreds of years to recover (DEC 2010).

11.1.4 Ningaloo Marine Park

The Ningaloo Marine Park was declared in May 1987 under the National Parks and Wildlife Conservation Act 1975 (Cmlth). The Ningaloo Coast, incorporating both key marine and terrestrial values was later granted World Heritage Status in June 2011. In November 2012, the Ningaloo Marine Park (Commonwealth Waters) was renamed to be incorporated in the North-west Commonwealth Marine Reserves Network. The park covers an area of 263,343 km^2, including both State and Commonwealth waters, extending 25 km offshore.

The park protects a large portion of Ningaloo Reef, which stretches over 300 km from North West Cape south to Red Bluff. It is the largest fringing coral reef in Australia, forming a discontinuous barrier that encloses a lagoon that varies in width from 200 m to 7 km. Gaps that regularly intercept the main reef line provide channels for water exchange with deeper, cooler waters (CALM 2005). The Ningaloo Marine Park forms the backbone of the nature-based tourism industry, and recreational activities in the Exmouth region. Seasonal aggregations of whale sharks, manta rays, sea turtles and whales, as well as the annual mass spawning of coral attract large numbers of visitors to Ningaloo each year (CALM 2005).

The reef is composed of partially dissected basement platform of Pleistocene marine or Aeolian sediments or tertiary limestone, covered by a thin layer of living or dead coral or macroalgae. Key features that characterise the Ningaloo Reef include (CALM 2005):

+ Over 217 species of coral (representing 54 genera);
+ Over 600 species of mollusc (clams, oysters, octopus, cuttlefish, snails);
+ Over 460 species of fish;
+ Ninety-seven species of echinoderms (sea stars, sea urchins, sea cucumbers);
+ Habitat for numerous threatened species, including whales, dugong, whale sharks and turtles; and
+ Habitat for over 25 species of migratory wading birds listed in CAMBA and JAMBA.

11.1.5 Muiron Islands Marine Management Area

The Ningaloo Marine Park Management Plan (CALM 2005) created a MMA for the Muiron Islands, immediately adjacent to the northern end of the Park. This is managed as an integrated area together with the Ningaloo Marine Park, but its status as a MMA means that some activities, including oil and gas exploration, are still permitted under a strict environmental assessment process involving DMIRS.

The Muiron Islands, located 15 km northeast of the North West Cape comprise the North and South Muiron Islands and cover an area of 1,400 ha (AHC 2006). They are low limestone islands (maximum height of 18 m above sea level (ASL)) with some areas of sandy beaches, macroalgae and seagrass beds in the shallow waters (particularly on the eastern sides) and coral reef up to depths of 5m, which surrounds both sides of South Muiron Island and the eastern side of North Muiron Island. The Muiron Islands MMA was WA's first MMA, gazetted in November 2004. It covers an area of 28,616 ha and occurs entirely within state waters (CALM 2005).

11.1.6 Barrow Island Marine Park

The Barrow Island Marine Park covers 4,169 ha, all of which is zoned as sanctuary zone (the Western Barrow Island Sanctuary Zone) (DEC 2007). It includes Biggada Reef, an ecologically significant fringing reef, and Turtle Bay, an important turtle aggregation and breeding area (DEC 2007). Representative areas of seagrass, macroalgal and deep water habitat are also represented within the marine park (DEC 2007). Passive recreational activities (such as snorkelling, diving and boating) are permitted but extractive activities such as fishing and hunting are not.

11.1.7 Barrow Island Marine Management Area

The Barrow Island Marine Management Area (MMA) is the largest reserve within the Montebello/Barrow Islands marine conservation reserves, covering 114,693 ha (DEC 2007). The MMA includes most of the waters around Barrow Island, the Lowendal Islands and the Barrow Island Marine Park, with the exclusion of the port areas of Barrow Island and Varanus Island.

The MMA is not zoned apart from one specific management zone: the Bandicoot Bay Conservation Area. This conservation area is on the southern coast of Barrow Island and has been created to protect benthic fauna and seabirds. It includes the largest intertidal sand/mudflat community in the reserves, is known to be high in invertebrate diversity and is an important feeding area for migratory birds.

As for the other reserves in the Montebello/Barrow Islands marine conservation reserves, the Barrow Island MMA includes significant breeding and nesting areas for marine turtles and the waters support a diversity of tropical marine fauna, important coral reefs and unique mangrove communities (DEC 2007). Green, hawksbill and flatback turtles regularly use the island’s beaches for breeding, and loggerhead turtles are also occasionally sighted.

11.1.8 Montebello Islands Marine Park

Montebello/Barrow/Lowendal Islands are part of a shallow submarine ridge, which extends north from the mainland near Onslow. The ridge contains extensive areas of intertidal and shallow subtidal limestone pavement surrounding the numerous, mostly small islands which are found in the region. The seabed is generally less than 5 m deep and consists of sand veneered limestone pavement with patches of fringing coral reef (DEC, 2007).

The island chain lies entirely within WA State waters, with the State-Commonwealth boundary extending out to encompass the islands and waters 3 nm west of Barrow Island and north of the Montebello Islands. These islands are protected within as marine conservation reserves: Montebello Islands Marine Park, Barrow Islands Marine Park and Barrow Island Marine Management Area.

The Montebello Islands Marine Park (58,331 ha), consists of two sanctuary zones, two recreation zones, one special purpose zone for benthic protection, eleven special purpose zones for pearling and general use zones.

The Montebello Islands comprise over 100 islands, the majority of which are rocky outcrops; rocky shore accounts for 81% of shoreline habitat (DEC 2007a).

The ecological and conservation values of the Montebello and Barrow Islands Marine Conservation Reserve (MCR) include important habitats including corals reefs and bommies, mangroves, seagrass and macroalgae meadows, rocky shorelines and hard substrate, intertidal sand and mudflat communities. These habitats provide protection, food and habitat for a large diversity of species, including dugongs, turtles, whales, other protected cetaceans and birds as well as sea snakes and fish. The area is considered to have a high biodiversity. The islands also provide feeding and resting areas for migrating shorebirds and seabird nesting areas.

Socio-economic values of the Montebello and Barrow Islands MCR include hydrocarbon exploration and production, pearling, nature-based tourism, commercial and recreational fishing, water sports, European history and maritime heritage and scientific research (DEC, 2007)

Special purpose zones for pearling are established for the existing leaseholder to allow pearling to be the priority use of these areas (DEC 2007a). Commercial fishing includes a trap fishery for reef fishes, mainly in water depths of 30–100 m, and wet lining for reef fish and mackerel. Fish trawling also occurs in the waters near to the Montebello Islands. A tourist houseboat operates out of Claret Bay, at the southern end of Hermite Island, during the winter months. The Montebello Islands are becoming more frequently used by recreational boaters for camping, fishing and diving activities.

11.1.9 Rowley Shoals Marine Park

Lying approximately 300 km north-north-west of Broome, the Rowley Shoals comprise three oceanic reef systems approximately 30–40 km apart, namely Mermaid Reef, Clerke Reef and Imperieuse Reef. The Rowley

Shoals Marine Park comprises the Clerke and Imperieuse Reefs which lie in State Waters. PaW has lead management responsibility for the Marine Park, in accordance with the Rowley Shoals Management Plan (DEC 2007b).

The Rowley Shoals Marine Park was originally gazetted on 25 May 1990 as a Class A reserve and on 10 December 2004 the boundary was amended to extend the Park to the State Waters limit. The Park now covers approximately 87,632 ha (DEC 2007b). Mermaid Reef lies in Commonwealth waters and comprises the Mermaid Reef Marine National Nature Reserve managed by the Commonwealth Department of Environment and Energy (DoEE) (DEWHA 2008).

The Rowley Shoals Marine Park is characterised by spectacular intertidal and subtidal coral reefs, exceptionally rich and diverse marine fauna and high water quality. These attributes and the low level of use of the area contribute to the Park's unique wilderness qualities, which are a significant drawcard for visitors. Lying in the headwaters of the Leeuwin Current, the Shoals are thought to provide a source of invertebrate and fish recruits for reefs further south and as such are regionally significant. The remoteness of the Shoals and low use have ensured that the marine environment of the Shoals is in a near natural state, particularly relative to other reefs in the Indo-West Pacific region which are subject to intense ongoing human pressures and destructive fishing practices. The Rowley Shoals are of national and international significance and provide an important global benchmark for Indo-West Pacific reefs (DEC 2007b).

11.1.10 Lalang-garram/Camden Sound Marine Parks

The Lalang-garram/Camden Sound Marine Park was created on 19 June 2012 under Section 13 of the Conservation and Land Management Act 1984 (CALM Act). It is a multiple zone marine park that includes; Sanctuary, Special Purpose, and General Use zones (DPaW 2013). The marine park falls within the west Kimberley, which was recently added to the Australian National Heritage List because of its natural, indigenous and historic values to the nation.

The marine park is located about 150 km north of Derby (or 300 km north of Broome) and lies within the traditional country of three Aboriginal native title groups. The Dambimangari people's determination overlies the majority of the marine park. A section of the Wunambal Gaambera people's Uunguu determination includes a small portion of St George Basin, while a small section of the Mayala people's claim (native title not determined at the time of writing of Management Plan) overlies the southwest corner of the marine park (DPaW 2013).

The marine park covers an area of approximately 705,000 ha. It recognises and provides special management arrangements for this area of the Kimberley, which is a principal calving habitat of the humpback whale (*Megaptera novaeangliae*) population that migrates annually along Western Australia's coast. The marine park also conserves a range of species listed as having special conservation status including marine turtles, snubfin and Indo-Pacific humpback dolphins, dugong, saltwater crocodiles, and several species of sawfish. The park also includes a wide range of marine habitats and associated marine life, such as coral reef communities, rocky shoals, and the extensive mangrove forests and marine life of the St George Basin and Prince Regent River (DPaW 2013).

11.1.11 Marmion Marine Park

Marmion Marine Park was Western Australia's first marine park, declared in 1987 and is a multi-use reserve (CALM 2002). Marmion Marine Park is located offshore from Perth's northern suburbs, between Trigg Island and Burns Beach.

Habitats in the area include intertidal reef platforms, coastal sand beaches, a high limestone reef about 1 km from shore, Little Island and the Three Mile Reef system. Of note are complex assemblages of sea floor communities, including seagrass meadows, algal limestone pavement communities and crevice animal associations (CALM 2002).

The marine park provides an important habitat for marine mammals, such as sea lions, dolphins and whales. The island nature reserves within Marmion Marine Park provide an important habitat for several species of seabirds and haul-out areas for Australian sea lions, especially at Little Island and Burns Rocks (CALM 2002).

11.1.12 Swan Estuary Marine Park

The Swan Estuary Marine Park (A Class marine reserve number 4) was gazetted on 25 May 1990. The Swan Estuary Marine Park and Adjacent Nature Reserves Management Plan 1999-2009 was gazetted 7 April 2000 (CALM 1999).

The Swan Estuary Marine Park encompasses Alfred Cove, 200 ha adjacent to the suburbs of Attadale and Applecross; Pelican Point, a 45 ha area in Crawley; and Milyu, 95 ha adjacent to the Como foreshore (CALM 1999). All three localities are within 20 minutes of the Perth CBD.

These areas encompass mudflats, seagrass beds and intertidal vegetation such as sedges and saltmarsh, which provide many different habitats for a host of animals. The most important of these, due to their international significance, are the migratory wading birds. They come from as far afield as Asia, Mongolia and Siberia. About 33 of these species are protected, including the red-necked stint (CALM 1999).

11.1.13 Shoalwater Islands Marine Park

The Shoalwater Islands Marine Park is located within the Perth metropolitan area, adjacent to the city of Rockingham and was gazetted in 1990 (DEC 2007). There are three sanctuary zones, two special purpose zones and a large general use zone in the park.

The Shoalwater Island region is dominated by beach and rocky shore shoreline habitats. The many jagged edged islands and rocky islets of the marine park provide important roosting and nesting areas for numerous bird species. The marine park has some of the healthiest seagrass meadows in the Perth metropolitan area, consisting of long lived species such as *Posidonia* spp. and *Amphibolis* spp. Seagrass meadows provide an important habitat and nursery area for a large number of marine species such as fish, rock lobsters, worms, shellfish, crustaceans, fish sharks and rays (DEC 2007).

The habitats of the marine park are important for the feeding, resting and breeding of little penguins and other sea and shore birds. Penguin Island which is found within the marine park has the largest breeding colony of little penguin on the west coast of Australia (DEC 2007). The bottlenose dolphin is the most common marine mammal, and Australian sea lions are commonly seen throughout the park.

11.1.14 Eighty Mile Beach Marine Park

The Eighty Mile Beach Marine Park, located between Port Hedland and Broome, was gazetted on 29 January 2013. It covers an area of approximately 200,000 ha stretching for some 220 km from Cape Missiessy to Cape Keraudren, and includes sanctuary, recreation, general use and special purpose zones. The park is managed under the Eighty Mile Beach Marine Park Management Plan 2014-20124 (DPaW, 2014).

The listed ecological values of the Eighty Mile Beach Marine Park include the high sediment and water quality, the juxtaposition of the beach, coastal topography and seabed and the diverse and ecologically important habitats and marine/coastal flora and fauna. The listed habitat values of the marine park are as follows:

+ The intertidal sand and mudflat communities supporting a high abundance and diversity of invertebrate life and providing a valuable food source for shorebirds (including migratory species) and other fauna;
+ The diverse subtidal filter-feeding communities;
+ Macroalgal and seagrass communities providing habitat and feeding opportunities for fish, invertebrates and dugongs;
+ High diversity intertidal and subtidal coral reef communities; and
+ Mangrove communities and adjacent saltmarshes provide nutrients to the surrounding waters and habitat for fish and invertebrates.

The listed marine and coastal fauna values are as follows:

+ A high diversity and abundance of nationally and internationally important shorebirds and waders (including migratory species) are found in the marine park;

+ Flatback turtles are endemic to northern Australia and nest at Eighty Mile Beach;
+ Dugongs and several whale and dolphin species inhabit or migrate through the marine park;
+ A highly diverse marine invertebrate fauna provides an important food source for a variety of animals, including birds, fish and turtles, along with recreational and commercial fishing opportunities;
+ A diversity of fish species provides recreational and commercial fishing opportunities; and
+ A diversity of sharks and rays, including several protected species, are found in the park.

In addition to these natural values, the marine park contains land and sea important to traditional Indigenous owners through identity and place, family networks, spiritual practice and resource gathering. The marine park also has a history of European activity including exploration, pastoralism and commercial fishing (e.g. the pearl oyster fishery). The park contains a historical WWII plane wreck (*Dornier Do-24 X-36*) and shipwrecks (two pearl luggers). The marine park provides tourism opportunity and recreational value through its remoteness, diversity and abundance of habitats and marine fauna and the pristine nature of the marine and coastal environment.

The marine park contains vast intertidal sand and mudflats that extend up to 4 km wide at low tide and provide a rich source of food for many species. Eighty Mile Beach Marine Park is one of the world's most important feeding grounds for small wading birds that migrate to the area each summer, travelling from countries thousands of kilometres away (DPaW 2014) (see **section 9.2.1**).

11.1.15 Lalang-garram/ Horizontal Falls and North Lalang-garram Marine Parks

The Lalang-garram/ Horizontal Falls and North Lalang-garram Marine Parks were established in 2016 under the State Government's *Kimberley Science and Conservation Strategy* and are jointly managed by Dambimangari Traditional Owners and the Department of Parks and Wildlife (DPaW 2016). The marine parks fall within the west Kimberly region, included in the Australian National Heritage List for its nationally significant natural, indigenous and historic values (DoEE 2017).

The Lalang-garram/ Horizontal Falls Marine Park extends from Talbot Bay (*Ganbadba*) in the west to Walcott Inlet (*Iledda*) and Glenelg River (*Molor Moloiyn*) in the east and covers approximately 353,000 ha (DPaW 2016). The marine park protects the internationally recognised Horizontal Falls and is important for the region's tourism. The North Lalang-garram Marine Park lies between the Lalang-garram / Camden Sound and North Kimberley Marine Parks and covers approximately 110,000 ha (DPaW 2016).

The area's large tidal range results in extensive intertidal areas with diverse ecosystems such as fringing coral reefs, mangroves and mudflat communities. Subtidal habitats and communities common to the marine parks include filter feeding communities of sponges and hard and soft corals. These intertidal and subtidal habitats provide critical foraging and nursery areas for dugong, marine turtles, estuarine crocodiles, snubfin and Indo-Pacific humpback dolphins, several species of sawfish and migratory seabirds. The marine parks are also a principal calving habitat for humpback whales (DPaW 2016).

11.1.16 North Kimberley Marine Park

The North Kimberley Marine Park was established in December 2016 as a Class A marine park under the CPC (DPaW 2016a). The marine park comprises four separate management areas including, Uunguu, Balanggarra, Miriuwung Gajerrong, and Wilinggin. It is a multiple zone marine park that includes: eight sanctuary zones, nine special purpose zones (recreation and conservation), two special use zone (cultural heritage), and general use areas (DPaW 2016a). The marine park is managed in accordance with the provisions of the CALM Act with joint management between the Department of Parks and Wildlife and Traditional Owners of the area.

The area within the marine park is recognised for its Aboriginal cultural and heritage values, natural values including coral reefs, marine turtle species, dugongs, seagrass and macroalgal communities, mangroves and saltmarshes, finfish, and water and sediment quality, as well as for its social values (i.e. recreation, tourism and community values) and commercial values and resource use (e.g. commercial fishing). The marine park lies within the Indian Ocean and Timor Sea of Western Australia's Kimberley region, covering an area of approximately 1,845,000 hectares (DPaW 2016a). The south-western boundary is approximately 270 km northeast of Derby.

11.1.17 Yawuru Nagulagun/ Roebuck Bay Marine Park

The Yawuru Nagulagun/Roebuck Bay Marine Park was approved by the State Minister for Environment in October 2016 and declared as a Class A reserve over the subtidal and intertidal areas of Roebuck Bay (excluding the Kimberley Ports Authority waters), (DBCA, 2017). The Marine Park is managed with a joint management framework between Parks and Wildlife and Yawuru Registered Native Title Body Corporation (RNTBC). The intent is to manage the areas from the offshore waters around Roebuck and Broome, collectively referred to as the Yawuru conservation estate, as one ecological system (DPaW 2016b). The development of the joint management plan is in accordance with the Conservation and Land Management Act 1984 (Yawuru Organisation 2017) as well as contributes to the State Governments commitment under the Kimberly Science and Conservation Strategy, released in June 2011.

The Yawuru people have lived along the foreshores of Roebuck Bay for thousands of years, the Bay is part of the Yawuru traditional estate (DPaW 2016b). Roebuck Bay is an internationally significant Ramsar wetland, declared in 1990, and an important feeding ground for many species of migratory shorebirds. It hosts possibly the greatest diversity of shorebird species at any site across the globe (PaWS 2017). The Bay has some of the most productive tropical intertidal flats in the world, and is consequently an important ground for Yawuru fishing, hunting and gathering of sea food. The Bay hosts communities of seagrass and macroalgae, providing food for protected species such as the dugong and flatback turtle. Marine mammals also pass through the waters of the Bay such as the Australian snubfin dolphin and the humpback dolphin, the humpback whale can also be found during annual migration (DPaW 2016b).

12. Australian Marine Parks

12.1 Introduction

In agreement with the States and Northern Territory governments, the Australian Commonwealth government was committed to establish Commonwealth marine reserves as a component of the National Representative System of Marine Protected Areas (DoE 2014) (See **Figure 9-1, Figure** 9-2 and **Figure 9-3**). In November 2012, the Commonwealth Marine Reserves Network was proclaimed with the purpose of protecting the biological diversity and sustainable use of the marine environment (Director of National Parks 2012a). Commonwealth Marine Reserves were renamed as Australian Marine Parks in October 2017. Six marine regions are included in the Australian Marine Parks Network, including the Coral Sea, the South-west, the Temperate East, the South-east the North and the North-west. The South-east network 10-year Management Plan came into effect on 1 July 2013. The remaining networks 10-year Management Plans were approved and came into effect on 1 July 2018.

The new management plans establish the management and zoning of the designated marine parks. The marine park networks pertinent to the area of interest include:

+ The South-West Marine Parks Network;
+ The North-West Marine Parks Network; and
+ The North Marine Parks Network.

The South-West Marine ParksNetwork comprises 14 marine parks. Six of these occur in West Australian waters in the area of interest, including:

+ Abrolhos Commonwealth Marine Park;
+ Jurien Marine Park;
+ Two Rocks Marine Park;
+ Perth Canyon Marine Park;
+ Geographe Marine Park; and
+ South-west Corner Marine Park.

The North-West Marine Parks Network comprises 13 marine parks which all occur in West Australian waters pertinent to the area of interest:

+ Carnarvon Canyon Marine Park;
+ Shark Bay Marine Park;
+ Gascoyne Marine Park;
+ Ningaloo Marine Park;
+ Montebello Marine Park;
+ Dampier Marine Park;
+ Eighty Mile Beach Marine Park;
+ Argo-Rowley Terrace Marine Park;
+ Mermaid Reef Marine Park;
+ Roebuck Marine Park;
+ Kimberley Marine Park;

- Ashmore Reef Marine Park; and
- Cartier Island Marine Park.

The Northern Marine Parks Network comprises eight marine parks. However, only the Oceanic Shoals Marine Park extends across the boundary with the North-West Marine Parks Network, into the area of interest.

The sizes of these marine parks range from 300—152,000 km^2, and the water depths within the marine parks vary from approximately 15—1,500 m deep. The EPBC Act requires that each management plan assign an International Union for the Conservation of Nature (IUCN) category to each marine park. Additionally, the Act also allows for the management plan to divide a marine park into zones and to assign a category to each zone, which may differ from the overall category of the marine park. Zoning takes into account the purposes for which the marine parks were declared, the objectives of the relevant management plans, the values of the marine park and requirements of the EPBC Act and EPBC Regulations.

Five types of zone is represented within the North Marine Parks Network. However, it is only the Multiple Use Zone (IUCN Category VI) of the Oceanic Shoals Marine Park which extends into the area of interest.

The North-West Marine Parks Network includes six different types of zoning:

- Sanctuary Zone (IUCN Category Ia);
- National Park Zone (IUCN Category II);
- Recreational Use Zone (IUCN Category IV);
- Habitat Protection Zone (IUCN Category IV);
- Multiple Use Zone (IUCN Category VI); and
- Special Purpose Zone (Trawl) (VI).

The South-west Marin Parks Network includes six different types of zoning:

- National Park Zone (IUCN Category II);
- Habitat Protection Zone (IUCN Category IV);
- Multiple Use Zone (IUCN Category VI);
- Special Purpose Zone (Mining Exclusion) (IUCN Category VI);
- Special Purpose Zone (IUCN Category VI); and
- Special Purpose Zone (Trawl) (IUCN Category VI).

A summary of the South-West and North-West Marine Parks Networks is provided in Table 12-1.

12.2 South-West Marine Parks Network

The South-West Commonwealth Marine Parks Network is aligned to the South-West Marine Region. The network covers 508,371 km^2 and includes 14 marine parks (Director of National Parks, 2018a). Broad values of the South-west Australian Marine Parks include:

- Natural values;
- Cultural values;
- Heritage values; and
- Socio-economic values.

Further detail on each of the relevant marine parks those that fall within the area of interest is provided below.

12.2.1 Abrolhos Marine Park

The Abrolhos Marine Park (including zones within the area of interest: Marine National Park Zone – IUCN Category II-2,548 km^2; Habitat Protection Zone – IUCN Category VI-23,239 km^2; Multiple Use Zone – IUCN Category VI-56,545 km^2; Special Purpose Zone – IUCN Category VI-5,729 km^2) covers and area of approximately 88,060 km^2 and protects the following conservation values (Director of National Parks, 2018a):

- Important foraging areas for the:
  - Threatened Australian lesser noddy;
  - Northernmost breeding colony of the threatened Australian sea lion;
  - Great white sharks; and
  - Migratory common noddy, wedge-tailed shearwater, bridled tern, Caspian tern and roseate tern.
- Important migration habitat for the protected humpback whale and pygmy blue whales;
- The second largest canyon on the west coast, the Houtman Canyon;
- Examples of the northernmost ecosystems of the Central Western Province and South-west Shelf Transition (including the Central West Coast meso-scale bioregion);
- Examples of the deeper ecosystems of the Abrolhos Islands meso-scale bioregion;
- Examples of the shallower, southernmost ecosystems of the Central Western Shelf Province provincial bioregion including the Zuytdorp meso-scale bioregion;
- Examples of the deeper ecosystems of the Central Western Transition provincial bioregion;
- Examples of diversity of seafloor features including: southern most banks and shoals of the North-west region; deep holes and valleys; slope habitats; terrace and shelf environments; and
- Seven key ecological features.

The Abrolhos Marine Park is adjacent to the Shark Bay World Heritage Property. The marine park does not contain any Commonwealth or National Heritage listings (Director of National Parks 2018a). The marine park contains 11 known shipwrecks listed under the *Historic Shipwrecks Act 1976*[14]. Commercial tourism, fishing, recreation and mining are important supported socio-economic activities in the park.

12.2.2 Jurien Marine Park

The Jurien Marine Park (including zones within the area of interest): Marine National Park Zone -IUCN Category II – 31 km^2 Special Purpose Zone -IUCN Category VI – 1,820 km^2) covers and area of approximately 1,851 km^2 and protects the following conservation values (Director of National Parks 2018a):

- Important foraging areas for the:
  - Threatened soft-plumaged petrel;
  - Threatened Australian sea lion;
  - Threatened white shark; and
  - Migratory roseate tern, bridled tern, wedge-tailed shearwater, and common noddy.
- Important migration habitat for the protected humpback whale;

[14] Note that the *Underwater Culture Heritage Act 2018* has been passed on 24 August 2018, however it has yet to commence, due to commence prior to 24 August 2019.

- Examples of the ecosystems of two provincial bioregions: the central part of the South-west Shelf Transition (which includes the Central West Coast meso-scale bioregion) and small parts of the Central Western Province;
- Three key ecological feature; and
- Heritage values represented by the SS Cambewarra and Oleander historic shipwreck.

The Jurien Marine Park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018a). Commercial tourism, fishing, recreation and mining are important supported socio-economic activities in the park.

12.2.3 Two Rocks Marine Park

The Two Rocks Marine Park (including zones within the area of interest): Multiple Use Zone - IUCN Category VI – 867 km^2; Marine National Park Zone - IUCN Category II – 15 km^2) covers an area of approximately 882 km^2 and protects the following conservation values (Director of National Parks 2018a):

- Important foraging areas for the:
  - Threatened soft-plumaged petrel;
  - Threatened Australian sea lion; and
  - Migratory roseate tern, bridled tern, Caspian tern, wedge-tailed shearwater, and common noddy.
- Important migratory areas for protected humpback whales and pygmy blue whales;
- Seasonal calving habitat for the threatened southern right whale;
- Examples of the ecosystem of the southernmost parts of the South-west Shelf Transition (including the Central West Coast meso-scale bioregion); and
- Three key ecological features.

The Two Rocks marine park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018a). Commercial tourism, fishing, recreation and scientific research are important supported socio-economic activities in the park.

12.2.4 Perth Canyon Marine Park

Perth Canyon Marine Park (including zones within the area of interest): Marine National Park Zone – IUCN Category II – 1,241 km^2; Habitat Protection Zone – IUCN Category IV –4,352 km^2; Multiple Use Zone – IUCN Category VI – 1,816 km^2) covers an area of approximately 7,409 km^2 and protects the following conservation values (Director of National Parks 2018a):

- Globally important seasonal feeding aggregation for the threatened blue whale;
- Important foraging areas for the:
  - Threatened soft-plumaged petrel;
  - Migratory sperm whale; and
  - Migratory wedge-tailed shearwater.
- Important migratory areas for protected humpback whales and blue whales;
- Seasonal calving habitat for the threatened southern right whale;
- Examples of the ecosystems of the southernmost parts of the Central Western Province and South-west Shelf Transition (including the Central West Coast meso-scale bioregion), and the northernmost parts of the South-west Transition and Southwest Shelf Province (including the Leeuwin-Naturaliste meso-scale bioregion); and

- Four key ecological features.

The Perth Canyon marine park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018a). Commercial tourism, fishing, shipping, recreation and defence training are important supported socio-economic activities in the park.

12.2.5 Geographe Marine Park

Geographe Marine Park (including zones within the area of interest): Marine National Park Zone - IUCN Category II – 15 km^2; Special Purpose Zone - IUCN VI – 650 km^2; Multiple Use Zone - IUCN Category VI – 291 km^2; Habitat Protection Zone (IV) 21 km^2) covers an area of approximately 977 km^2 and protects the following conservation values (Director of National Parks 2018a):

- Important foraging areas for the:
  - Threatened soft-plumaged petrel; and
  - Migratory wedge-tailed shearwater.
- Important pre-migration aggregation area for the migratory flesh-footed shearwater;
- Important migratory habitat for the protected humpback whale and blue whale;
- Seasonal calving habitat for the threatened southern right whale.
- Seasonal calving habitat for the threatened southern right whale.
- Representation of the South-west Shelf Province on the continental shelf as well as the Leeuwin-Naturaliste meso-scale bioregion;
- Two key ecological features; and
- Representation of the seagrass habitats of the Geographe Bay key ecological feature, which in this location extend the furthest into Commonwealth waters.

The Geographe marine park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018a). The marine park contains eight known shipwrecks listed under the *Historic Shipwrecks Act 1976*[15]*.* Commercial tourism, fishing and recreation are important supported socio-economic activities in the park.

12.2.6 South-west Corner Marine Park

The South-west Corner Marine Park (including zones within the area of interest: Marine National Park Zone - IUCN II – 54,841 km2; Multiple Use Zone - IUCN VI –106,602km2; Special Purpose Zone (Mining exclusion) - IUCN VI – 9,550 km2, Special Purpose Zone – IUCN VI – 5753 km2; Habitat Protection Zone - IUCN IV – 95,088 km2) covers an area of approximately 271,833 km2 within the area of interest and protects the following conservation values (Director of National Parks 2018a):

- Important migratory area for protected humpback whales and blue whales;
- Important foraging areas for the:
  - Threatened white shark;
  - Threatened Australian sea lion;
  - Threatened Indian Yellow-nosed albatross and soft-plumaged petrel;
  - Sperm whale;

[15] Note that the *Underwater Culture Heritage Act 2018* has been passed on 24 August 2018, however it has yet to commence, due to commence prior to 24 August 2019

- o Migratory flesh-footed shearwater, short-tailed shearwater and Caspian tern; and

+ Seasonal calving habitat for the threatened southern right whale.
+ Representation of three provincial bioregions (the South-west Transition and Southern Province in the off-shelf area, and the South-west Shelf Province on the continental shelf) and two meso-scale bioregions (southern end of the Leeuwin-Naturaliste meso-scale bioregion and western and central parts of the Western Australia South Coast meso-scale bioregion); and
+ Representation of the Donnelly Banks, east of Augusta, characterised by higher productivity and including nursery habitats.
+ Six key ecological features.
+ The marine park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018a). The marine park contains ten known shipwrecks listed under the *Historic Shipwrecks Act 1976*[15]. Commercial tourism, fishing, shipping and recreation are important supported socio-economic activities in the park.

12.3 North-West Marine Park Network

The Nouth-West Marine Parks Network is aligned to the North-west Marine Region. The network covers 335, 341 km^2 and includes 13 marine parks (Director of National Parks, 2018b). Broad values of the Nouth-west Commonwealth Marine Reserves Network include:

+ Natural values;
+ Cultural values;
+ Heritage values; and
+ Socio-economic values.

Further detail on each of the relevant marine parks within the area of interest is provided below.

12.3.1 Carnarvon Canyon Marine Park

The Carnarvon Canyon Marine Park (Habitat Protection Zone – IUCN Category IV) covers an area of approximately 6,177 km^2 and protects the following conservation values (Director of National Parks 2018b):

+ The Carnarvon Canyon a single channel canyon with seabed features that include slope, continental rise and deep holes and valleys;
+ The Carnarvon Canyon ranges in depth from 1500 m to over 5,000 m, thereby providing habitat diversity for benthic and demersal species; and
+ Central Western Transition provincial bioregion ecosystem examples are found here, which are characteristic of the biogeographic faunal transition between tropical and temperate species.
+ There is limited information about species' use of this Marine Park (Director of National Parks 2017b). The marine park does not contain any international, Commonwealth or National Heritage listings (Director of National Parks 2018b). Commercial fishing, tourism, shipping and mining are important supported socio-economic activities in the marine park.

12.3.2 Shark Bay Marine Park

The Shark Bay Marine Park (Multiple Use Zone – IUCN Category VI) covers an area of approximately 7,443 km^2 and protects the following conservation values (Director of National Parks 2018b):

+ Foraging areas adjacent to important breeding areas for several species of migratory seabirds;
+ Part of the migratory pathway of protected humpback whales;

- Internesting habitat for marine turtles;
- Waters that are adjacent to the largest nesting area for loggerhead turtles in Australia;
- Marine park and adjacent coastal areas important for shallow-water snapper;
- Protection to shelf and slope habitats as well as a terrace feature;
- Examples of the shallower ecosystems of the Central Western Shelf Province and Central Western Transition provincial bioregions including the Zutydorp meso-scale bioregion; and
- Connectivity between the inshore waters of the Shark Bay World Heritage Area and the deeper waters of the area.

Whilst no listed international, Commonwealth or National Heritage places are within the marine park, the park is adjacent to Shark Bay World Heritage Area (Director of National Parks 2018b). Commercial tourism, fishing, mining and recreation are important socio-economic values of the park.

12.3.3 Gascoyne Marine Park

The Gascoyne Marine Park (Multiple Use Zone – IUCN Category VI-33,652 km^2; Habitat Protection Zone – IUCN Category IV-38,982 km^2; Marine National Park Zone – IUCN Category II-9,132 km^2) covers an area of approximately 81,766 km^2 and protects the following conservation values (Director of National Parks 2018a):

- Important foraging areas for: migratory seabirds threatened and migratory hawksbills and flatback turtles; and vulnerable and migratory whale shark;
- A continuous connectivity corridor from shallow depths around 15 m out to deep offshore waters on the abyssal plain at over 5,000 m in depth;
- Seafloor features including canyon, terrace, ridge, knolls, deep hole/valley and continental rise. It also provides protection for sponge gardens in the south of the reserve adjacent to Western Australian coastal waters;
- Ecosystems examples from the Central Western Shelf Transition, the Central Western Transition and the Northwest province provincial bioregions as well as the Ningaloo meso-scale bioregion;
- Four key ecological features for the region:
  - Canyons on the slope between the Cuvier Abyssal Plain and the Cape Range Peninsula (enhanced productivity, aggregations of marine life and unique sea-floor feature);
  - Exmouth Plateau (unique sea-floor feature associated with internal wave generation);
  - Continental slope demersal fish communities (high species diversity and endemism – the most diverse slope bioregion in Australia with over 500 species found with over 64 of those species occurring nowhere else); and
  - Commonwealth waters adjacent to Ningaloo Reef.
- The canyons in this reserve are believed to be associated with the movement of nutrients from deep water over the Cuvier Abyssal Plain onto the slope where mixing with overlying water layers occurs at the canyon heads. These canyon heads, including that of Cloates Canyon, are sites of species aggregation and are thought to play a significant role in maintaining the ecosystems and biodiversity associated with the adjacent Ningaloo Reef; and
- The reserve therefore provides connectivity between the inshore waters of the existing Ningaloo Commonwealth marine park and the deeper waters of the area.

The park is also adjacent to World Heritage listings associated with the Ningaloo Coast. Commercial tourism, commercial fishing, mining and recreation are important socio-economic values of the park (Director of National Parks 2018b).

12.3.4 Ningaloo Marine Park

Ningaloo Marine Park stretches approximately 300 km along the west coast of the Cape Range Peninsula and is adjacent to the Western Australian Ningaloo Marine Park and Gascoyne Marine Park (Director of National Parks, 2018b). Ningaloo Reef is the longest fringing barrier reef in Australia forming a discontinuous barrier that encloses a lagoon that varies in width from 200 m to 7 km. Gaps that regularly intercept the main reef line provide channels for water exchange with deeper, cooler waters (CALM 2005). It is the only example in the world of extensive fringing coral reef on the west coast of a continent.

The Ningaloo Marine Park (Recreational Use Zone – IUCN Category II) covers an area of approximately 2,435 km^2 and protects the following conservation values (Director of National Parks 2018a):

+ Important habitat (foraging areas) for vulnerable and migratory whale sharks;
+ Areas used for foraging by marine turtles adjacent to important internesting sites;
+ Part of the migratory pathway of the protected humpback whale;
+ Foraging and migratory pathway for pygmy blue whales;
+ Breeding, calving, foraging and nursing habitat for dugong;
+ Shallow shelf environments which provides protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features;
+ Seafloor habitats and communities of the Central Western Shelf Transition;
+ Three key ecological features; and
+ The Ningaloo Coast World Heritage Property, the Ningaloo Coast National Heritage listing and Ningaloo Marine Area Commonwealth Heritage Listing.

Commercial tourism and recreation are important socio-economic values of the marine park (Director of National Parks 2018b).

12.3.5 Montebello Marine Park

The Montebello Marine Park is located offshore of Barrow Island and 80 km west of Dampier extending from the Western Australian state water boundary, and is adjacent to the Western Australian Barrow Island and Montebello Islands Marine Parks. The Montebello Marine Park (Multiple Use Zone – IUCN Category VI) covers an area of approximately 3,413 km^2 and protects the following conservation values (Director of National Parks 2018b):

+ Foraging areas for migratory seabirds that are adjacent to important breeding areas;
+ Areas used by vulnerable and migratory whale sharks for foraging;
+ Foraging areas marine turtles which are adjacent to important nesting sites;
+ Section of the north and south bound migratory pathway of the humpback whale;
+ Shallow shelf environments with depths ranging from 15–150 m which provides protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features;
+ Seafloor habitats and communities of the Northwest Shelf Province provincial bioregions as well as the Pilbara (offshore) meso-scale bioregion; and
+ One key ecological feature for the region is the ancient Coastline (a unique seafloor feature that provides areas of enhanced biological productivity).

Commercial tourism, commercial fishing, mining and recreation are important socio-economic values for the park.

12.3.6 Dampier Marine Park

The Dampier Marine Park (Marine National Park Zone – IUCN Category I-73 km^2; Habitat Protection Zone – IUCN Category IV-104 km^2; Multiple Purpose Zone – IUCN Category VI-1,074 km^2) covers an area of approximately 1,252 km^2 and protects the following conservation values (Director of National Parks 2018b):

- Foraging areas for migratory seabirds that are adjacent to important breeding grounds;
- Important foraging areas for marine turtles adjacent to significant nesting sites;
- Part of the migratory pathway of the protected humpback whale;
- Protection for offshore shelf habitats and shallow shelf habitats adjacent to the Dampier Archipelago; and
- Communities and seafloor habitats of the Northwest Shelf Province provincial bioregion as well as the Pilbara (nearshore) and Pilbara (offshore) meso-scale bioregions are included.

Port activities, commercial fishing and recreation are important activities in the marine park (Director of National Parks 2018b). No heritage listings apply to the marine park.

12.3.7 Eighty Mile Beach Marine Park

The Eighty Mile Beach Marine Park (Multiple Use Zone – IUCN Category VI) covers an area of approximately 10,785 km^2 and protects the following conservation values (Director of National Parks 2018b):

- Foraging areas for migratory seabirds that are adjacent to important breeding grounds**;**
- Important foraging areas for marine turtles adjacent to significant nesting sites**;**
- Part of the migratory pathway of the protected humpback whale**;**
- Areas adjacent to important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish;
- Protection for terrace, banks and shoal habitats on the shelf, with depths ranging from 15–70 m**;** and
- Communities and seafloor habitats of the Northwest Shelf Province provincial bioregion and the Canning, Northwest Shelf, Pilbara (nearshore), Pilbara (offshore) and Eighty Mile Beach meso-scale bioregions; and
- Sea country valued for indigenous cultural identity, health and well-being for the Nyangumarta, Ngarla and the Karajarri people (Director of National Parks 2018b).
- No heritage listings apply to the marine park. Commercial tourism, fishing, pearling and recreation are important socio-economic values of the marine park (Director of National Parks 2018b).

12.3.8 Argo-Rowley Terrace Marine Park

The Agro-Rowley Marine Park is located approximately 270 km north-west of Broome, Western Australia, and extends to the limit of Australia's exclusive economic zone. The Marine Park (Multiple Use Zone – IUCN Category VI-108,812 km^2; Marine National Park Zone – IUCN Category II-36,050 km^2; Special Purpose Zone – IUCN Category VI-1,141 km^2) covers an area of approximately 146,003 km^2 and protects the following conservation values (Director of National Parks 2018b):

- Foraging areas that are important for migratory seabirds as well as the endangered loggerhead turtle;
- Important habitat and foraging for sharks;
- Migratory pathway for pygmy blue whales (Director of National Parks 2018b);
- Protection for communities and habitats of the deeper offshore waters (220 m to over 5,000 m) of the region;

- Seafloor features including aprons and fans, canyons, continental rise, knolls/abyssal hills and the terrace and continental slope;
- Communities and seafloor habitats of the Northwest Transition and Timor Province provincial bioregions;
- Connectivity between the existing Mermaid Reef Marine National Nature Reserve and reefs of the Western Australian Rowley Shoals Marine Park and the deeper waters of the region;
- Two key ecological features in the reserve include:
  - The canyons linking the Argo Abyssal Plain with the Scott Plateau (unique seafloor feature with enhanced productivity and feeding aggregations of species); and
  - Mermaid Reef and the Commonwealth waters surrounding Rowley Shoals (an area of high biodiversity with enhanced productivity and feeding and breeding aggregations).

No heritage listings apply to this marine park (Director of National Parks 2018b). Commercial fishing, mining and recreation are important socio-economic values for the park.

12.3.9 Mermaid Reef Marine Park

The Mermaid Reef Marine Park (Sanctuary Zone – IUCN Category Ia) covers an area of approximately 540 km^2. During periods of high tide, Mermaid Reef is completely submerged underwater, and therefore, is under the legal jurisdiction of the Australian Commonwealth government (DSEWPaC 2012). The reef is listed on Australia's Commonwealth Heritage List and protects the following conservation values (DoE 2014):

- National and international significant habitats including, coral formations, geomorphic features and diverse marine life;
- Key area for over 200 species of hard corals and 12 classes of soft corals with coral formations in pristine condition;
- Important areas for sharks including the grey reef shark, the white tip reef shark and the silvertip whaler;
- Important foraging area for marine turtles;
- Important area for toothed whales, dolphins, tuna and billfish;
- Important resting and feeding sites for migratory seabirds;
- A migratory pathway for the pygmy blue whale (Director of National Parks 2018b);
- The reserve, along with nearby Rowley Shoals Marine Park, provides the best geological example of shelf atolls in Australia; and
- Examples of the seafloor habitats and communities of the Northwest Transition.

The Mermaid Reef-Rowley Shoals Commonwealth Heritage Listing is located in this marine park. No international or National Heritage listings apply to this park (Director of National Parks 2018b). Commercial tourism, recreation and scientific research are important socio-economic values of this marine park.

12.3.10 Roebuck Marine Park

The Roebuck Marine Park (Multiple Use Zone – IUCN Category VI) covers an area of approximately 304 km^2 and protects the following conservation values (Director of National Parks 2018b):

- Foraging habitat area for migratory seabirds adjacent to important breeding areas;
- Foraging area adjacent to important nesting sites for flatback turtles;
- Parts of the migratory pathway of the protected humpback whale;
- Habitat adjacent to important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish;

- Foraging and calving areas for Australian snubfin, Indo-Pacific humpback and Indo-Pacific bottlenose dolphins;
- Foraging habitat for dugong;
- Protection for shallow shelf habitats ranging in depth from 15–70 m;
- Ecosystems example of the Northwest Shelf Province provincial bioregion and the Canning meso-scale bioregion; and
- Sea country valued for indigenous cultural identity, health and well-being for the Yawuru people (Director of National Parks 2018b).

No heritage listings apply to the marine park. Commercial tourism, fishing, pearling and recreation are important socio-economic values of the marine park (Director of National Parks 2017b).

12.3.11 Kimberley Marine Park

The Kimberley Marine Park (Multiple Use Zone – IUCN Category VI-62,411 km^2; Habitat Protection Zone – IUCN Category IV-5,665 km^2; Marine National Park Zone – IUCN Category II-6,392 km^2) covers an area of approximately 74,469 km^2 and protects the following conservation values (Director of National Parks 2018b):

- Important foraging areas for migratory seabirds, migratory dugongs, dolphins and threatened and migratory marine turtles;
- Important migration pathway and nursery areas for the protected humpback whale;
- Migratory pathway for pygmy blue whales (Director of National Parks 2017b);
- Foraging habitat for whale sharks (Director of National Parks 2017b);
- Adjacent to important foraging and pupping areas for sawfish and important nesting sites for green turtles;
- Protection for communities and habitats of waters offshore of the Kimberley coastline (ranging in depth from less than 15–800 m);
- Representation of continental shelf, slope, plateau, pinnacle, terrace, banks and shoals and deep hole/valley seafloor features;
- Communities and seafloor habitats of the Northwest Shelf Transition, Northwest Shelf Province and Timor Province provincial bioregions along with the Kimberley, Canning, Northwest Shelf and Oceanic Shoals meso-scale bioregions; and
- Two key ecological features included in the reserve are:
  - Ancient coastline (an area of enhanced productivity attracting baitfish which, in turn, supplies food for migrating species); and
  - Continental slope demersal fish communities (the second richest area for demersal fish species in Australia).

The marine park also holds cultural values of Sea country, valued for indigenous cultural identity, health and well-being for the Wunambal Gaambera, Dambimangari, Bardi Jawi and the Nyul Nyul people (Director of National Parks 2018b). No heritage listings apply to the marine park. Commercial tourism, commercial fishing, mining, recreation and traditional use are important socio-economic values of the marine park (Director of National Parks 2018b).

12.3.12 Ashmore Reef Marine Park

The Ashmore Reef Marine Park (Sanctuary Zone – IUCN Category Ia; Recreational Use Zone – IUCN Category II) covers an area of approximately 583 km^2 (Director of National Parks 2018b). It forms part of the North-west Park Network. As the only oceanic reef in the north-east Indian Ocean with vegetated islands (East, Middle and West Islands), Ashmore is also the largest of three emergent, oceanic reefs in the region

(DSEWPaC 2012). Both the Ashmore and Cartier Islands fall under the legal memorandum of understanding between Indonesia and Australia, as both areas are located within Australia's external territory (DSEWPaC 2012).

Ashmore Reef Marine Park is located on Australia's North West Shelf in the Indian Ocean, about 450 nautical miles (840 km) west of Darwin and 330 nautical miles (610 km) north of Broome. The reserve covers 583 km^2 and includes two extensive lagoons, shifting sand flats and cays, seagrass meadows, a large reef flat covering an area of 239 km^2. Within the reserve are three small islands known as East, Middle and West Islands (DoE, 2002).

Ashmore was designated a Ramsar Wetland of International Importance in 2003 due to the importance of its islands providing a resting place for migratory shorebirds and supporting large seabird breeding colonies.

The proclaimed marine park will protect the following conservation values (DoE 2014):

+ Ecosystems, habitats and communities associated with; the North West Shelf; Timor Province; and emergent oceanic reefs;
+ The island and reef habitats:
  - Contains critical nesting and internesting habitat for green turtles (including one of three genetically distinct breeding populations in the North-west Marine Region). Low level nesting activity by loggerhead turtles has also been recorded;
  - Large and significant feeding populations of green, hawksbill and loggerhead turtles occur around the reefs (it is estimated that approximately 11,000 marine turtles feed in the area throughout the year);
  - Supports a small dugong population of less than 50 individuals that breed and feed around the reef. This population is thought to be genetically distinct from other Australian populations;
  - Migratory pathway for pygmy blue whales (Director of National Parks 2018b);
  - Support some of the most important seabird rookeries on the North West Shelf including colonies of bridled terns, common noddies, brown boobies, eastern reef egrets, frigatebirds, tropicbirds, red-footed boobies, roseate terns, crested terns and lesser crested terns;
  - Is an important staging points/feeding areas for many migratory seabirds; and
  - Is internationally significant for its abundance and diversity of sea snakes.
+ Two key ecological features:
  - Ashmore Reef and Cartier Island and surrounding Commonwealth waters; and
  - Continental slope demersal fish communities (Director of National Parks 2018b);
+ Cultural and heritage sites, including;
  - Ashmore lagoon as a rest/staging area for traditional Indonesian fishers
  - Indonesian artefacts; and
  - Grave sites.
+ Commonwealth heritage listing – Ashmore Reef

Ashmore Reef and nearby islands and reefs are associated with benthic communities consisting predominantly of sand and coral rubble, with noteworthy hard coral, soft coral, algae and seagrasses (Heyward et al., 2012; Skewes et al., 1999a, 1999b). The reefs host similar benthic communities, with areas of relatively high live coral cover, although episodes of coral bleaching have been recorded (Heyward et al., 2012). Benthic organisms that depend on photosynthesis such as seagrasses, macroalgae and zooxanthellate corals are typically restricted to shallower waters around the reefs, although in the clear tropical waters may be found at considerable depths. Given the shallowest sampling location is greater than 60 m, and that most sampling locations are greater than 100 m deep, diverse benthic communities driven by primary producers such as seagrasses, algae and zooxanthellate corals are not expected to occur at the sampling locations. Data collected in the vicinity of Ashmore Reef indicates that corals are likely to spawn during March and April (Heyward et al., 2010).

Soft sediments are widespread in the region, with sediment infauna communities in the region dominated by polychaetes and crustaceans. These taxa accounted for over 80% of benthic infauna sampled, both in terms of numbers of species and individual organisms (Smith *et al.,* 1997).

Commercial tourism, recreation and scientific research are important socio-economic values of the marine park (Director of National Parks 2017b).

12.3.13 Cartier Island Marine Park

The Cartier Island Marine Park (Sanctuary Zone – IUCN Category Ia), the legal jurisdiction of Cartier Island is a memorandum of understanding between Indonesia and Australia, as the island is located in Australia's external territory (DSEWPaC 2012). The reserve covers an area of approximately 172 km^2, which contains an unvegetated island, mature reef, a submerged pinnacle and two shallow pools (DSWEPaC 202). The marine reserve protects the following conservation values (DoE 2014):

- Ecosystems, habitats and communities associated with; the North West Shelf; Timor Province; and emergent oceanic reefs;
- Cartier Island is an important area for protected species including large and significant feeding populations of green, hawksbill and loggerhead turtles;
- Important seabird rookeries on the North West Shelf including colonies of bridled terns, common noddies, brown boobies, eastern reef egrets, frigatebirds, tropicbirds, red-footed boobies, roseate terns, crested terns and lesser crested terns;
- Important staging points/feeding areas for many migratory seabirds;
- Internationally significant abundance and diversity of sea snakes;
- Foraging habitat for whale sharks (Director of National Parks 2018b);
- Two key ecological features:
- Ashmore Reef and Cartier Island and surrounding Commonwealth waters; and
- Continental slope demersal fish communities (Director of National Parks 2017b)
- Ann Millicent historic shipwreck is an important cultural and heritage site; and
- Scientific research as an important activity occurring in the park (Director of National Parks 2017b).

12.4 North Marine Park Network

The North Park Network is aligned to the North Marine Region. The network covers 157,480 km^2 (Director of National Parks, 2018c). Broad values of the North Network include:

- Natural values;
- Cultural values;
- Heritage values; and
- Socio-economic values.

Further detail on the applicable Oceanic Shoals Marine Park is provided below.

12.4.1 Oceanic Shoals Marine Park

The Oceanic Shoals Marine Park (zones within area of interest: Multiple Use Zone - IUCN Category VI-32,488 km^2; Special Purpose Zone – IUCN VI-24,443 km^2) covers an area of approximately 56,931 km^2 within the area of interest.

The marine park protects the following conservation values (DoE 2014):

+ Important resting area for turtles between egg laying (internesting area) for the threatened flatback turtle and olive ridley turtle;
+ Important foraging area for the threatened loggerhead turtle and olive ridley turtle;
+ Examples of the ecosystems of two provincial bioregions: the Northwest Shelf Transition Province (which includes the Bonaparte, Oceanic Shoals, and Tiwi meso-scale bioregions) and the Timor Transition Province;
+ Key ecological features represented in the park are:
  - carbonate bank and terrace system of the Van Diemen Rise (unique sea-floor feature);
  - carbonate banks and terrace system of the Sahul Shelf (unique sea-floor feature);
  - pinnacles of the Bonaparte Basin (enhanced productivity, unique sea-floor feature); and
  - shelf break and slope of the Arafura Shelf (unique sea-floor feature) (Director of National Parks 2018c).

No heritage listings apply to the marine park. Commercial fishing and mining are important socio-economic values for the park (Director of National Parks 2018c).

Table 12-1 Summary of marine network values, pressures, management programs and actions applicable to the area of interest

Marine Network	Values	Pressures	Management Programs & Actions
SOUTH WEST	• Nine bioregions • Key ecological features • EPBC listed species • Biologically important areas • Sea country indigenous values • Historic shipwrecks • Adjacent to Shark Bay World Heritage Area • Shipping and port activities • Commercial fishing • Marine tourism	• Climate change • Hydrological changes from coastal development and agriculture (increase sediment loads and pollutants) • Illegal/unregulated/unreported fishing • Bycatch of non-target species • Habitat modification from mining • Human presence • Invasive species • Marine pollution	• Communication, education and awareness programs • Promote suitable tourism experience • Facilitate partnerships between tourism operators and Indigenous operators • Indigenous engagement program • Marine monitoring programs • Park management via assessments/authorisation program for marine park activities • Marine park management and development of suitable infrastructure • Compliance planning and surveillance
NORTH WEST	• Eight bioregions • Key ecological features • EPBC listed species • Biologically important areas • Sea country indigenous values • Native title determinations • Traditional Indonesian fishers • World Heritage Properties (Ningaloo Coast, Shark Bay) • Ashmore Reef Marine Park Ramsar site • Shipping and port activities • Commercial fishing, pearling, aquaculture • Marine tourism	• Climate change • Hydrological changes from coastal development and agriculture (increase sediment loads and pollutants) • Illegal/unregulated/unreported fishing • Bycatch of non-target species • Habitat modification from mining • Human presence • Invasive species • Marine pollution	• Communication, education and awareness programs • Promote suitable tourism experience • Facilitate partnerships between tourism operators and Indigenous operators • Indigenous engagement program • Marine monitoring programs • Park management via assessments/authorisation program for marine park activities • Marine park management and development of suitable infrastructure • Compliance planning and surveillance

13. Conservation Management Plans

In order to protect, maintain and enhance recovery of certain threatened species and ecological communities the DoEE may prepare conservation management plans in the form of Conservation Advice or Recovery Plans.

13.1 Conservation Advice

When a native species or ecological community is listed as threatened under the EPBC Act, conservation advice is developed to assist its recovery. Conservation advice provides guidance on immediate recovery and threat abatement activities that can be undertaken to ensure the conservation of a newly listed species or ecological community.

13.2 Recovery Plans

The Australian Government Minister for the Environment may make or adopt and implement recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and threatened ecological communities listed under the Commonwealth EPBC Act. Recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long-term survival in the wild of a threatened species or ecological community.

Table 13-1: Summary of EPBC Act recovery plans applicable to the area of interest

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
Bird	Australian Lesser Noddy	Approved Conservation Advice for *Anous tenuirostris melanops* (Australian lesser noddy) (2015)	Habitat modification by pied cormorants
			Catastrophic destruction of habitat by cyclones
	Christmas Island Frigatebird	National recovery plan for the Christmas Island Frigatebird (*Fregata andrewsi*) (2004)	Habitat loss
			Crazy ants
			Dust from phosphate dryers
			Storms
			Fire
			Diseases
			Weeds
	Australasian Bittern	Approved Conservation Advice for *Botaurus poiciloptilus* (Australasian Bittern) (2011)	Reduction in extent and quality of habitat due to the diversion of water away from wetlands
			Drainage of swamps
			Loss or alteration of wetland habitats due to clearing for urban and agricultural development
			Peat mining
			Predation by introduced vertebrate pests such as foxes and cats
			Reduced water quality as a result of increasing salinity, siltation and pollution
			Overgrazing by livestock
			Detrimental fire regimes
	Red Knot	Approved Conservation Advice for *Calidris canutus* (Red knot) (2016)	Habitat loss and habitat degradation
			Over-exploitation of shellfish
			Pollution/contamination impacts

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Disturbance
			Direct mortality (hunting)
			Diseases
			Extreme weather events
			Climate change impacts
	Curlew Sandpiper	Approved Conservation Advice for *Calidris ferruginea* (Curlew Sandpiper) (2015)	Ongoing human disturbance
			Habitat loss and degradation from pollution
			Changes to the water regime
			Invasive plants
	Great Knot	Approved Conservation Advice for *Calidris tenuirostriss* (Great knot) (2016)	Habitat loss and habitat degradation
			Pollution/contaminants
			Disturbance
			Diseases
			Direct mortality (hunting)
			Climate change impacts
	Greater Sand Plover	Approved Conservation Advice for *Charadrius leschenaultii* (Greater sand plover) (2016)	Habitat loss and habitat degradation
			Pollution/contamination impacts
			Disturbance
			Direct mortality (hunting)
			Diseases
			Climate change impacts
	Lesser Sand Plover	Approved Conservation Advice for *Charadrius mongolus* (Lesser sand plover) (2016)	Habitat loss and habitat degradation
			Pollution/contamination impacts

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Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Disturbance
			Direct mortality (hunting)
			Diseases
			Climate change impacts
	Amsterdam Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Tristan Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Southern Royal Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Wandering Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Loss of nesting habitat
			Competition for nest space
	Northern Royal Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Blue Petrel	Approved Conservation Advice for *Halobaena caerulea* (blue petrel) (2015)	Habitat loss, disturbance and modification
			Predation
	Western Alaskan Bar-tailed Godwit	Approved Conservation Advice for *Limosa lapponica baueri* (Bar-tailed godwit (western Alaskan)) (2016)	Habitat loss and habitat degradation
			Over-exploitation of shellfish
			Pollution/contamination impacts
			Disturbance
			Direct mortality (hunting)
			Diseases
			Extreme weather events
			Climate change impacts

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
	Northern Siberian Bar-tailed Godwit	Approved Conservation Advice for *Limosa lapponica menzbieri* (Bar-tailed godwit (northern Siberian)) (2016)	Habitat loss and habitat degradation
			Over-exploitation of shellfish
			Pollution/contamination impacts
			Disturbance
			Direct mortality (hunting)
			Diseases
			Extreme weather events
			Climate change impacts
	Southern Giant Petrel	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Northern Giant Petrel	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Eastern Curlew	Approved Conservation Advice *for Numenius madagascariensis* (Eastern Curlew) (2015)	Ongoing human disturbance
			Habitat loss and degradation from pollution
			Changes to the water regime
			Invasive plants
	Fairy Prion (southern)	Approved Conservation Advice for *Pachyptila turtur subantarctica* (fairy prion (southern)) (2015)	Competition with blue petrels
			Soil erosion
			Fire
	Abbott's Booby	Approved Conservation Advice for *Papasula abbotti* (Abbott's booby) (2015)	Clearance of about a third of the former nesting rainforest habitat
			Crazy ants
	Christmas Island White-tailed Tropicbird	Conservation Advice for *Phaethon lepturus fulvus* white-tailed tropicbird (Christmas Island) (2014)	Introduced predators on Christmas Island
			Crazy ants
	Sooty Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Soft-plumaged Petrel	Approved Conservation Advice for *Pterodroma mollis* (soft-plumaged petrel) (2015)	Accidental introduction of predators
	Australian Painted Snipe	Commonwealth Conservation Advice on *Rostratula australis* (Australian Painted Snipe) (2013)	Loss and degradation of wetlands, through drainage and the diversion of water for agriculture and reservoirs
	Australian Fairy Tern	Commonwealth Conservation Advice on *Sternula nereis nereis* (Fairy Tern) (2011)	Predation by introduced mammals and native birds
			Disturbance by humans, dogs and vehicles
			Increasing salinity in waters adjacent to Fairy Tern colonies
			Irregular water management
			Weed encroachment
			Oil spills, particularly in Victoria
	Indian Yellow-nosed Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Shy Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	White-capped Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Loss of nesting habitat
			Competition for nest space
	Campbell Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat
			Competition for nest space
	Black-browed Albatross	National recovery plan for threatened albatrosses and giant petrels 2011-2016 (2011)	Incidental catch resulting from fishing operations
			Competition with fisheries for marine resources
			Dependence on discards
			Marine pollution
			Climate change
			Intentional shooting/killing
			Feral pest species
			Human disturbance at the nest
			Parasites and diseases
			Loss of nesting habitat

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Competition for nest space
Mammals	Sei Whale	Approved Conservation Advice for *Balaenoptera borealis* (sei whale) (2015)	Climate and oceanographic variability and change
			Anthropogenic noise and acoustic disturbance
			Habitat degradation including pollution (increasing port expansion and coastal development)
			Pollution (persistent toxic pollutants)
			Vessel strike
			Prey depletion due to fisheries (potential threat)
			Resumption of commercial whaling (potential threat)
	Blue Whale	Blue Whale Conservation Management Plan 2015 - 2025 (2015)	Whaling
			Climate Variability and Change
			Noise Interference
			Habitat Modification
			Vessel Disturbance
			Overharvesting of prey
	Fin Whale	Approved Conservation Advice for *Balaenoptera physalus* (fin whale) (2015)	Climate and oceanographic variability and change
			Anthropogenic noise and acoustic disturbance
			Habitat degradation including coastal development, port expansion and aquaculture
			Pollution (persistent toxic pollutants)
			Fisheries catch, entanglement and bycatch
			Vessel strike
			Resource depletion due to fisheries (potential threat)
			Resumption of commercial whaling (potential threat)

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
	Southern Right Whale	Conservation Management Plan for the Southern Right Whale 2011 – 2021 (2012)	Entanglement
			Vessel disturbance
			Whaling
			Climate variability and change
			Noise interference
			Habitat modification
			Overharvesting of prey
	Humpback Whale	Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (2015)	Whaling
			Climate and Oceanographic Variability and Change
			Overharvesting of Prey
			Noise Interference
			Habitat degradation including coastal development and port expansion
			Entanglement
	Australian Sea-lion	Recovery Plan for the Australian Sea Lion (*Neophoca cinerea*) (2013)	Fishery bycatch
			Entanglement in marine debris
			Marine aquaculture
			Habitat degradation
			Human disturbance
			Direct killing
			Disease
			Pollution
			Oil spills
			Noise

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Competition and prey depletion
			Climate change
Reptiles	Short-nosed Seasnake	Commonwealth Conservation Advice on *Aipysurus apraefrontalis* (Short-nosed Seasnake) (2011)	Degradation of reef habitat
			Oil and gas exploration
			Incidental catch and death in commercial prawn trawling fisheries
	Leaf-scaled Seasnake	Commonwealth Conservation Advice on *Aipysurus foliosquama* (Leaf-scaled Seasnake) (2011)	Degradation of reef habitat
			Oil and gas exploration
	Loggerhead Turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Bycatch of marine turtles in fisheries
			Unknown levels of harvest by Indigenous Australians and unsustainable levels of harvest by people in neighbouring countries of the Asia/Pacific region
			Predation of turtle eggs by native and introduced animals
			Coastal development
			Deteriorating water quality
			Marine debris
			Loss of habitat and/or habitat modification
			Climate change and variability
			International take and/or illegal taking of turtles in Australian waters
			Light pollution
			Vessel disturbance
			Noise interference
			Recreational activities and human interactions
			Diseases and pathogens
			Cumulative impacts of threats

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
	Green Turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Bycatch of marine turtles in fisheries
			Unknown levels of harvest by Indigenous Australians and unsustainable levels of harvest by people in neighbouring countries of the Asia/Pacific region
			Predation of turtle eggs by native and introduced animals
			Coastal development
			Deteriorating water quality
			Marine debris
			Loss of habitat
			Climate change and variability
			International take and/or illegal taking of turtles in Australian waters
			Light pollution
			Vessel disturbance
			Noise interference
			Recreational activities and human interactions
			Diseases and pathogens
			Cumulative impacts of threats
	Leatherback Turtle	Commonwealth Conservation Advice on *Dermochelys coriacea* (2008)	Incidental capture in commercial fisheries
			Harvest of eggs and meat
			Ingestion of marine debris
			Boat strike
			Predation on eggs by wild dogs, pigs and monitor lizards
			Degradation of foraging areas
			Changes to breeding sites

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
		Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Bycatch of marine turtles in fisheries
			Unknown levels of harvest by Indigenous Australians and unsustainable levels of harvest by people in neighbouring countries of the Asia/Pacific region
			Predation of turtle eggs by native and introduced animals
			Coastal development
			Deteriorating water quality
			Marine debris
			Loss of habitat
			Climate change and variability
			International take and/or illegal taking of turtles in Australian waters
			Light pollution
			Vessel disturbance
			Noise interference
			Recreational activities and human interactions
			Diseases and pathogens
			Cumulative impacts of threats
	Hawksbill Turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Bycatch of marine turtles in fisheries
			Unknown levels of harvest by Indigenous Australians and unsustainable levels of harvest by people in neighbouring countries of the Asia/Pacific region
			Predation of turtle eggs by native and introduced animals
			Coastal development
			Deteriorating water quality
			Marine debris

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Loss of habitat
			Climate change and variability
			International take and/or illegal taking of turtles in Australian waters
			Light pollution
			Vessel disturbance
			Noise interference
			Recreational activities and human interactions
			Diseases and pathogens
			Cumulative impacts of threats
	Olive Ridley Turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Bycatch of marine turtles in fisheries
			Unknown levels of harvest by Indigenous Australians and unsustainable levels of harvest by people in neighbouring countries of the Asia/Pacific region
			Predation of turtle eggs by native and introduced animals
			Coastal development
			Deteriorating water quality
			Marine debris
			Loss of habitat
			Climate change and variability
			International take and/or illegal taking of turtles in Australian waters
			Light pollution
			Vessel disturbance
			Noise interference
			Recreational activities and human interactions

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Diseases and pathogens
			Cumulative impacts of threats
	Flatback Turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Bycatch of marine turtles in fisheries
			Unknown levels of harvest by Indigenous Australians and unsustainable levels of harvest by people in neighbouring countries of the Asia/Pacific region
			Predation of turtle eggs by native and introduced animals
			Coastal development
			Deteriorating water quality
			Marine debris
			Loss of habitat
			Climate change and variability
			International take and/or illegal taking of turtles in Australian waters
			Light pollution
			Vessel disturbance
			Noise interference
			Recreational activities and human interactions
			Diseases and pathogens
			Cumulative impacts of threats
Sharks	Grey Nurse Shark	Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*) (2014)	Incidental capture by commercial and recreational fisheries
			Shark control programs
			Ecotourism
			Aquarium trade
			Pollution and disease

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Ecosystem effects - habitat modification and climate change
	Great White Shark	Recovery plan for the White Shark (*Carcharodon carcharias*) (2013)	Mortality related to being caught accidentally (bycatch) or illegally (targeted) by commercial and recreational fisheries, including issues of post release mortality
			Mortality related to shark control activities such as beach meshing or drumlining (east coast population)
			Illegal trade in white shark products
			Ecosystem effects as a result of habitat modification and climate change
			Ecotourism
	Northern River Shark	Approved Conservation Advice for *Glyphis garricki* (northern river shark) (2014)	Commercial fishing activities
			Recreational fishing
			Indigenous fishing
			Illegal, unreported and unregulated fishing
			Habitat degradation and modification
		Sawfish and River Sharks Multispecies Recovery Plan (2015)	Fishing activities including: being caught as by-catch in the commercial and recreational sectors; through indigenous fishing; and illegal, unreported and unregulated fishing
			Habitat degradation and modification
	Dwarf Sawfish	Commonwealth Conservation Advice on *Pristis clavata* (Dwarf Sawfish) (2009)	Being caught as bycatch in commercial and recreational net fishing
			Illegal, unreported and unregulated (IUU) fishing
		Sawfish and River Sharks Multispecies Recovery Plan (2015)	Fishing activities including: being caught as by-catch in the commercial and recreational sectors; through indigenous fishing; and illegal, unreported and unregulated fishing
			Habitat degradation and modification
	Freshwater/Largetooth Sawfish	Approved Conservation Advice for *Pristis pristis* (largetooth sawfish) (2014)	Commercial fishing activities
			Recreational fishing

Taxa	Common Name	Recovery Plan / Conservation Advice	Threats
			Indigenous fishing
			Illegal, unreported and unregulated fishing (IUU)
			Habitat degradation and modification
		Sawfish and River Sharks Multispecies Recovery Plan (2015)	Fishing activities including: being caught as by-catch in the commercial and recreational sectors; through indigenous fishing; and illegal, unreported and unregulated fishing
			Habitat degradation and modification
	Green Sawfish	Approved Conservation Advice for *Pristis zijsron* (Green Sawfish) (2008)	Capture as bycatch and byproduct in gillnet and trawl fisheries
			Illegal capture for fins and rostra
			Habitat degradation through coastal development
		Sawfish and River Sharks Multispecies Recovery Plan (2015)	Fishing activities including: being caught as by-catch in the commercial and recreational sectors; through indigenous fishing; and illegal, unreported and unregulated fishing
			Habitat degradation and modification
	Whale Shark	Approved Conservation Advice for *Rhincodon typus* (whale shark) (2015)	Intentional and unintentional mortality from fishing outside of Australian waters
			Boat strike from large vessels
			Habitat disruption from mineral exploration, production and transportation
			Disturbance from domestic tourism operations
			Marine debris
			Climate change

14. Social, Economic and Cultural Features

14.1 Industry

In 2012/13, Western Australia's petroleum industry was worth $24.5 billion per annum, making it the State's most valuable industry. In the last decade Western Australia's petroleum sales have increased by an average of nine percent each year, with much of these sales coming from liquefied natural gas. Currently Western Australia has three operating Liquefied Natural Gas (LNG) projects, the North West Shelf, Gorgon and Pluto, with three more under construction/commissioning, Wheatstone, Prelude and the Ichthys offshore LNG Facility. There area also a number of Floating Production and Storage Offtake (FPSO) facilities in the Timor Sea and North West Shelf, as denoted on **Figure 14-1** to **Figure 14-3.** Offshore development is focussed in the Carnarvon Basin, Browse Basin and on the North West Shelf (DMP 2014). There are also domestic gas plants on Varanus Island in the North West Shelf, Devil Creek Onshore Gas Plant and Macedon Gas Plant in the Pilbara region and an oil facility near Dongara called Cliff Head. There are several exploration and production permits and leases throughout the Western Australian and Commonwealth waters in the area of interest. Existing petroleum infrastructure, permits and licences are shown in **Figure 14-1** to **Figure 14-3.**

14.1 Other Infrastructure

The Jasuraus submarine communication cable links Australia with Indonesia. The cable was installed as a link from Australia to provide telephone services connection to the world in 1995-1996. Travelling north out of Port Hedland for approximately 210 km the cable then heads north-west toward Jakarta, Indonesia. The cable runs up through Permit Areas WA-435-P and WA437-P. It's capacity and major role was overtaken in 2000 by other subsea cables out of Australia. However, Telstra continues to manage the cable as it remains an emergency backup link out of Australia. The cable includes two submerged repeaters in the wider region.

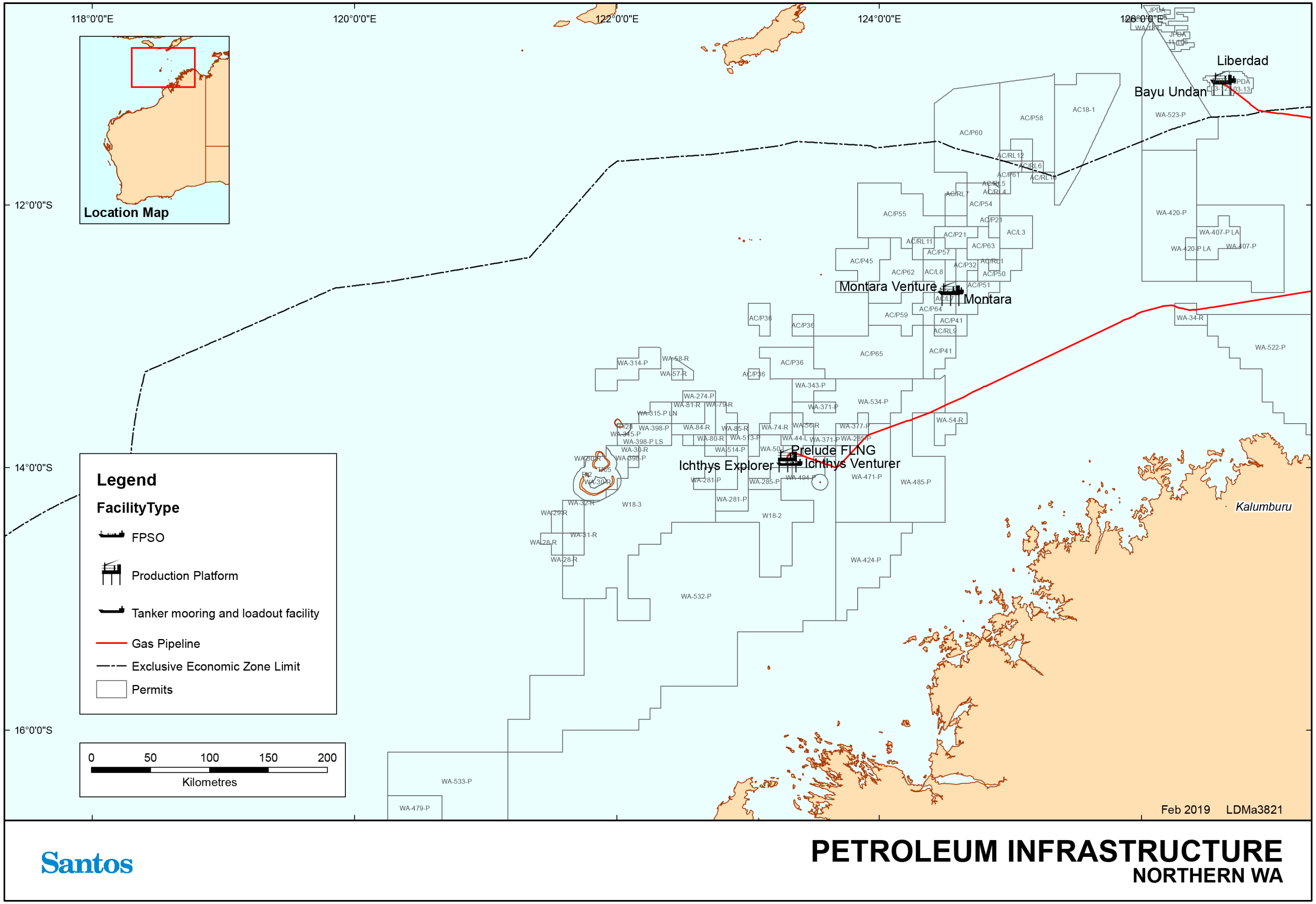

Figure 14-1: Existing petroleum infrastructure, permits and licences – Northern WA

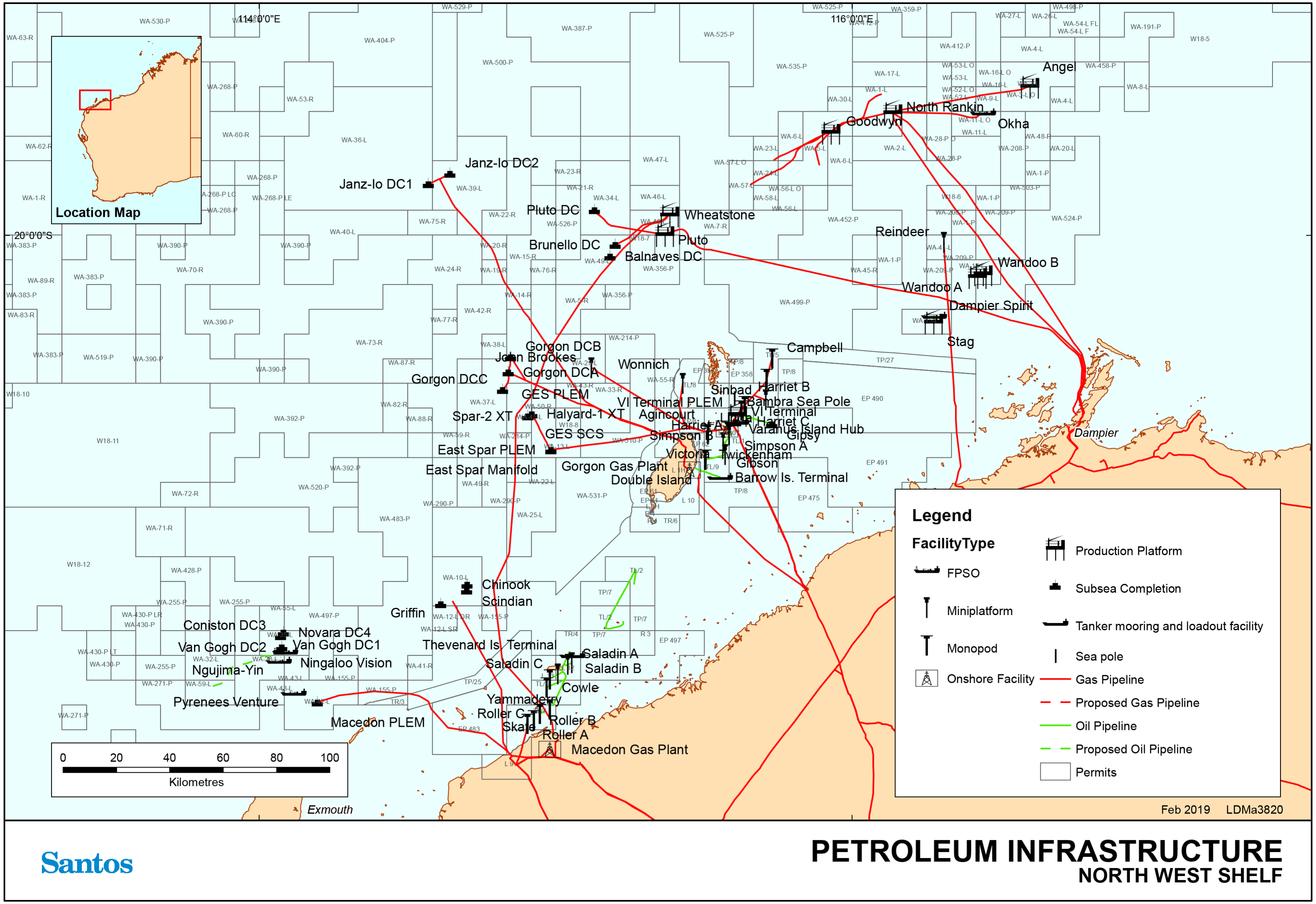

Figure 14-2: Existing petroleum infrastructure, permits and licences – North West Shelf

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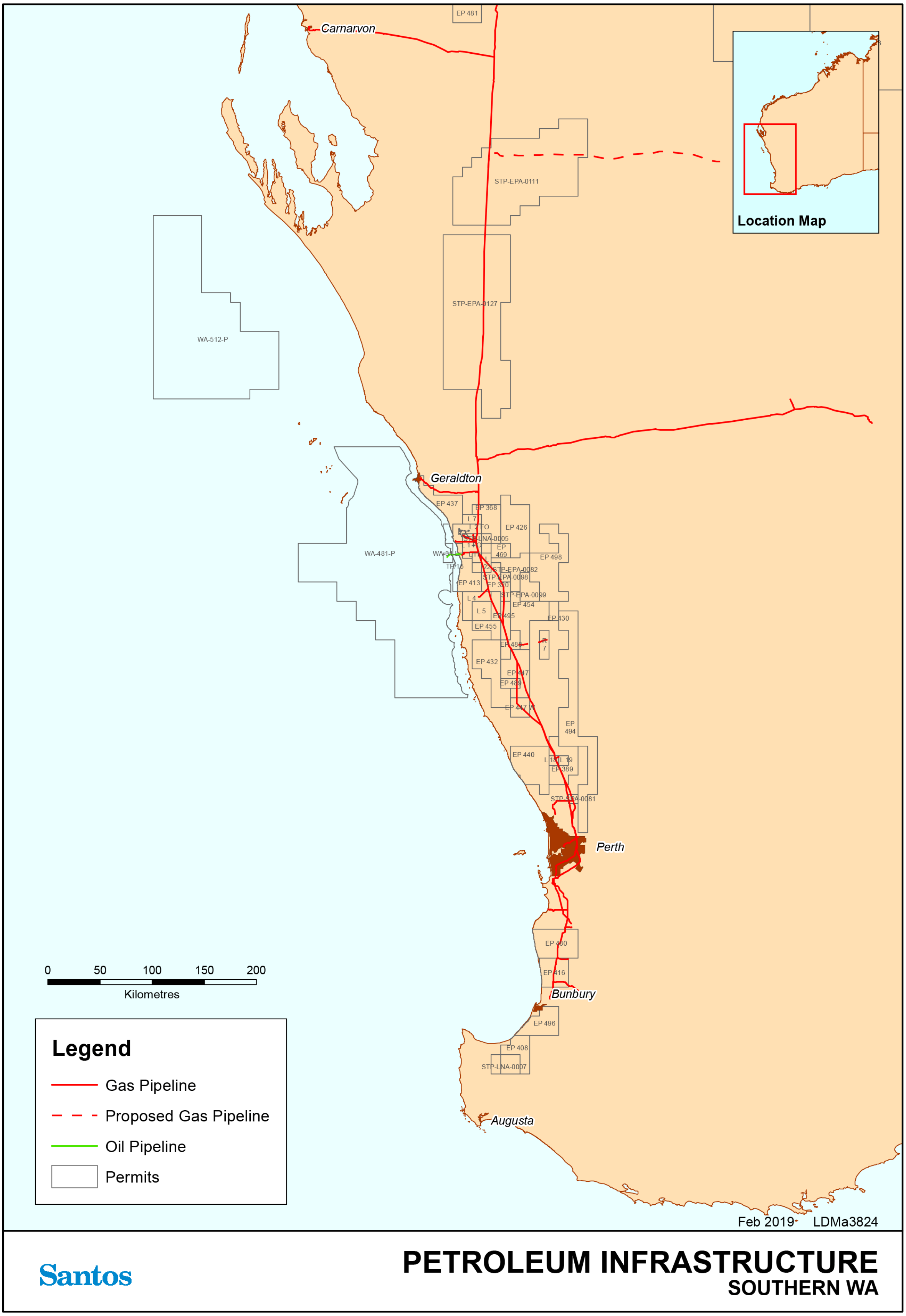

Figure 14-3: Existing petroleum infrastructure, permits and licences –Southern WA

14.2 Shipping

The coastline from South Australia to the Northern Territory border supports twelve ports including the major ports of Dampier, Port Hedland and Broome which are operated by their respective port authorities. Large cargo vessels move through the region to and from Fremantle, transiting along coastline. Commercial shipping also moves to and from marine terminals associated with the oil and gas industry (see **Section 14.1**). Other large ports include Geraldton, Busselton, Albany and Esperance. Closer proximity shipping also includes construction vessels/barges/dredges, domestic support vessels, and offshore survey vessels.

The Australian Maritime Safety Authority (AMSA) has established a network of shipping fairways off the north-west coast of Australia to manage traffic patterns (AMSA 2013). The Shipping Fairways are designed to keep shipping traffic away from offshore infrastructure and aims to reduce the risk of collision (AMSA 2013).

Use of the fairways is strongly recommended but not mandatory. The International Regulations for *Preventing Collisions at Sea 1972* apply to all vessels navigating within or outside the shipping fairways. The use of these fairways does not give vessels any special right of way (AMSA 2012). Data from AMSA, collected from January to June 2015, indicates that from 1 to 3 bulk carriers a day may use the shipping fairways and therefore, may transit to Port Hedland.

Under the *Commonwealth Navigation Act 2012*, certain vessels operating in Australian waters are required to report their location on a daily basis to the Rescue Coordination Centre (RCC) in Canberra. This Australian Ship Reporting System (AUSREP) is an integral part of the Australian Maritime Search and Rescue system and is operated by Australian Maritime Safety Authority (AMSA) through the RCC. Vessels recorded in waters in the area of interest through the AUSREP system in 2017 are shown in **Figure 14-4**.

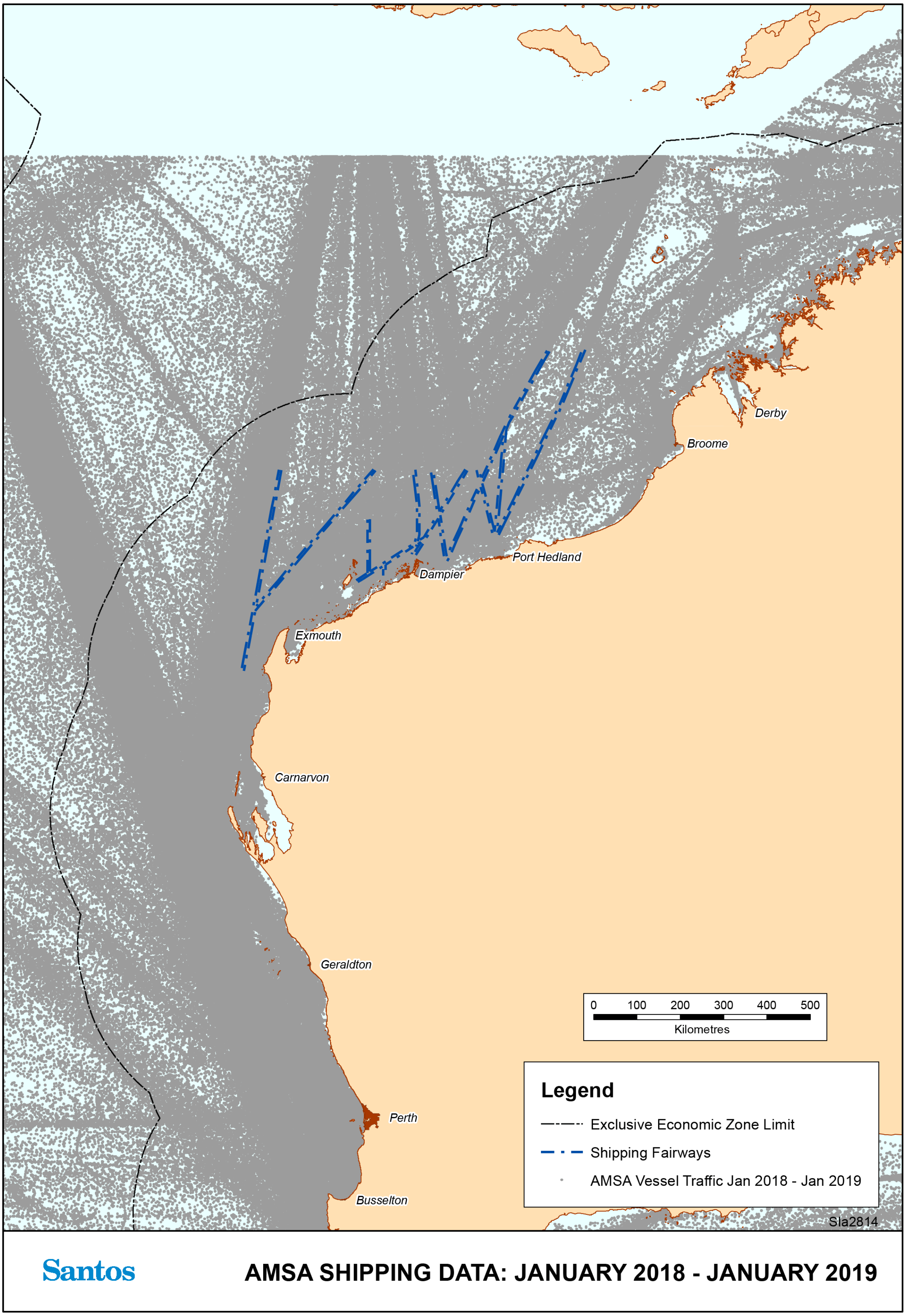

Figure 14-4: AMSA ship locations and shipping routes

14.3 Defence Activities

Key defence bases and facilities are illustrated in **Figure** 14-5**.**

The Naval Communication Station Harold E. Holt is located on the northwest coast of Australia, 6 km north of Exmouth. The town of Exmouth was built at the same time as the communications station to provide support to the base and to house dependent families of US Navy personnel (Shire of Exmouth 2014, DoE 2014).

The station provides very low frequency (VLF) radio transmission to US Navy and Royal Australian Navy ships and submarines in the western Pacific Ocean and eastern Indian Ocean. With a transmission power of 1 megawatt, it is the most powerful transmission station in the southern hemisphere (Shire of Exmouth 2014, DoE 2014).

Two Royal Australian Airforce (RAAF) bases are located in the northwest of Western Australia; Learmonth RAAF Base, near Exmouth and Curtin RAAF Base near Derby (RAAF 2014).

Designated military exercise areas occur over waters and airspace of the north west of Western Australia and may be activated following the required notifications.

Additional defence activities that occur within the area of interest include:

+ Broome training depot;
+ Exmouth admin and high frequency transmitting;
+ Exmouth VLF transmitting station;
+ Geraldton training depot “A” Company 16th Battalion;
+ HMAS Stirling-Rockingham; HMAS Stirling-Garden Island;
+ Karratha training depot;
+ Learmonth –air weapons range;
+ Learmonth radar site – Vlaming Head Exmouth; and
+ Yampi Sound training area.

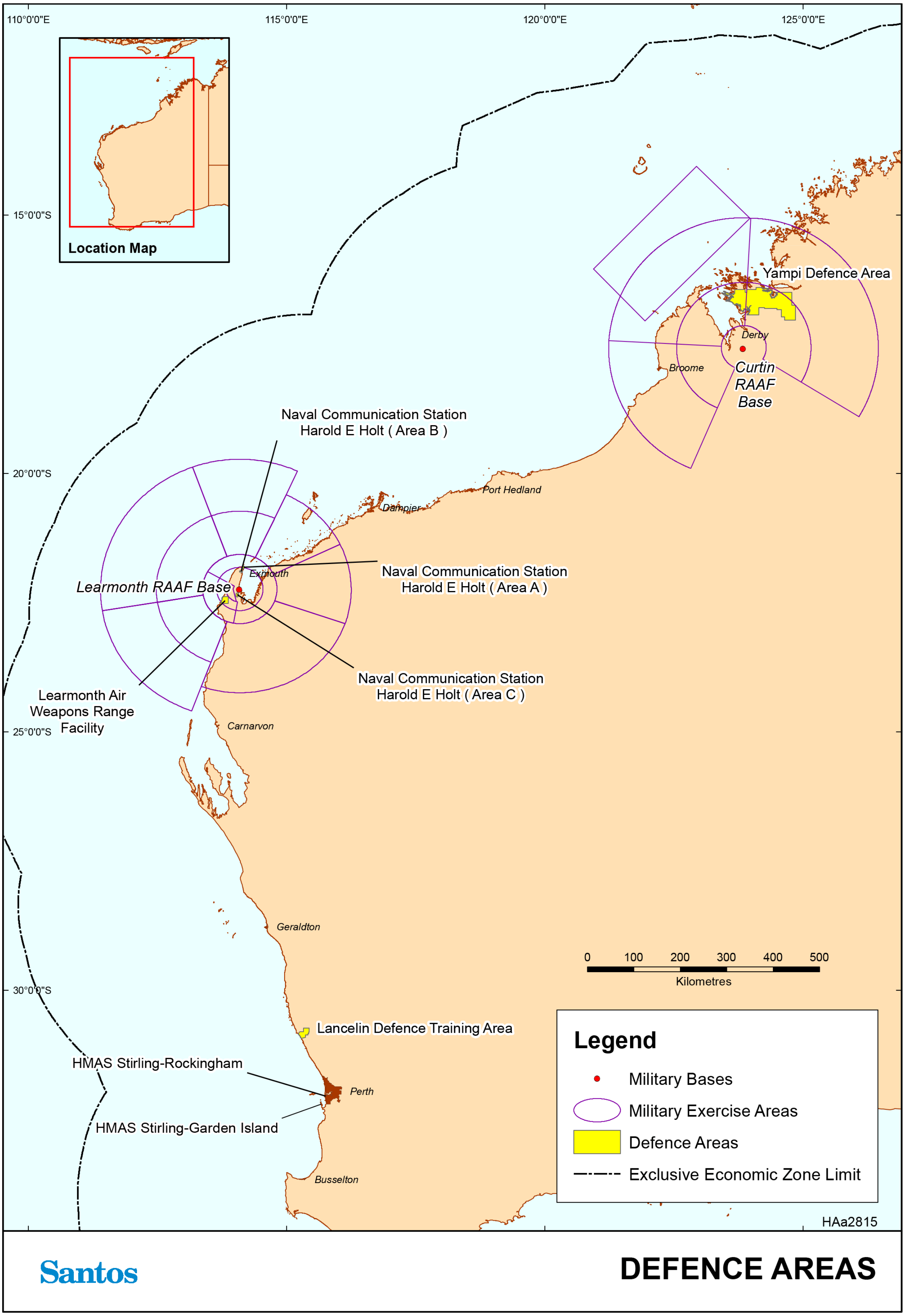

Figure 14-5: Defence activities in WA

14.4 Tourism

The Kimberley, Pilbara and Gascoyne regions are popular visitor destination for Australian and international tourists. Tourism is concentrated in the vicinity of population centres including Broome, Dampier, Exmouth, Coral Bay and Shark Bay.

Marine and coastal use is also clustered around major population centres along the Western Australian coastline including Perth, Bunbury, Geraldton, Margaret River, Jurien Bay, August and Albany.

Tourism contributes to local economies in terms of both income and employment and tourists include local, interstate and international visitors. Popular water based activities include fishing, swimming, snorkelling/ diving, surfing/windsurfing/kiting and boating, while popular land based activities include bushwalking, camping, bird watching and four-wheel driving.

Seasonal nature-based tourism such as humpback whale watching, whale shark encounters and tours of turtle hatching mainly occurring around Ningaloo Reef, Cape Range National Park, Broome and Perth (Tourism Western Australia). Seasonal aggregations of whale sharks, manta rays, sea turtles and whales, as well as the annual mass spawning of coral attract large numbers of visitors to Ningaloo each year (CALM 2005).

14.5 Cultural Heritage

Four places of cultural significance are protected as National Heritage Places in the waters from Busselton to the Northern Territory border. The Dampier Archipelago (including Burrup Peninsula), Batavia Shipwreck Site and Survivor Camps Area 1629 – Houtman Abrolhos, Dirk Hartog Landing Site 1616 – Cape Inscription area and the HMAS Sydney II and HSK Kormoran Shipwreck Site are discussed in **Section 9**. Additional Commonwealth Heritage Places denoted for their historic value in the area of interest are listed in **Appendix A**.

14.5.1 Indigenous Heritage

Indigenous people have a strong ongoing association with the area that extends from the beginning of human settlement in Australia some 50,000 years ago. The close, long standing relationship between Aboriginal peoples and the coastal and marine environments of the area is evident in indigenous culture today in addition to archaeological sites such as the Burrup Peninsula. The Indigenous peoples of the northwest continue to rely on coastal and marine environments and resources for their cultural identity, health and wellbeing, as well as their domestic and commercial economies (DEWHA 2008). With the area of interest, Barrow Island, Montebello Islands, Exmouth, Ningaloo Reef, Eighty Mile Beach, Roebuck Bay, Dampier Peninsula and the South West and the adjacent foreshores have a long history of occupancy by Indigenous communities. Areas that are covered by registered native title claims are likely to practice indigenous fishing techniques at various sections of the WA coast line; most notably in the Kimberley coastal region and islands.

Marine resource use by Indigenous people is generally restricted to coastal waters. Fishing, hunting and the maintenance of maritime cultures and heritage through ritual, stories and traditional knowledge continue as important uses of the nearshore region and adjacent areas. However, while direct use by Aboriginal people deeper offshore waters is limited, many groups continue to have a direct cultural interest in decisions affecting the management of these waters. The cultural connections Aboriginal people maintain with the sea may be affected, for example, by offshore fisheries and industries. In addition, some Indigenous people are involved in commercial activities such as fishing and marine tourism, so have an interest in how these industries are managed in offshore waters with respect to their cultural heritage and commercial interests (DEWHA 2008).

14.5.2 Maritime Heritage

Details of recorded shipwreck sites are available on the Australian National Shipwreck Database are managed by the DoEE although precise locations of the wrecks are sometimes unknown. A search of the Australian National Shipwreck Database in the area of interest identified 939 shipwrecks. Key shipwrecks in the North West Marine Region are listed in **Table** 14-1 and shown in **Figure 14-6** to **Figure 14-9**, in addition to the Ann

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Millicent (DEWHA 2008). Under the Commonwealth *Historic Shipwrecks Act 1976*[16] all shipwrecks older than 75 years are protected, while those dated pre-1900 are protected by WA law under the *Maritime Archaeology Act 1973*. Within the area of interest, there are 697 shipwrecks in excess of 75 years old.

Table 14-1: Shipwrecks

Name	Description	Location
Ann Millicent	Iron hulled barque, wrecked c. 1888	Cartier Island
Crown of England	1,847 t sailing ship, wrecked c. 1912	Wreck Point, Depuch Island
Eddystone	2,040 t brigantine rigged iron steamship	Cossack Roads, Depuch Island Passage
Fin	Early iron whaler	Frazer Island, Point Cloates
Karrakatta	1,271 t, schooner rigged, coastal steamship	King Sound, 140 km north-northwest of Derby
Manfred	587 t barque	3 km north west of West Island in the Lacepede Islands
Perth	499 t, iron coastal steamship	Ningaloo Reef
Rowley Shoals unconfirmed wreck	Armed whaler of 200–250 t, possibly the Lively, wrecked c 1800	Mermaid Reef
Zvir	Iron steamer	Frazer Island, Point Cloates
Browse Island (East) unconfirmed wreck	Late nineteenth century iron sailing vessel of approximately 1,000 t	Browse Island
Fairy Queen	115 t Singapore built brigantine	Point Murat, North West Cape
Gudrun	Iron frames and fastenings	Cape Peron Flats in Shark Bay
SS Sunbeam	Iron hulled, single screw steamer	Middle Osborne Island, Admiralty Gulf
Trial	English East Indiaman of about 500 t, wrecked c 1622	Trial (or Tryal) Rocks, 20 km northwest of the Montebello Islands
Zuytdorp	Seventeenth century Dutch East Indiaman	Zuytdorp Cliffs, 75 km north of Kalbarri

[16] Note that the *Underwater Culture Heritage Act 2018* has been passedon 24 August 2018, however it has yet to commence, due to commence prior to 24 August 2019. The new Act enables protection for other types of underwater culture e.g. aircraft wrecks.

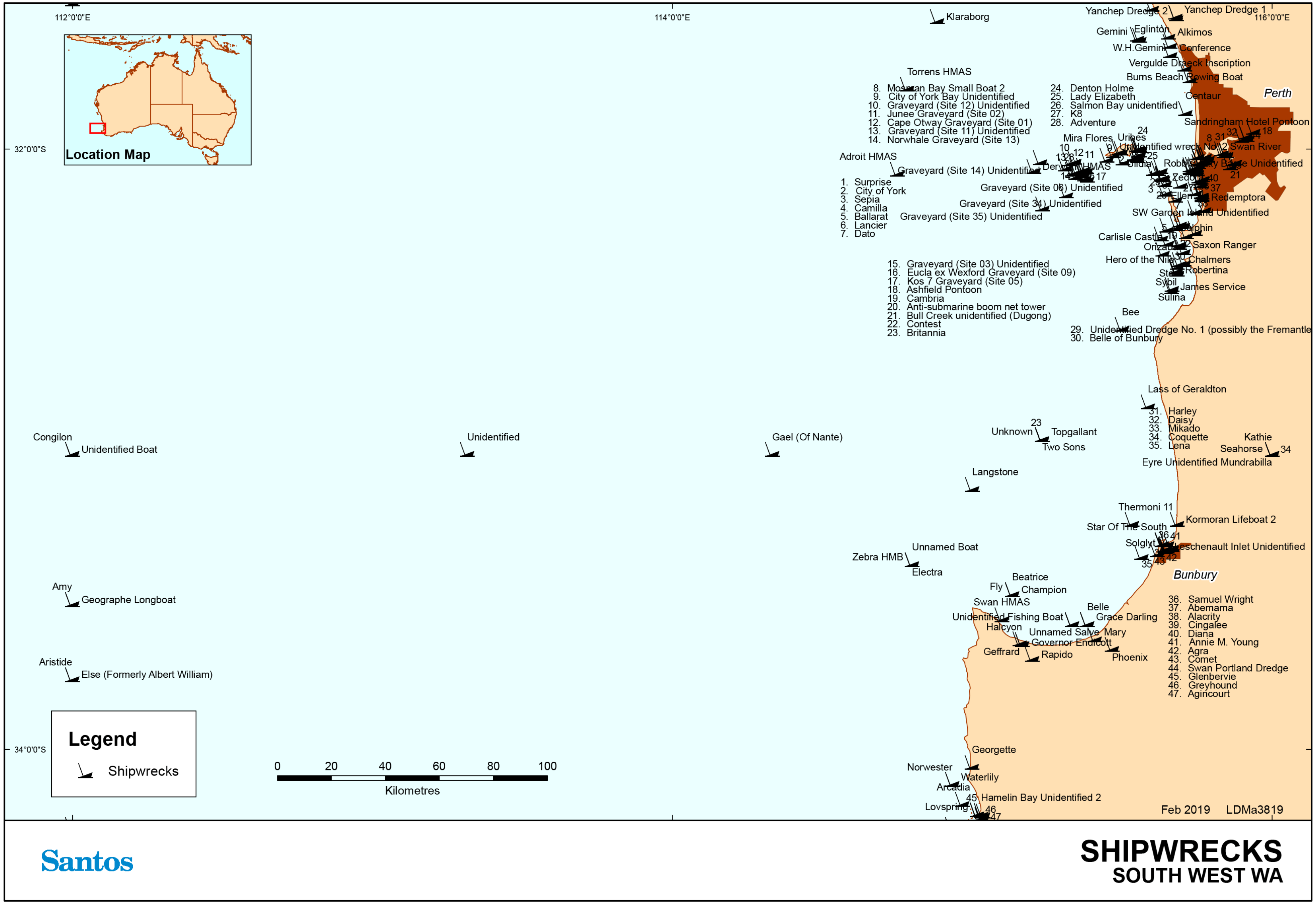

Figure 14-6: Shipwrecks – South West WA

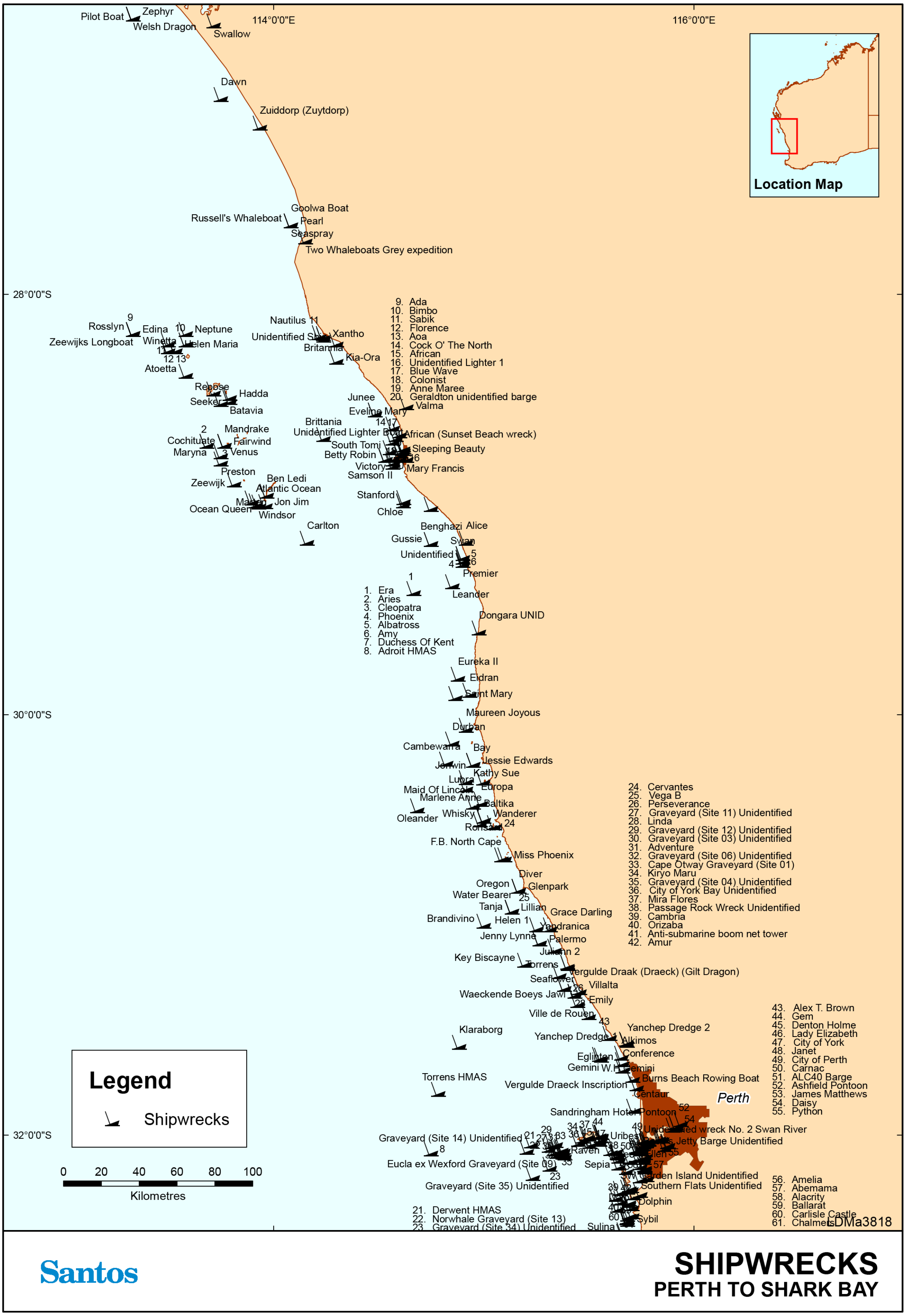

Figure 14-7: Shipwrecks – Perth – Shark Bay

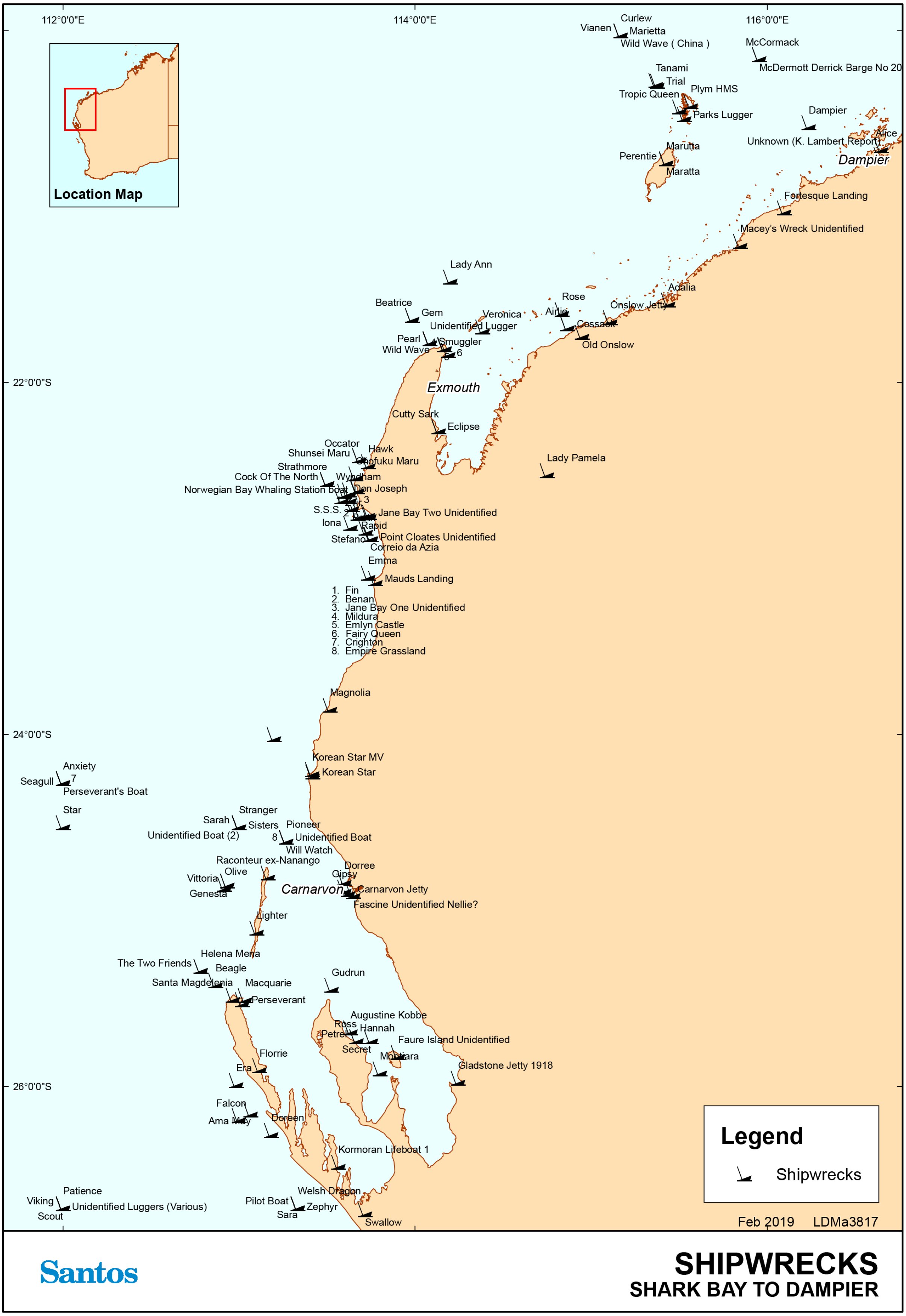

Figure 14-8: Shipwrecks – Shark Bay – Dampier

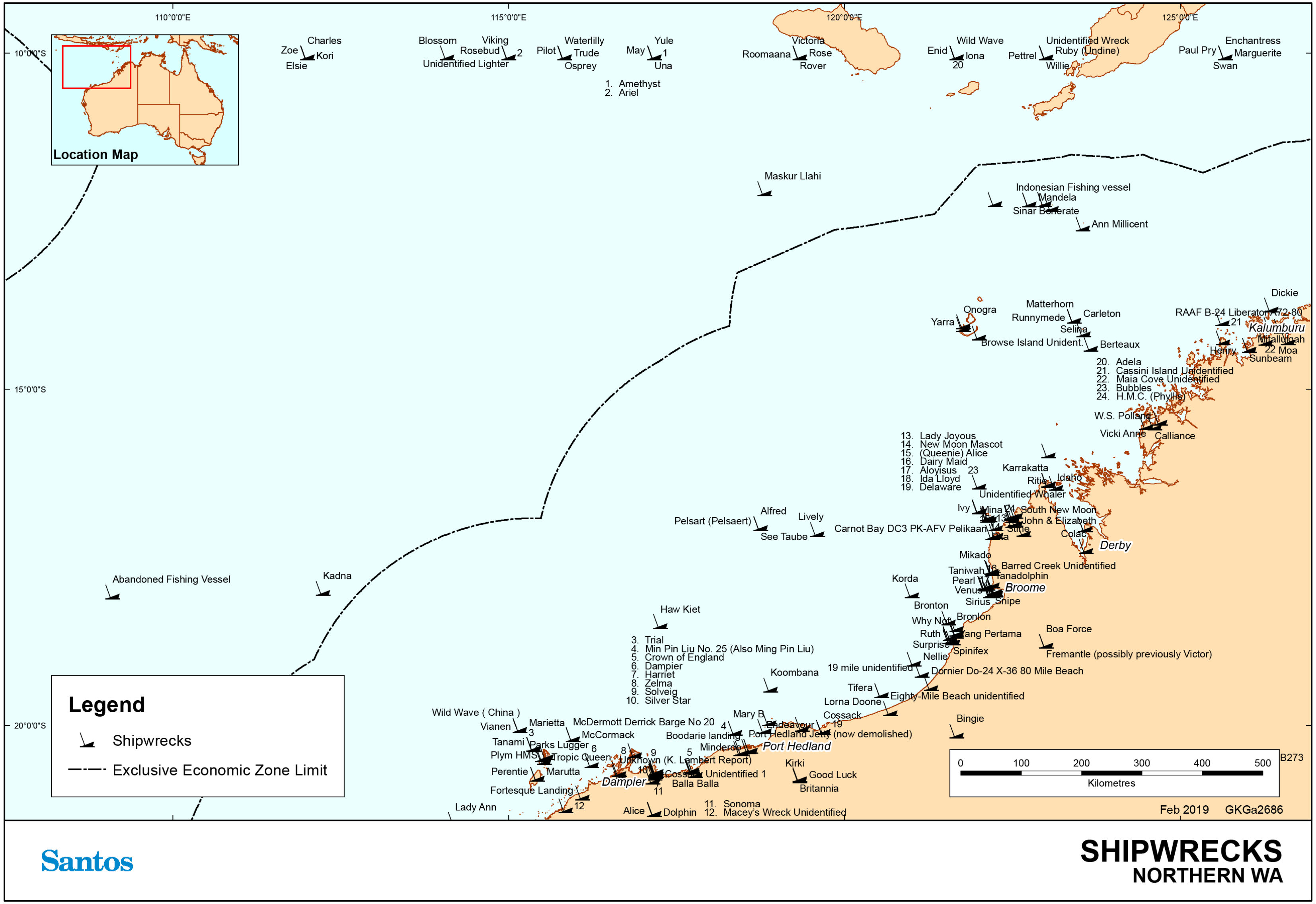

Figure 14-9: Shipwrecks – Northern WA

14.6 Commercial Fisheries

A valuable and diverse commercial fishing industry is supported by both the offshore and coastal waters in the North Coast, Gascoyne, West Coast and South Coast Bioregions between the Western Australian (WA) and Northern Territory (NT) and South Australian (SA) borders. The major fisheries in this area target tropical finfish, large pelagic fish species, crustaceans (prawns and scampi), Western Rock Lobster and pearl oysters (Fletcher and Santoro 2013). A number of smaller fisheries also exist in this area including the octopus and beche-de-mer fisheries.

14.6.1 State Fisheries

State fisheries are managed by the WA Department of Fisheries (DoF) with specific management plans, regulations and a variety of subsidiary regulatory instruments under the *Fish Resources Management Act* 1994 (WA). The information on State managed fisheries has been derived from '*The State of the Fisheries'* Report 2015/2016 (Fletcher et al. 2017) and direct consultation with the DoF. Santos WA consults regularly with State fisheries relevant to activity operational areas, mainly by distribution of an Annual Consultation Update by post.

State commercial fisheries that exist between Kalbarri (WA) and the Northern Territory border are shown in **Figure** 14-10. A summary of all commercial fisheries in the area is also summarised **Table** 14-2. These are:

North Coast Bioregion

+ Onslow Prawn Managed Fishery (OPMF);
+ Nickol Bay Prawn Managed Fishery (NBPMF) – referred to as Nickol Bay Prawn Limited Entry Fishery in Figure 14-10 ;
+ Broome Prawn Managed Fishery (BPMF);
+ Kimberley Prawn Managed Fishery (KPMF);
+ Kimberley Gillnet & Barramundi Managed Fishery (KGBF);
+ Northern Demersal Scalefish Managed Fishery (NDSF);
+ Kimberley Developing Mud Crab Fishery – not shown in Figure 14-10;
+ Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF);
+ Pilbara Trap Managed Fishery (PTMF);
+ Pilbara Line Fishery – not shown in Figure 14-10;
+ Western Australian Sea Cucumber Fishery (also known as Beche-de-mer Fishery);
+ Mackerel Fishery (Area 1 – Kimberley and Area 2 – Pilbara);
+ Western Australian Pearl Oyster Fishery – referred to as Pearl Oyster Managed Fishery in Figure 14-10;
+ Northern Shark Fisheries (closed) including:
+ Western Australian North Coast Shark Fishery; and
+ Joint Authority Northern Shark Fishery;
+ North Coast Trochus Fishery – not shown in Figure 14-10; and
+ Pilbara Developmental Crab Fishery – not shown in Figure 14-10.

Gascoyne Bioregion

+ Exmouth Gulf Prawn Managed Fishery;
+ Gascoyne Demersal Scalefish Managed Fishery;

- Shark Bay Scallop Managed Fishery – referred to as Shark Bay Scallop Limited Entry Fishery on Figure 14-10;
- Shark Bay Prawn Managed Fishery – referred to as Shark Bay Prawn Limited Entry Fishery on Figure 14-10;
- Shark Bay Crab Interim Managed Fishery
- Mackerel Fishery (Area 3 – Gascoyne/West Coast); and
- West Coast Deep Sea Crab (Interim) Managed Fishery.

West Coast Bioregion

- Roe's Abalone;
- Abrolhos Islands and Mid-West Trawl Managed Fishery (AIMWRMF) (Closed) – referred to as Abrolhos Islands and Mid-West Trawl Limited Entry Fishery in Figure 14-10;
- West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF);
- South West Trawl Managed Fishery – referred to as South West Trawl Limited Entry Fishery in Figure 14-10;
- Mandurah to Bunbury Developing Crab Fishery – not shown in Figure 14-10;
- Cockburn Sound Crab Managed Fishery – not shown in Figure 14-10;
- Cockburn Sound Line and Pot Managed Fishery – not shown in Figure 14-10;
- Cockburn Sound Mussel Managed Fishery – not shown in Figure 14-10;
- Warnbro Sound Crab Managed Fishery (closed) – not shown in Figure 14-10;
- West Coast Nearshore and Estuarine Finfish Fisheries, including:
- Cockburn Sound Fish Net Managed Fishery – not shown in Figure 14-10;
- South West Coast Salmon Managed Fishery;
- West Coast Beach Baited Managed Fishery – not shown in Figure 14-10;
- South West Beach Seine Fishery – not shown in Figure 14-10; and
- West Coast Estuarine Managed Fishery – not shown in Figure 14-10;
- Temperate Demersal Gillnet and Demersal Longline Fisheries, including:
- West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery (West Coast Bioregion) – not shown in Figure 14-10;
- West Coast Deep Sea Crab (Interim) Managed Fishery;
- West Coast Nearshore Net Managed Fishery – not shown in Figure 14-10;
- Octopus Interim Managed Fishery – Referred to as Octopus in Figure 14-10;
- West Coast Rock Lobster Managed Fishery; and
- West Coast Purse Seine Fishery – not shown in Figure 14-10.

South Coast Bioregion

- Greenlip/Brownlip Abalone Fishery – not shown in Figure 14-10;
- South Coast Deep-Sea Crab Fishery – not shown in Figure 14-10;

- Temperate Demersal Gillnet and Demersal Longline Fisheries including:
- Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery (South Coast Bioregion)
- South West Trawl Managed Fishery (SWTMF); and
- Windy Harbour/Augusta Rock Lobster Managed Fishery – not shown in Figure 14-10.

Whole of State Fisheries

- Marine Aquarium Fish Managed Fishery (MAFMF);
- Specimen Shell Managed Fishery;
- Hermit Crab Fishery (HCF) – not shown in Figure 14-10;
- Unknown Region;
- South Coast Open Access Netting Fishery; and
- South West Coast Beach Net.

Some of the fisheries listed above will be more susceptible to impacts than others, particularly fisheries without the ability to escape impacts. For example, above average water temperatures over the last three years will have had an impact on prawn fisheries in Exmouth and scallops and blue swimmer crabs in Shark Bay which have been significantly affected by the initial heat wave event of 2010/11 (Caputi *et al*. 2014). It is important that susceptibility of certain fisheries to environmental impacts be monitored going forward.

14.6.2 Commonwealth Fisheries

Commonwealth fisheries are those within the 200 nautical mile Australian Fishing Zone (AFZ) managed by Australian Fisheries Management Authority (AFMA) and are, on the high seas, and, in some cases, by agreement with the States and Territory, to the low water mark. Information on Commonwealth managed fisheries has been derived from '*Fishery Status'* Report 2017 (Patterson et al. 2018)

Commonwealth fisheries who have permits to operate in the area of interest include:

- North West Slope Trawl (NWST);
- Southern Bluefin Tuna Fishery (SBFTF);
- Western Tuna and Billfish Fishery (WTBF) (including Southern Tuna and Billfish Fishery shown in **Figure** 14-11**)**;
- Small Pelagic Fishery (SPF);
- Skipjack Tuna Fishery (STF); and
- Western Deepwater Trawl (WDTF) (Referred to as Western Deepwater Fishery in **Figure** 14-11**)**.

Commonwealth commercial fisheries between Kalbarri (WA) and the Northern Territory Border are shown in **Figure** 14-11 and summarised in **Table** 14-2.

14.6.3 Indonesian Commercial and Subsistence Fishing

Within the northeastern extent of the area of interest is a defined area where a Memorandum of Understanding (MoU) exists between the Australian and Indonesian governments. The Agreement between the Government of Australia and the Government of the Republic of Indonesia Relating to Cooperation in Fisheries (1992 Fisheries Cooperation Agreement) provides the framework for fisheries and marine cooperation between Australia and Indonesia, and facilitates information exchange on research, management and technological developments, complementary management of shared stocks, training and technical exchanges, aquaculture development, trade promotion and cooperation to deter illegal fishing.

Cooperation under the Agreement today takes place under the auspices of the Working Group on Marine Affairs and Fisheries. Established in 2001, the Working Group on Marine Affairs and Fisheries is the primary bilateral forum to enhance collaboration across the spectrum of marine and fisheries issues relevant to the areas of the Arafura and Timor seas. The Working Group brings together the fisheries, environment and scientific research portfolios and agencies from both countries.

The MOU Box (shown on **Figure** 14-10 and **Figure** 14-11) is an area of Australian water in the Timor Sea where Indonesian traditional fishers, using traditional fishing methods only, are permitted to operate. Officially it is known as the Australia-Indonesia Memorandum of Understanding regarding the Operations of Indonesian Traditional Fishermen in Areas of the Australian Fishing Zone and Continental Shelf – 1974.

As part of negotiations to delineate seabed boundaries, Australia and Indonesia entered into the MoU which recognises the rights of access for traditional Indonesian fishers in shared waters to the north of Australia. This access was granted in recognition of the long history of traditional Indonesian fishing in the area. The MoU provides Australia with a tool to manage access to its waters while for Indonesia, it enables Indonesian traditional fishers to continue their customary practices and target species such as trepang, trochus, abalone and sponges. Guidelines under the MoU were agreed in 1989 in order to clarify access boundaries for traditional fishers and take into account the declaration of the 200 nautical mile fishing zones. Because of its approximate shape the MoU area became known as the MoU Box.

Between 2006 and 2008, a series of surveys were undertaken to understand the traditional practice of Indonesian fishers that journey to Scott Reef within the MoU boundary (ERM 2008, 2009). The majority of perahu (vessels) that travel to Scott Reef originate from the islands of Rote (near West Timor) and Tonduk and Raas (in East Java). Some crew from the Rote perahus are recruited from the region of Alor (one of the Lesser Sundas chain, located north of East Timor and east of Bali). In 2007, an estimated 800 fishers (approximately 80 vessels) travelled from these home islands to Scott Reef, mainly to collect trepang. Similar vessel numbers sailed to Scott Reef in 2008.

Journeys to Scott Reef are generally restricted to drier months when wind speeds and directions are more desirable. Most Indonesian fishers travel to Scott Reef during July to October, although a few Rotenese make the journey to Scott Reef in the early season between April and June. Other fishers plan to go after Aidil Fitri, a religious holiday widely celebrated on Tonduk Island that celebrates the end of Ramadan.

The fishers focus their activities in and around the shallow water lagoons of Scott Reef primarily targeting trepang; and opportunistically gather trochus shells. They also catch fish largely for subsistence purposes although the average fish catch per lete-lete (traditional Indonesian fishing vessel) in 2008 increased to commercial volumes. Although deeper waters are more plentiful in trepang, deep diving is generally not undertaken by the fishers due to the MoU stipulation on the exclusive use of traditional equipment only (Woodside Energy Limited 2011).

14.7 Aquaculture

14.7.1 North Coast Bioregion

Aquaculture development in this region is dominated by the production of pearls from the species *Pinctada maxima.* A large number of pearl oysters for seeding is obtained from wild stocks and supplemented by hatchery-produced oysters with major hatcheries operating at Broome and the Dampier Peninsular. Pearl farm sites are located mainly along the Kimberley coast, particularly in the Buccaneer Archipelago, in Roebuck Bay and at the Montebello Islands. Developing marine aquaculture initiatives in this region include growing trochus and barrumundi. Marine production of barramundi is focussed in Cone Bay fishing (Fletcher and Santoro 2015).

The Pearl Oyster Fishery of Western Australia operates in shallow coastal waters (DoF 2006). All the leases are within the 35m diving depth. Through consultation the Pearl Producer's Association (PPA) have raised concern that spawning stock is found to the 100 m depth contour. However, this is not supported in the study by Condie *et al* (2006) who modelled oyster larva transport in the Eighty Mile Beach region and found that while some larvae travelled more than 60 km, most were transported less than 30 km. The model results suggest that spawning in the Eighty Mile Beach region is concentrated around the 8 to 15m depth range, with potential smaller contributions from the northeast. These spawning events are likely to lead to successful recruitment locally and alongshore to the southwest.

They also feed larvae into neighbouring shallow coastal environments (through tidal oscillations) and deeper waters to the west (>20 m). However, spat abundances seem to be low in these areas, suggesting that recruitment is strongly limited by habitat availability and possibly high mortality rates in shallow water. High local abundances of broodstock and spat observed occasionally in deeper water (<30 m) seem to be supported by intermittent larval transport from inshore populations. Spawning in this area seems to contribute little to recruitment in the inshore populations.

Further aquaculture operations are expected in the region with recent funding supporting the establishment of an aquaculture zone (Fletcher et al. 2017).

14.7.2 Gascoyne Coast Bioregion

Hatchery production of oysters is the core of the pearling industry in the Gascoyne region. Hatcheries in Carnarvon and Exmouth supply spat to pearl farms in the north-west and several hatcheries supply juveniles to the blac-lip pearl oyster to developing black pearl farms in the region. Pearl production is carried out on a small scale in Shark Bay and Exmouth Gulf. The local aquiculture sector is also focussing on the production of aquarium species.

14.7.3 West Coast Bioregion

The principal aquaculture development activities in this region are the production of blue mussels (*Mytilus galloprovincialis*) and marine algae (*Dunaliella salina*) and the emerging black pearl industry based on the production of *Pinctada margaritifera* at the Abrolhos Islands. The main mussel farming area is in southern Cockburn Sound, where conditions are sheltered and the nutrient and planktonic food levels are sufficient to promote good growth rates fishing (Fletcher and Santoro 2015).

Currently, the Department of Fisheries is seeking to secure strategic environmental approvals for a Mid-West Aquaculture Development Zone (Fletcher et al. 2017).

14.7.4 South West Bioregion

The predominant aquaculture activity undertaken in this region is the production of mussels and oysters from Oyster Harbour at Albany. This activity is restricted to this area where there are sufficient nutrient levels related to terrestrial run-off to provide the planktonic food necessary to promote growth of filter-feeding bivalves fishing (Fletcher and Santoro 2015). The high-energy environment and limited protected deep waters limits other forms of aquaculture.

14.7.5 Indonesian Aquaculture

An analysis by WorldFish has indicated that aquaculture will overtake capture fisheries as the major source of fish in Indonesia before 2030 (Phillips *et al.* 2015). By volume, Indonesian aquatic production is dominated by seaweeds, but by value, domestically consumed species such tilapia and milkfish, together with export-orientated commodities such as shrimp and tuna, are of greater importance (Phillips *et al*. 2015).

Carrageenan seaweed farming based primarily on the cultivation of *Kappaphycus* and *Eucheuma* species has grown significantly in Indonesia. Due to the simple farming techniques required, low requirements of capital and material inputs, and short production cycles it has become a favourable livelihood for smallholder farmers and fishers (Valderrama *et al*. 2013). Indonesia's coastline provides ideal conditions for fish farming in "brackish waters". Aquaculture in Indonesia is predominantly used for seaweed production, whilst offshore fish cultivation remains relatively undeveloped (Global Business Guide 2014).

14.8 Recreational Fisheries

14.8.1 North Coast Bioregion

The North Coast Bioregion (Pilbara/Kimberley) runs from the Ashburton River to the Western Australia/Northern Territory border (WAFIC 2016). The oceanography of this region includes waters of Pacific Ocean origin that enter through the Indonesian archipelago bringing warm, low salinity waters polewards via the Indonesian throughflow and Holloway currents which flow seasonally and interact with Indian ocean waters. Recreational fishing is experiencing a significant growth in this region, with a distinct seasonal peak in winter when the local population increases by significant numbers of metropolitan and inter-state tourists. This has been added to by the increased recreational fishing by those involved in the construction or operation of major developments in this region. Owing to the high tidal range, much of the angling activity is boat-based with beach fishing limited to periods of flood tides and high water. Numerous creek systems, mangroves, rivers and ocean beaches provide shore and small boat fishing for a variety of species including barramundi, tropical emperors, mangrove jack, trevallies, sooty grunter, threadfin, mud crabs and cods. Offshore islands, coral reef systems and continental shelf waters provide species of major recreational interest including saddetail snapper and red emperor, cods, coral and coronation trout, sharks, trevally, tuskfish, mackerals and billfish (WAFIC 2016).

14.8.2 Gascoyne Coast Bioregion

The Gascoyne Coast Bioregion extends from just north of Kalbarri to the Ashburton River, south of Onslow. The marine environment of this region represents a transition between the fully tropical waters of the north-west shelf of the north coast region and the temperate waters of the west coast region. This region has been identified as one of the 18 world 'hotspots' in terms of tropical reef endemism and the second most divers marine environment in the world in terms of tropical reef species. This region is a focal point for winter recreational fishing and is a key component of many tourist visits. Angling activities include beach and cliff fishing (e.g. Steep Point and Quobba), embayment and shallow-water boat angling (e.g. Shark Bay, Exmouth Gulf and Ningaloo lagoons), and offshore boat angling for demersal and larger pelagic species (e.g. off Ningaloo). The predominant target species include the tropical species such as emperors, tropical snappers, groupers, mackerals, trevallies and other game fish. Temperate species at the northern end of their ranges such as pink snapper, tailor and whiting also provide significant catches, particularly in Shark Bay (WAFIC 2016).

14.8.3 West Coast Bioregion

The marine environment of the West Coast Bioregion which lies between Kalbarri and Augusta is predominantly a temperate oceanic zone, but it is heavily influenced by the Leeuwin current, which transports warm tropical water southward along the edge of the continental shelf. This region contains the state's major population centres and is the most heavily used bioregion for recreational fishing (Fletcher and Santoro 2015). The range of recreational fishing opportunities includes estuarine fishing, beach fishing and boat fishing either in embayments or offshore for demersal and pelagic game species often around the islands and out to the continental shelf (WAFIC 2016).

14.8.4 South West Bioregion

The South West Bioregion includes the water from Augusta to Eucla on the Western Australia/South Australia border. The continental shelf waters of this region are generally temperate but low in nutrients due to the seasonal presence of the tail of the tropical Leeuwin current and limited terrestrial run-off. As much of the south coast is remote or difficult to access, recreational beach and boat fishing tends to be concentrated around the main population and holiday centres. The major target species for beach and rock anglers are salmon, herring, whiting and trevally, while boat anglers target pink snapper, queen snapper, Bight redfish, a number of shark species, salmon fish and King George whiting. Another component of the recreational fishery is dinghy and shoreline fishing off estuaries and rivers where the main angling targets are black bream and whiting. Recreational netting primarily targeting mullet also occurs in these estuaries (WAFIC 2016).

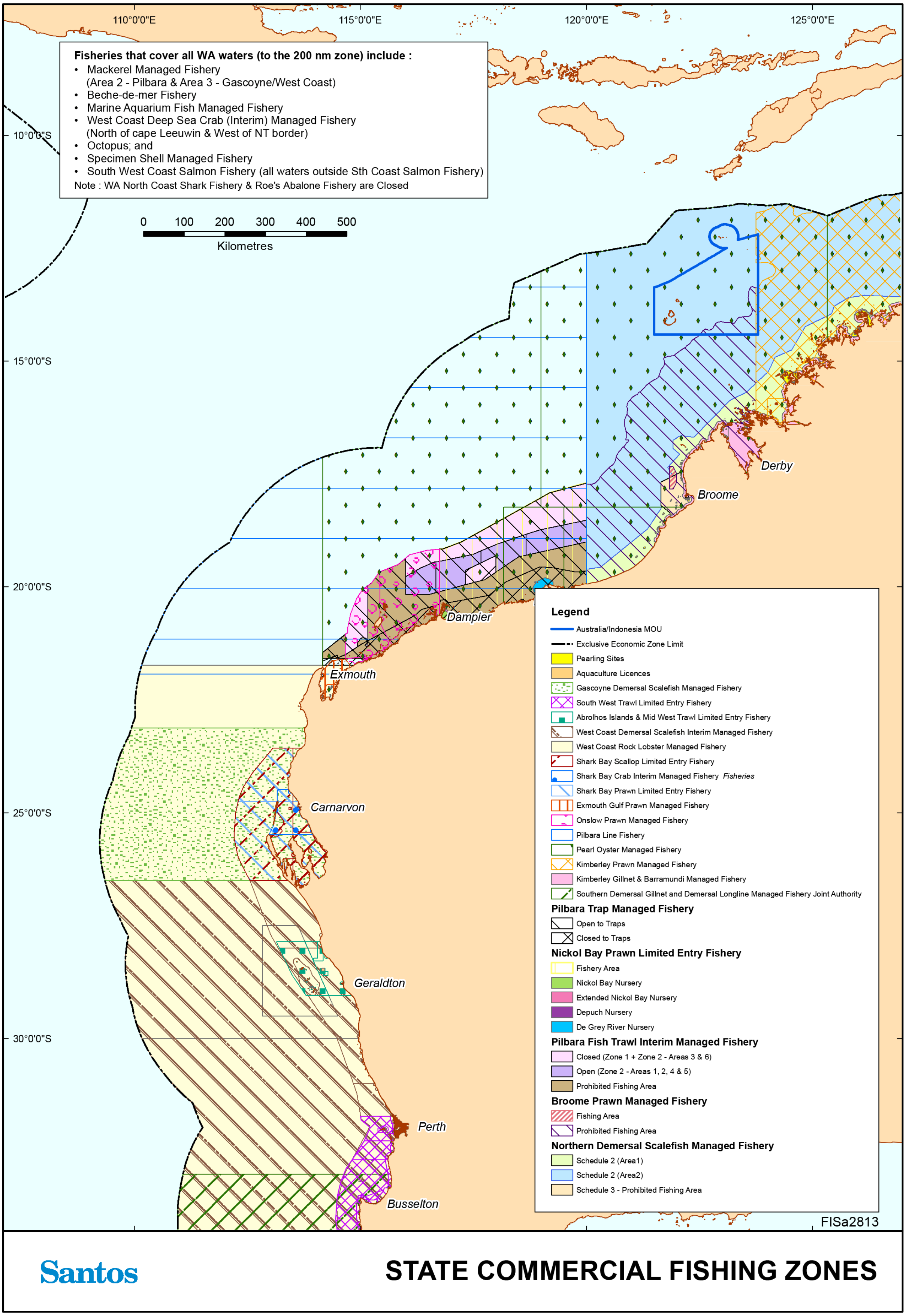

Figure 14-10: State commercial fishing zones

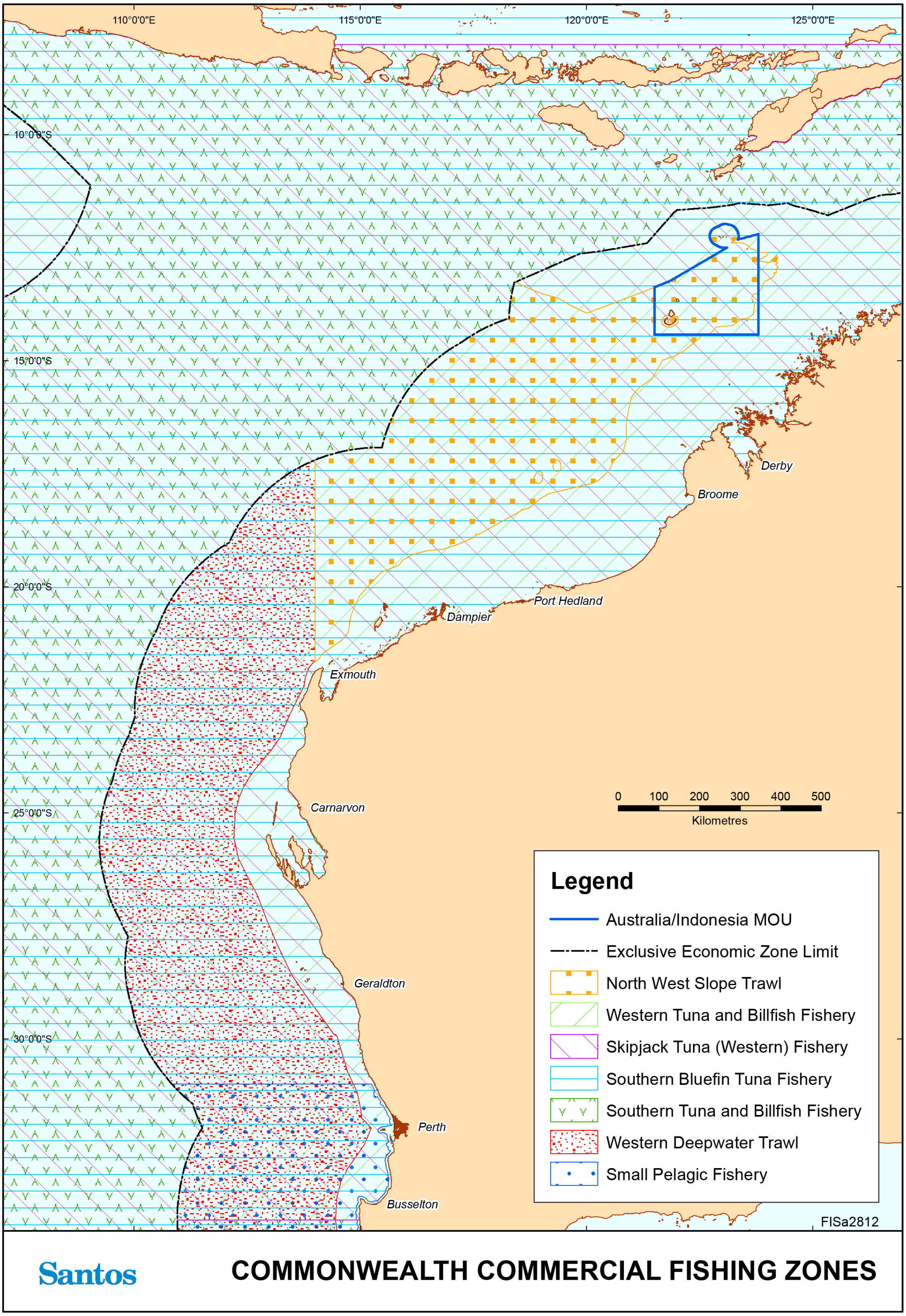

Figure 14-11: Commonwealth commercial fishing zones

Table 14-2: Commercial fisheries with permits to operate within the area of interest

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
State Managed Fisheries				
Abrolhos Islands and Mid-West Trawl Managed Fishery (AIMWTMF)	Saucer scallops (*Ylistrum balloti*), with a small component targeting the western king prawn (*Penaeus latisulcatus*)	2017 /2018: 651 tonnes	Operates using low opening otter trawl systems.	All the waters of the Indian Ocean adjacent to Western Australia between 27°51´ south latitude and 29°03´ south latitude on the landward side of the 200 m isobath'.
Broome Prawn Managed Fishery (BPMF)	Western king prawns (*Penaeus latisulcatus*) and coral prawns (a combined category of small penaeid species).	Neglibible: Minimal fishing occurred in 2017/2018	Otter trawl	The BPMF operates in a designated trawl zone off Broome. The boundaries of the BPMF are 'all Western Australian waters of the Indian Ocean lying east of 120° east longitude and west of 123°45' east longitude on the landward side of the 200 m isobath'. The actual trawl area is contained within a delineated small area north west of Broome.
Cockburn Sound Mussel Managed Fishery	Blue mussels (*Mytilus edulis*)	2015: Unspecified	Agriculture	Main mussel farming occurs in southern Cockburn Sound.
Cockburn Sound Crab Managed Fishery	Blue Swimmer (*Portunus armatus)* Blue swimmer crab (*Portunus armartus)*	2017/2018: 5: closed to commercial and recreational fishing since April 2014	Drop nets, scoop nets, diving	Encompasses the inner waters of Cockburn Sound, from South Mole at Fremantle to Stagglers Rocks, through Mewstone to Carnac Island and Garden Islande, along the eastern shore of Garden Island and back to John Point on the mainland.
Cockburn Sound Line and Pot Managed Fishery	Southern garfish (*Hyporhamphus melanochir*), Australian herring (*Arripis geogianus*)	2016: 252 tonnes	Line (fish) Shelter and trigger pots (octopus)	Encompasses the inner waters of Cockburn Sound, from South Mole at Fremantle to Stagglers Rocks, through Mewstone to Carnac Island and Garden Islande, along the eastern shore of Garden Island and back to John Point on the mainland.
Exmouth Gulf Prawn Managed Fishery	Western king prawns (*Penaeus latisulcatus*), brown tiger prawns	2017/2018: 713 tonnes	Low opening otter trawls.	Sheltered waters of Exmouth Gulf Essentially the western half of the Exmouth Gulf (eastern

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
	(*Penaeus esculentus*), endeavour prawns (*Metapenaeus* spp.) and banana prawns (*Penaeus merguiensis*).			part is a nursery ground). The Muiron Islands and Point Murat provide the western boundary; Serrurier Island provides the northern limit
Gascoyne Demersal Scalefish Managed Fishery (GDSMF)	Targets pink snapper (*Pagrus auratus*) and goldband snapper (*Pristipomoides multidens*). Other demersal species caught include the rosy snapper (*P. filamentosus*), ruby snapper (*Etelis carbunculus*), red emperor (*Lutjanus sebae*), emperors (Lethrinidae, including spangled emperor, *Lethrinus nebulosus*, and redthroat emperor, *L. miniatus*), cods (Epinephelidae, including Rankin cod, *Epinephelus multinotatus* and goldspotted rockcod, *E. coioides*), pearl perch (*Glaucosoma burgeri*), mulloway (*Argyrosomus japonicas*), amberjack (*Seriola dumerili*) and trevallies (Carangidae).	2017/2018: Snapper: 133 tonnes Other demersals: 144 tonnes	Mechanised handlines	The GDSF operates in the waters of the Indian Ocean and Shark Bay between latitudes 23°07'30"S and 26°30'S. Vessels are not permitted to fish in inner Shark Bay.
Abalone Managed Fishery	Greenlip abalone (*Haliotis laevigata*) Brownlip abalone (*H. conicopora)*	2017/2018: 98 tonnes	Dive fishery The principal harvest method is a diver working off 'hookah' (surface supplied breathing apparatus) or SCUBA using an abalone 'iron' to prise the shellfish off rocks – both commercial and recreational divers employ this method.	Shallow coastal waters off the south-west and south coasts of Western Australia Covers all Western Australian coastal waters, which are divided into eight management areas. Commercial fishing for greenlip/brownlip abalone is managed in three separate areas.
Hermit Crab Fishery (HCF)	Australian land hermit crab (*Coenobita variabilis*)	2016: 79,437	Land based hand collection typically using four-wheel	Operates in Western Australian waters north of the Exmouth Gulf (22°30'S)

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
			drives to access remote beaches	
Kimberley Developing Mud Crab Managed Fishery	Mud crab (*Scylla serrata*)	2016: 36.9 tonnes (also includes catch data from Pilbara Developmental crab fishery)	Mud Crab traps	This fishery operates between Broom and Cambridge Gulf. Three commercial operators are permitted to fish from King Sound to the Northern Territory border, with closed areas around communities and fishing camps. One Aboriginal Corporation is permitted to fish in King Sound, with the other Aboriginal Corporation permitted to fish in a small area on the western side of the Dampier peninsula, north of Broome. Notices ssued under the Fish Resources Management Act 1994 prohibit all commercial fishing for mud crabs in Roebuck Bay and an area of King Sound near Derby.
Kimberley Gillnet and Barramundi Managed Fishery (KGBF)	Barramundi *(Lates calcarifer),* King threadfin *(Polydactylus macrochir),* Blue threadfin *(Eleutheronema tetradactylum)*	2016: 74.6 tonnes	Gill net in inshore waters	Nearshore and estuarine zones of the North Coast Bioregion from the WA/NT border (129ºE) to the top end of Eighty Mile Beach, south of Broome (19ºS). The waters of the KGBF are defined as 'all Western Australian waters north of 19° south latitude and west of 129° east longitude and within three nautical miles of the high water mark of the mainland of Western Australia and the waters of King Sound south of 16°21.47´ south latitude.
Kimberley Prawn Managed Fishery (KPMF)	Banana prawns (*Penaeus merguiensis*) Tiger prawns (*Penaeus esculentus*) Endeavour prawns (*Metapenaeus endeavouri*)	2017/2018: 269 tonnes	Otter trawl	The KPMF operates off the north of the state between Koolan Island and Cape Londonderry. The boundaries of the KPMF are 'all Western Australian waters of the Indian Ocean lying east of 123°45´ east longitude and west of

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
	Western king prawns (*Penaeus latisulcatus*)			126°58´ east longitude'. It abuts the western boundary of the Commonwealth Northern Prawn Fishery (NPF).
Mandurah to Bunbury Developing Crab Fishery	Blue swimmer crab (*Portunus armartus)*	2016: 3.4 tonnes	Drop nets, scoop nets, diving	Fishery extends from south of the Shoalwater Islands Marine Park (32°22'40''S) to Point McKenna near Bunbury (33°16'S) and offshore to 115°30'E. The fishery is divied into two zones with crab fishing historically being permitted within Area 1, Comet Bay between 32°22''40''S and 32°30'S, and Area 2, Cape Bouvard to the southern boundary of the fishery. In 2015 crab fishing within Area 2 ceased.
Marine Aquarium Fish Managed Fishery (MAFMF)	Over 250 target species of finfish. (228 species caught in 2012). Fishermen can also take coral, live rock, algae, seagrass and invertebrates. The main fish species landed in 2012 were scribbled angelfish (*Chaetodontoplus duboulayi*) and green chromis (*Chromis cinerascens*) The main coral species landed in 2012 were the coral like anemones of the Corallimorpharia.	2016: Total catch of 15,424 fish, 3,514 hard kilograms of hard coral, 4, 298 kilograms of soft coral, 8, 621 kolograms of living rock and sand, 3, 972 sponges and 75 litres of algae/seagrasses	Hand harvest while diving or wading. Hand held nets	Dive based fishery operating all year throughout WA waters, but restricted by diving depths. The MAFMF is able to operate in all State waters (between the Northern Territory border and South Australian border). The fishery is typically more active in waters south of Broome with higher levels of effort around the Capes region, Perth, Geraldton, Exmouth and Dampier. Operators in the MAFMF are also permitted to take coral, live rock, algae, seagrass and invertebrates under the Prohibition on Fishing (Coral, 'Live Rock' and Algae) Order 2007 and by way of Ministerial Exemption (Gaughan & Santoro, 2018).
Nickol Bay Prawn Managed Fishery (NBPMF)	Primarily targets banana prawns (*Penaeus merguiensis*)	2017/2018: 227 tonnes	Otter trawl	Operates along the western part of the North-West Shelf in coastal shallow waters The boundaries of the NBPMF are 'all the waters of the Indian Ocean and Nickol Bay between 116°45' east longitude and 120° east longitude on the landward side of the

Santos

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
				200 m isobath'. The NBPMF incorporates the Nickol Bay, Extended Nickol Bay, Depuch and De Grey size managed fish grounds (State of the Fisheries 2014-15).
North Coast Trochus Fishery	Trochus (*Tectus niloticus*)	2016: Unspecified	Harvested by with handheld levers or chisels	Indigenous fishery operating within King Sound
Northern Demersal Scalefish Managed Fishery (NDSF)	Red emperor (*Lutjanus sebae*) Goldband snapper (*Pristipomoides multidens*)	2017/2018:1317 tonnes (total) Goldband snapper (not including other jobfish): 473 tonnes Red emperor: 34 – 47 tonnes	The permitted means of operation within the fishery include handline, dropline and fish traps, but since 2002 it has essentially been a trap based fishery which uses gear time access and spatial zones as the primary management measures (State of the Fisheries 2014-15).	The Northern Demersal Scalefish Managed Fishery (NDSF) operates off the northwest coast of Western Australia in the waters east of 120° E longitude. These waters extend out to the edge of the Australian Fishing Zone (200 nautical miles). The Fishery consists of three zones; Zone A is an inshore area, Zone B comprises the area with most historical fishing activity and Zone C is an offshore deep slope developmental area. The fishery is further divided into two fishing areas; an inshore sector and an offshore sector The inshore waters in the vicinity of Broome are closed to commercial fishing.
WA North Coast Shark Fisheries	Sandbar (*Carcharhinus plumbeus)*, hammer head (*Sphyrnidae*), blacktip (*Carcharhinus melanopterus*) and lemmon sharks (*Negaprion brevirostris*).	2017/2018: closed since 2008/2009	Gill net, longline	Comprised of the State-managed WA North Coast Shark Fishery in the Pilbara and western Kimberley, and the Joint Authority Northern Shark Fishery in the eastern Kimberley.
Octopus Interim Managed Fishery	*Octopus cf. tetricus*, with occasional bycatch of *O. ornatus* and *O. cyanea* in the northern parts of the fishery, and *O.maorum* in the southern and deeper sectors.	2017/2018: Commerical: 257 tonnes Recreational: 1 tonne	Line and pots Trawl and trap (land Octopus as byproduct)	Fishery in development phase. Four main categories in WA waters. Octopus are primarly caught in the Developing OOctopus Interm Managed Fishery (largest fishery) are limited to the boundaries of the developmental fishery, which is an area bounded by the Kalbarri Cliffs (26°30'S) in the north and Esperance in the south.

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
				Passive and by-product harvests of octopus occur in both the Cockburn Sound (Line and Pot) Managed Fishery and the West Coast Rock Lobster Managed Fishery.
Onslow Prawn Managed Fishery (OPMF)	Western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus* spp.)	2017/2018: Neglible (Minimal fishing occurred in 2017) (	Otter trawl	Operates along the western part of the North-West Shelf with most prawning activities concentrated in the shallower water off the main land. The boundaries of the OPMF are 'all the Western Australian waters between the Exmouth Prawn Fishery and the Nickol Bay prawn fishery east of 114º39.9' on the landward side of the 200 m depth isobath'.
Pilbara Developmental Crab Fishery	Blue Swimmer (*Portunus armatus)* Mud Crab (*Scylla* spp)	2016: total of 36.9 tonnes (total number includes Kimberley Developing Mud Crab Fishery)	Variety of gear but mostly commercial crab pots (Hourglass traps used in inshore waters from Onslow through to Port Hedland with most commercial and activity occurring in and around Nickol Bay) Recreational fishers use drop nets or scoop nets, with diving for crabs becoming increasingly popular	The majority of the commercially and recreationally-fished stocks are concentrated in the coastal embayments and estuaries between Geographe Bay in the south west and Nickol Bay in the north. Crabbing activity along the Pilbara coast is centred largely on the inshore waters from Onslow through to Port Hedland, with most commercial and recreational activity occurring in and around Nickol Bay (State of the Fisheries 2014/15).
Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)	Variety of demersal scalefish including goldband snapper (*Pristipomoides multidens*), red emperor (*Lutjanus sebae*), bluespotted emperor (*Lethrinus punctulatus*), crimson snapper (*Lutjanus erythropterus*), saddletail snapper (*Lutjanus malabaricus*), Rankin cod (*Epinephelus multinotatus*), brownstripe snapper (*Lutjanus vitta*),	2017/2018: 1780 tonnes	Demersal trawl	The Pilbara Fish Trawl (Interim) Managed Fishery is situated in the Pilbara region in the north west of Australia. It occupies the waters north of latitude 21°35'S and between longitudes 114°9'36"E and 120°E. The Fishery is seaward of the 50 m isobath and landward of the 200 m isobath. The Fishery consists of two zones; Zone 1 in the south west of the Fishery (which is closed

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
	rosy threadfin bream (*Nemipterus furcosus*), spangled emperor (*Lethrinus nebulosus*) and frypan Moses' snapper (*Argyrops Lutjanusspinifer russelli*).			to trawling) and Zone 2 in the North, which consists of six management areas.
Pilbara Trap Managed Fishery (PTMF)	Blue-spot emperor (*Lethrinus hutchinsi*), Red snapper (*Lutjanus erythropterus*), Goldband snapper (*Pristipomoides multidens*), Scarlet perch (*Lutjanus malabaricus*), Red emperor (*Lutjanus sebae*), Spangled emperor (*Lethrinus nebulosus*), Rankin cod (*Epinephelus multinotatus*)	2017/2018: 400 – 600 Tonnes	Use of rectangular traps with single opening and 50 mm x 70 mm rectangular mesh panels. Trap fishing normally targets areas around rocky outcrops and reefs	Permitted to operate within waters bounded by a line commencing at the intersection of 21°56´ S latitude and the high water mark on the western side of the North West Cape.
Pilbara Line Managed Fishery	Variety of demersal scalefish including goldband snapper (*Pristipomoides multidens*), red emperor (*Lutjanus sebae*), bluespotted emperor (*Lethrinus punctulatus*), crimson snapper (*Lutjanus erythropterus*), saddletail snapper (*Lutjanus malabaricus*), Rankin cod (*Epinephelus multinotatus*), brownstripe snapper (*Lutjanus vitta*), rosy threadfin bream (*Nemipterus furcosus*), spangled emperor (*Lethrinus nebulosus*) and frypan snapper (*Argyrops spinifer*), Ruby snapper (*Etelis carbunculus*) and eightbar grouper (*Hyporthodus octofasciatus)*	2017/2018: 50 - 115 tonnes	Line	The Pilbara Trap Managed Fishery lies north of latitude 21°44´ S and between longitudes 114°9´36´´ E and 120° E on the landward side of a boundary approximating the 200 m isobath and seaward of a line generally following the 30 m isobath.
Roe's Abalone	Western Australian Roe's abalone (*Haliotis roei*)	2017/2018: Commercial: 49 tonnes	Dive and wade fishery.	Operating in shallow coastal waters along WA's western and southern coasts from

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
		Recreational: 23 tonnes	The commercial fishery harvest method is a single diver working off a 'hookah' (surface-supplied breathing apparatus) using an abalone 'iron' to prise the shellfish off rocks. Abalone divers operate from small fishery vessels (generally less than 9 metres in length).	Shark Bay to the SA border. Divided into 8 management areas. Commercial fishing for Roe's abalone is managed in 6 separate regions from the South Australian border to Busselton Jetty – Areas 1, 2, 5, 6, 7 and 8 Area 8 of the fishery was not fished in 2013.
Shark Bay Crab Interim Managed Fishery	Blue swimmer crab (*Portunus armatus*)	2017/2018: 443 tonnes total Crab: 153 tonnes	Trawl and trap	Waters of Shark Bay north of Cape Inscription, to Bernier and Dorre Islands and Quobba Point. In addition, two fishers with long-standing histories of trapping crabs in Shark Bay are permitted to fish in the waters of Shark Bay south of Cape Inscription.
Shark Bay Prawn Managed Fishery	Western king prawn (*Penaeus latisulcatus*), brown tiger prawn (*Penaeus esculentus*), Variety of smaller prawn species including endeavour prawns (*Metapenaeus* spp.) and coral prawns (various species).	2017/2018: 1608 tonnes	Low opening otter trawls	The boundaries of the Shark Bay Prawn Managed Fishery are located in and near the waters of Shark Bay
Shark Bay Scallop Managed Fishery	Saucer Scallop (*Ylistrum balloti*)	2016: 816 tonnes	Low opening otter trawls	The boundaries of the Shark Bay Scallop Managed Fishery are located in and near the waters of Shark Bay
South Coast Open Acess Netting Fishery	Insufficient information	Insufficient information	Insufficient information	Insufficient information
Specimen Shell Managed Fishery (SSF)	Shells (cowries, cones) The Specimen Shell Managed Fishery (SSF) is based on the collection of individual shells for the purposes of	2016: 8,531 shells	Hand harvest while diving or wading along coastal beaches below the high water mark	Dive based fishery operating all year throughout WA waters, but restricted by diving depths.

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
	display, collection, cataloguing, classification and sale. Just under 200 (196) different Specimen Shell species were collected in 2012, using a variety of methods.		A new exemption method being employed by the fishery is using a remote controlled underwater vehicle at depths between 60 and 300 m.	The fishing area includes all Western Australian waters between the high water mark and the 200 m isobath. While the fishery covers the entire Western Australian coastline, there is some concentration of effort in areas adjacent to population centres such as Broome, Karratha, Exmouth, Shark Bay, metropolitan Perth, Mandurah, the Capes area and Albany.
South West Coast Beach Net	Insufficient information	Insufficient information	Insufficient information	Insufficient information
South West Trawl Managed Fishery (SWTMF)	Saucer scallops (*Ylistrum balloti*)	2016: 143 tonnes	Otter trawls	Waters between 31°34'27''S and 115°8'8''E where it intersects with the high water mark at Cape Leeuwin and on the landward side of the 200 m isobath.
Temperate Demersal Gillnet and Demersal Longline Fisheries (TDGDLF)	Gummy shark (*Mustelus antarcticus*), dusky shark (*Carcharhinus obscurus*), whiskery shark (*Furgaleus macki*) and sandbar shark (*Carcharhinus plumbeus*).	2016: Sharks and rays: 994 tonnes Scalefish: 143 tonnes	Demersal gillnets and power-hauled reels (to target sharks) Demersal longline	The Temperate Demersal Gillnet and Demersal Longline fisheries consists of Zone 1 of the Joint Austhority Southern Demersal Gillnet and DSemersal Longline Managed Fishery and the West Coast Demersal Gillnet and Demersal Longling (Interim) Managed Fishery. The Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery (JASDGDLF) spans the waters from 33° S latitude to the WA/SA border and comprises three management zones Zone 1 extends southwards from 33° S to 116° 30' E longitude off the south coast. Zone 2 extends from 116°30' E to the WA/SA border (129° E). A small number of Zone 3 units permit fishing throughout Zone 1 and eastwards to 116° 55'40" E.

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
				The West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery (WCDGDLF) technically extends northwards from 33° S latitude to 26° S longitude. However, the use of shark fishing gear has been prohibited north of 26° 30' S (Steep Point) since 1993. Demersal gillnet and longline fishing inside the 250 metre depth contour has been prohibited off the Metropolitan coast (between latitudes 31° S and 33° S) since November 2007.
Warnbro Sound Crab Managed Fishery	Blue Swimmer (*Portunus armatus)* Blue swimmer crab (*Portunus armartus)*	2016: closed to commercial and recreational fishing	Drop nets, scoop nets, diving	Includes Warnboro sound and adjacent water, extending from Becher Point to John Point.
West Coast Deep Sea Crustacean (Interim) Managed Fishery	Crystal (Snow) crabs (*Chaceon albus*), Giant (King) crabs (*Pseudocarcinus gigas*) and Champagne (Spiny) crabs (*Hypothalassia acerba*).	2016 154 tonnes (Q); 61 k – 101.5 K potlifts	Baited pots operated in a longline formation in the shelf edge waters (>150 m)	North of latitude 34° 24' S (Cape Leeuwin) and west of the Northern Territory border on the seaward side of the 150 m isobath out to the extent of the AFZ, mostly in 500 to 800 m of water.
West Coast Demersal Scalefish (Interim) Managed Fishery	West Coast Inshore Demersals: West Australian Dhufish (*Glaucosoma hebraicum*), Pink snapper (*Pagrus auratus*) with other species captured including Redthroat Emperor (*Lethrinus miniatus*), Bight Redfish (*Centroberyx gerrardi*) and Baldchin Groper (*Choerodon rubescens*). West Coast Offshore Demersals: Eightbar Grouper *Hyporthodus octofasciatus*, Hapuku *Polyprion oxygeneios*, Blue-eye Trevalla *Hyperoglyphe antarctica* and Ruby Snapper *Etelis carbunculus*.	2016: 256 ytonnes	Handline and drop line	The WCDSIMF encompasses the waters of the Indian Ocean just south of Shark Bay (at 26°30'S) to just east of Augusta (at 115°30'E) and extends seaward to the 200 nm boundary of the Australian Fishing Zone (AFZ). The commercial fishery is divided into five management areas comprising four inshore areas and one offshore area. The inshore areas, i.e. Kalbarri, Mid-West, Metropolitan and South-West, extend outwards to the 250 m depth contour, while the Offshore Area extends the entire length of the fishery from the 250 m depth contour to the boundary of the AFZ.

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
West Coast Estuarine Managed Fishery	Blue swimmer crab (*Portunus armartus)*	2015: 97 tonnes (blue swimmer crab)	Drop nets, scoop nets, diving (crabs)	Includes the waters of the Swan and Canning Rivers (Area 1), the waters of the Peel Inlet and Harvey Estuary, together with the Murray Serpentine, Harvey and Dandalup Rivers (Area 2) and waters of the Hardy Inlet (Area 3). Of these areas only Areas 1-2 are permitted for crab fishing.
West Coast Nearshore and Esuarine Finfish Fisheries	<u>Nearshore:</u> whitebait (*Hyperlophus vittatus*), western Australian salmon (*Arripis truttaceus*), Australian herring (*Arripis georgianus*), southern school whiting (*Sillago bassensis*), yellowfin whiting (*Sillago schomburgkii*), yelloweye mullet (*Aldrichetta forsteri*), tailor (*Pomatomus saltarix*), southern garfish (*Hyporhamphus melanochir*), silver trevally (*Pseudocaranx georgianus*) and King George whtiting (*Sillaginodes punctate*). <u>Estuarine*:*</u> sea mullet (*Mugil cephalus*), estuary cobbler (*Cnidoglanis macrocephalus*) and black bream (*Acanthopagrus butcheri*).	2016: 380 tonnes	Haul, beach seine and gill netting (commercial). Line fishing (recreational)	Five commercial fisheries target nearshore and/or estuarine finfish in the West Coast Bioregion. <u>Nearshore:</u> Cockburn Sound Fish Net Managed Fishery operating within in Cockburn sound, South West Coast Salmon Managed Fishery operating on varous beaches south of the Perth Metropolitan area, West Coast Beach Bait Managed Fishery operating on beaches spanning from Moore River to Tim's Thicket and the South West Beach Seine Fishery operating on various beaches from Tim's Thicket southwards to Port Geographe Bay Marina. <u>Estuarine*:*</u> West Coast Estuarine Managed Fishery operating in the Swan/Canning and Peel Harvey estuaries, and in the Hardy Inlet
West Coast Nearshore Net Managed Fishery	Southern garfish (Hyporhamphus melanochir), Australian herring (Arripis georgianus),	Insufficient information	Insufficient information	Insufficient information
West Coast Purse Seine Fishery	Scaly mackeral (*Sardinella lemuru*), pilchard (*S. sagax*), Australian anchovy (*Engraulis australis*), yellowtail scad (*Trachurus novaezelandiae*) and maray (*Etrumeus teres*).	2016: 1, 177 toness	Purse seine gear	Waters between Ningaloo and Cape Leewin including three separate zones: Northern Development (22°00'S to 31°00'S), Perth Metropolitan (31°00'S to 33°00'S) and Southern Development Zone (33°00'S to Cape Leeuwin).

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
West Coast Rock Lobster Managed Fishery (WCRLMF)	Western rock lobster (*Panulirus cygnus*)	2016: 272 – 400 tonnes (346-481 tonnes based on updated average weight)	Baited traps (pots). Pots and diving (recreational catch)	The fishery is situated along the west coast of Australia between Latitudes 21°44´ to 34°24´ S. The fishery is managed in three zones: Zone A – Abrolhos Islands, north of latitude 30° S excluding the Abrolhos Islands (Zone B) and south of latitude 30° S (Zone C).
Western Australian Mackerel Managed Fishery (MMD)	Spanish mackerel *(Scomberomorus commerson)*, grey mackerel *(S.semifasciatus)*, with other species from the genera *Scomberomorus*, *Grammatorcynus* and *Acanthocybium* also contributing to commercial catches.	2016: Commercial: The commercial catch of spanish mackerel was 276 tonnes in 2016 (Gaughan & Santoro, 2018)	Trolling or handline Near-surface trolling gear from vessels in coastal areas around reefs, shoals and headlands. Jig fishing is also used to capture grey mackerel *(S.semifasciatus)*	The Fishery extends from the West Coast Bioregion to the WA/NT border, to the 200 nautical mile AFZ with most effort and catches recorded north of Geraldton, especially from the Kimberley and Pilbara coasts of the Northern Bioregion. Restricted to coastal and shallower waters. Catches are reported separately for three Areas: Area 1 - Kimberley (121º E to WA/NT border); Area 2 -Pilbara (114º E to 121º E); Area 3 - Gascoyne (27º S to 114º E) and West Coast (Cape Leeuwin to 27º S).
Western Australian Pearl Oyster Managed Fishery	Indo- Pacific silver-lipped pearl oyster (*Pinctada maxima*).	2016: 541,260 shells	Drift diving restricted to shallow diveable depths. The collection of pearl oysters for the Pearl Oyster Managed Fishery is restricted to shallow diving depths below 35 m. Divers are attached to large outrigger booms on a vessel and towed slowly over the pearl oyster beds, harvesting legalised oysters by hand as they are seen.	The fishery is separated into four zones: Pearl Oyster Zone 1: NW Cape (including Exmouth Gulf) to longitude 119°30'E. There are five licensees in this zone. No fishing in this zone since 2008 Pearl Oyster Zone 2: East of Cape Thouin (118°20´ E) and south of latitude 18°14´ S. The 9 licensees in this zone also have full access to Zone 3. This zone is the mainstay of the fishery. Pearl Oyster Zone 3: West of longitude 125°20´ E and north of latitude 18°14´ S. The 2 licensees in this zone also have partial access to Zone 2.

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
				Pearl Oyster Zone 4: East of longitude 125°20´ E to the Western Australia/Northern Territory border. Although all licensees have access to this zone, exploratory fishing has shown that stocks in this area are not economically viable. However, pearl farming does occur.
Western Australian Sea Cucumber Fishery (formerly known as Beche-de-mer)	Sandfish (*Holothuria scabra*) and deepwater redfish (*Actinopyga echinites*).	2016: 93 tonnes	Hand-harvest fishery, with animals caught principally by diving, and a smaller amount by wading.	The Western Australian Sea Cucumber Fishery is permitted to operate throughout WA waters with the exception of a number of specific closures around the Dampier Archipelago, Cape Keraudren, Cape Preston and Cape Lambert, the Rowley Shoals and the Abrolhos Islands. The fishery is primarily based in the northern half of the State, from Exmouth Gulf to the Northern Territory border.
Commonwealth Managed Fisheries				
North West Slope Trawl	Scampi (crayfish): velvet scampi (*Metanephrops velutinus*) and boschmai scampi (*Metanephrops boschmai*). Deepwater prawns (penaeid and carid): pink prawn (*Parapenaeus longirostris*), red prawn (*Aristaeomorpha foliacea*), striped prawn (*Aristeus virilis*), giant scarlet prawn (*Aristaeopsis edwardsiana*), red carid prawn (*Heterocarpus woodmasoni*) and white carid prawn (*Heterocarpus sibogae*). Snapper.	2016- 17: 57.8 total tonnes.	Demersal crustacean trawl seaward of the 200 m isobath.	Extends from 114° E to approximately 125° E off the WA coast between the 200 m isobath and the outer limit of the Australian Fishing Zone (AFZ).
Western Skipjack Tuna Fishery	Skipjack tuna (*Katsuwonus pelamis*)	2016-17: None in either zones	Purse seine	The Skipjack Tuna Fishery is split into two sectors; east and west. The Western Skipjack

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
				Tuna Fishery is located in all Australia waters west of 142º 30’ 00ºE, out to 200 nm from the coast. There has been no fishing effort in the Skipjack Tuna Fishery since the 2009 season, and in that season activity concentrated off South Australia (Patterson et al 2018).
Small Pelagic Fishery	Australian sardine (*Sardinops sagax*), blue mackeral (*Scomber australasicus*), jack mackerel (*Trachurus declivis*) and redbait (*Emmelichthys nitidus*).	2017-18: 5,713 tonnes	Purse-seince and midwater trawling	Extends from Queensland to southern Western Australia.
Southern Bluefin Tuna Fishery	Southern bluefin tuna (*Thunnus maccoyii*).	2016-17: 5,334 tonnes.	Purse seine vessels primarily in Great Australian Bight all year round and longline off southern NSW in winter. Around 98% of Australia’s SBT quota is taken by 5–10 purse seine vessels fishing for 13–25 kg southern bluefin tuna.	Fishery includes all waters of Australia, out to 200 nm from the coast. No current effort on NWS, fishing activity is concentrated in the Great Australian Bight and off South-east Australia (Patterson et al. 2018).
Western Deepwater Trawl Fishery	A diverse range of species are caught, ranging from tropical and ruby snappers on the shelf edge to orange roughy (*Hoplostethus atlanticus*), oreo dories and bugs (*Ibacus* spp.) in the deeper temperate waters.	2016-17: 8.3 tonnes.	Demersal fish trawl seaward of the 200 m isobath.	Its northernmost point is from the boundary of the AFZ to longitude 114° E, and its southernmost point is from the boundary of the AFZ to longitude 115°08’ E. Deep water off WA, from the 200 m isobath to the edge of the AFZ.
Western Tuna and Billfish Fishery	Broadbill swordfish (*Xiphias gladius*), albacore tuna (*Thunnus alalunga*), striped marlin (*Kajikia audax*), bigeye tuna (*T. obesus*) and yellowfin tuna (*T. albacares*).	2017: 322 tonnes	Pelagic, longline, minor line and purse seine.	Extends westward from Cape York Peninsula (142°30’ E) off Queensland to 34° S off the WA west coast. It also extends eastward from 34° S off the west coast of WA across the Great Australian Bight to 141° E at the South

Fishery	Target Species	Catch[1]	Fishing Method	Area Description
				Australian–Victorian border. In recent years, fishing effort has concentrated off south-west Western Australia and South Australia with no current effort on NWS (Patterson et al. 2018).

Source: Apache (2008); Australian Fisheries Management Authority (2011); Department of Fisheries (2013), Stakeholder consultation.

[1]Sources for catch data: Patterson et al., 2018; Gaughan and Santoro, 2018; DPIRD 2018.

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Appendix C – EPBC Act Protected Matters Search Reports (Operational Area and EMBA) and Aboriginal Heritage Inquiry System Searches

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

Search Criteria

3 Registered Aboriginal Sites in Custom search area - Polygon - 115.12367061842°E, 20.6357999643643°S (GDA94) : 115.094309565981°E, 20.210200777212°S (GDA94) : 115.094309565981°E, 20.2016175695091°S (GDA94) : 119.08237391654°E, 19.7955810807948°S (GDA94) : 119.329566299352°E, 19.9626183548802°S (GDA94) : 119.067734755013°E, 20.0400459781817°S (GDA94) : 118.923072158727°E, 19.95399573432°S (GDA94) : 116.925400603001°E, 20.1431976366847°S (GDA94) : 115.923832408522°E, 20.546685225406°S (GDA94) : 115.40931514967°E, 20.539818242518°S (GDA94) : 115.12367061842°E, 20.6357999643643°S (GDA94)

Disclaimer

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The information provided is made available in good faith and is predominately based on the information provided to the Department of Planning, Lands and Heritage by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at heritageenquiries@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

Copyright

Coordinate Accuracy

Coordinates (Easting/Northing metres) are based on the GDA 94 Datum. Accuracy is shown as a code in brackets following the coordinates.

Terminology (NB that some terminology has varied over the life of the legislation)

Place ID/Site ID: This a unique ID assigned by the Department of Planning, Lands and Heritage to the place.
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  - Lodged: Information has been received in relation to the place, but an assessment has not been completed at this *stage* to determine if it meets Section 5 of the *Aboriginal Heritage Act 1972.*

Access and Restrictions:

- File Restricted = No: Availability of information that the Department of Planning, Lands and Heritage holds in relation to the place is not restricted in any way.
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- Boundary Restricted = No: Place location is shown as accurately as the information lodged with the Registrar allows.
- Boundary Restricted = Yes: To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least $4km^2$) provides a general indication of where the place is located. If you are a landowner and wish to find out more about the exact location of the place, please contact the Department of Planning, Lands and Heritage.
- Restrictions:
  - No Restrictions: *Anyone* can view the information.
  - Male Access Only: Only *males* can view restricted information.
  - Female Access Only: *Only* females can view restricted information.

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place. This has been replaced by the Place ID / Site ID.

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Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
873	MONTEBELLO IS: NOALA CAVE.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, BP Dating: 27,220 +/- 640	*Registered Knowledge Holder names available from DAA	348188mE 7741053mN Zone 50 [Reliable]	P07287
926	MONTEBELLO IS: HAYNES CAVE.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Rockshelter, Arch Deposit	*Registered Knowledge Holder names available from DAA	348289mE 7741005mN Zone 50 [Reliable]	P07286
12550	CONDINI LANDING WEST	No	No	No Gender Restrictions	Registered Site	Skeletal Material / Burial	*Registered Knowledge Holder names available from DAA	737640mE 7789656mN Zone 50 [Unreliable]	K02698

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

Map of Registered Aboriginal Sites

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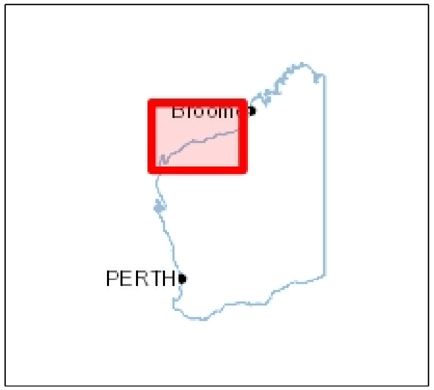
Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

150.50 kilometres

Map Scale 1 : 4,560,000

MGA Zone 50 (GDA94)



Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

Search Criteria

13 Registered Aboriginal Sites in Custom search area - Polygon - 119.416591702332°E, 20.0170795171638°S (GDA94) : 121.342879282613°E, 18.8463648020113°S (GDA94) : 121.588231670041°E, 18.6937928788725°S (GDA94) : 121.569911847193°E, 19.0212864436965°S (GDA94) : 121.478368388791°E, 19.2617396107926°S (GDA94) : 121.027928935666°E, 19.6622539069794°S (GDA94) : 120.324804103305°E, 19.9292866922233°S (GDA94) : 119.775460036774°E, 19.9809460911891°S (GDA94) : 119.780953200837°E, 20.0101890408626°S (GDA94) : 119.583199294587°E, 20.1133861566005°S (GDA94) : 119.416591702332°E, 20.0170795171638°S (GDA94)

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Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place. This has been replaced by the Place ID / Site ID.

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List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
7784	BUNNEENYA.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Water Source	*Registered Knowledge Holder names available from DAA	780640mE 7783456mN Zone 50 [Unreliable]	P05053
7785	WALUBIDI-MARINGDJINE.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Water Source	*Registered Knowledge Holder names available from DAA	781090mE 7783956mN Zone 50 [Unreliable]	P05054
7786	BAALYINNYE.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Water Source	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	P05055
11397	PARDOO 1	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Repository / Cache	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	P00747
11449	PARDOO 2.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Skeletal Material / Burial, Camp, Other: PA 44, NE	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	P00745
12964	CAPE KERAUDREN 2	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter	*Registered Knowledge Holder names available from DAA	791440mE 7789156mN Zone 50 [Reliable]	K02265
12965	CAPE KERAUDREN 3.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02266
12966	CAPE KERAUDREN 4	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DAA	788440mE 7786856mN Zone 50 [Reliable]	K02267
12967	CAPE KERAUDREN 5	Yes	Yes	No Gender Restrictions	Registered Site	Midden / Scatter, Skeletal Material / Burial	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02268
12968	CAPE KERAUDREN 6	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Grinding Patches / Grooves, Midden / Scatter	*Registered Knowledge Holder names available from DAA	791940mE 7789556mN Zone 50 [Reliable]	K02269
12969	WARRA MURRANGA TALU	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02270
14432	CAPE JAUBERT	No	No	No Gender Restrictions	Registered Site	Fish Trap	*Registered Knowledge Holder names available from DAA	348472mE 7903559mN Zone 51 [Reliable]	K00650

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14483	N.W. COASTAL HIGHWAY	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00583

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

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Map of Registered Aboriginal Sites

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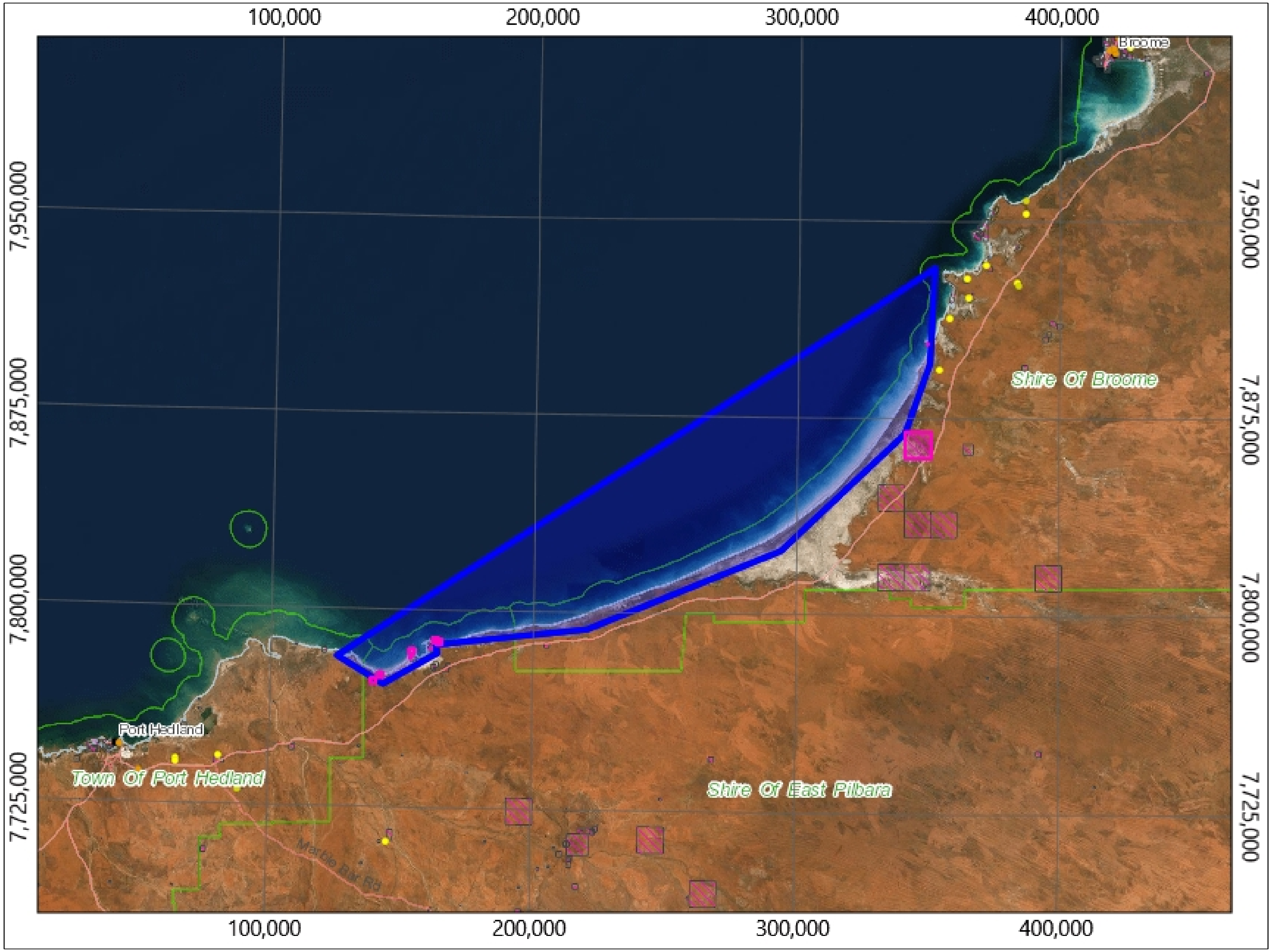


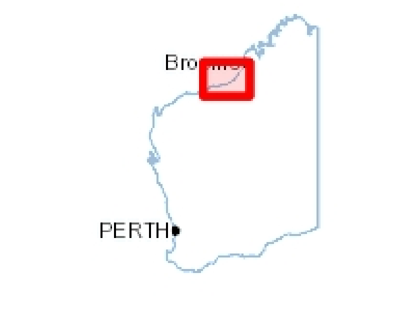
Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

77.17 kilometres

Map Scale 1 : 2,340,000

MGA Zone 51 (GDA94)



Map created: 06/11/2019 10:25:13 AM by: GIS_NET_USER

Identifier: 423008

Search Criteria

14 Registered Aboriginal Sites in Custom search area - Polygon - 121.581818592396°E, 18.6765168830383°S (GDA94) : 121.988285240378°E, 16.6930876053564°S (GDA94) : 121.991965566423°E, 16.6509896398643°S (GDA94) : 122.233664785173°E, 16.6579889978079°S (GDA94) : 121.973673571494°E, 18.440434402926°S (GDA94) : 121.883942615833°E, 18.4838634392203°S (GDA94) : 121.832691468891°E, 18.4647424602828°S (GDA94) : 121.829010975208°E, 18.4751628818294°S (GDA94) : 121.830851305869°E, 18.5168382333267°S (GDA94) : 121.796051990833°E, 18.5619924244613°S (GDA94) : 121.581818592396°E, 18.6765168830383°S (GDA94)

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Basemap Copyright

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ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12468	GALYUNGA	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Fish Trap, Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02772
12469	GUNJI CEREMONIAL GROUND	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02773
12470	GULGUDUNG	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02774
12471	MARUNGUDA	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02775
14433	PORT SMITH.	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Camp	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00651
14439	BIDIR-NGA:BA	Yes	Yes	No Gender Restrictions	Registered Site	Fish Trap, Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00657
17573	CAPE VILLARET AREA 08	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, Arch Deposit, BP Dating: 1800+/-70, Ochre	*Registered Knowledge Holder names available from DAA	391987mE 7963761mN Zone 51 [Reliable]	
17574	CAPE VILLARET AREA 09	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DAA	389337mE 7961161mN Zone 51 [Reliable]	
17575	CAPE VILLARET AREA 10	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DAA	388087mE 7960511mN Zone 51 [Reliable]	
17576	CAPE VILLARET AREA 11 / GUMALIINGA	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DAA	386937mE 7959761mN Zone 51 [Reliable]	
17577	CAPE VILLARET AREA 12	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Midden / Scatter, BP Dating: 1700+/-60, Other: Baler shell	*Registered Knowledge Holder names available from DAA	379037mE 7957761mN Zone 51 [Reliable]	
17578	CAPE VILLARET AREA 13	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DAA	378787mE 7958211mN Zone 51 [Reliable]	

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
17579	CAPE VILLARET AREA 14	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, BP Dating: 3060+/-50, Camp, Other: Baler shell	*Registered Knowledge Holder names available from DAA	378844mE 7957964mN Zone 51 [Reliable]	
17580	CAPE VILLARET AREA 15	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Camp, Other: Baler shell	*Registered Knowledge Holder names available from DAA	376937mE 7959911mN Zone 51 [Reliable]	

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

Map of Registered Aboriginal Sites

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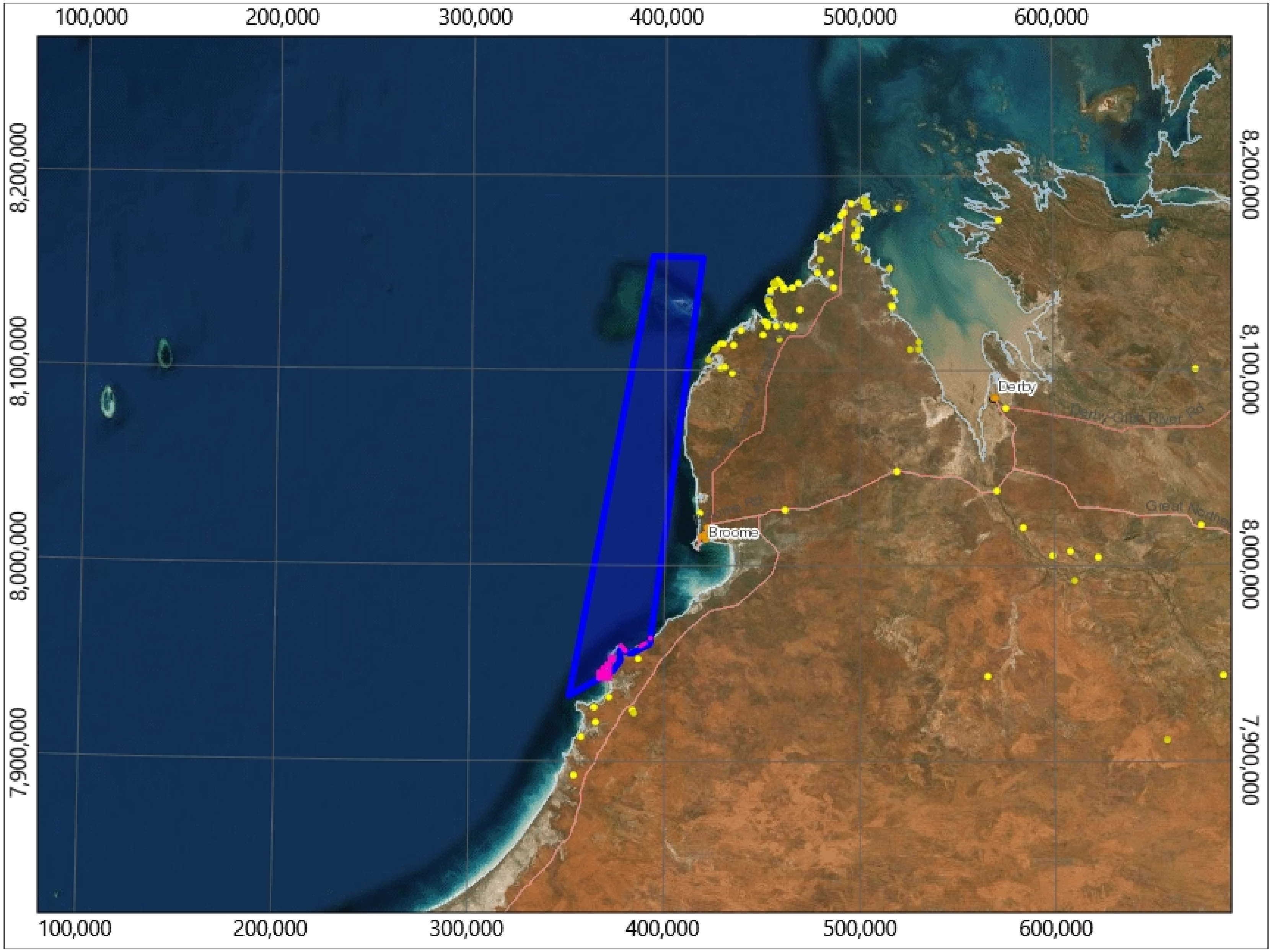

Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

103.00 kilometres

Map Scale 1 : 3,120,000

MGA Zone 51 (GDA94)

Aboriginal Heritage Inquiry System

List of Other Heritage Places

Search Criteria

2 Other Heritage Places in Custom search area - Polygon - 115.279312554552°E, 20.5518995933232°S (GDA94) : 115.275192681508°E, 20.546755957438°S (GDA94) : 115.220261040883°E, 19.6543329064199°S (GDA94) : 118.680954400257°E, 19.4472747901086°S (GDA94) : 119.702682915881°E, 19.5870681805319°S (GDA94) : 119.771347466663°E, 20.0237828085077°S (GDA94) : 119.559860650256°E, 20.1063387836745°S (GDA94) : 119.406052056506°E, 20.0121698924834°S (GDA94) : 119.088821831897°E, 20.0353948667947°S (GDA94) : 118.988571587756°E, 19.9476380920396°S (GDA94) : 117.218399468615°E, 20.1011803087601°S (GDA94) : 116.38481182213°E, 20.4348391166611°S (GDA94) : 115.279312554552°E, 20.5518995933232°S (GDA94)

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Aboriginal Heritage Inquiry System

List of Other Heritage Places

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
20621	Bedout Island	No	No	No Gender Restrictions	Lodged	Mythological, Natural Feature, Other: Island	*Registered Knowledge Holder names available from DAA	720197mE 7832653mN Zone 50 [Reliable]	
36971	Pardoo Grinding Grooves	No	No		Lodged		*Registered Knowledge Holder names available from DAA	767628mE 7777649mN Zone 50 [Reliable]	

Department of Planning, Lands and Heritage
GOVERNMENT OF WESTERN AUSTRALIA

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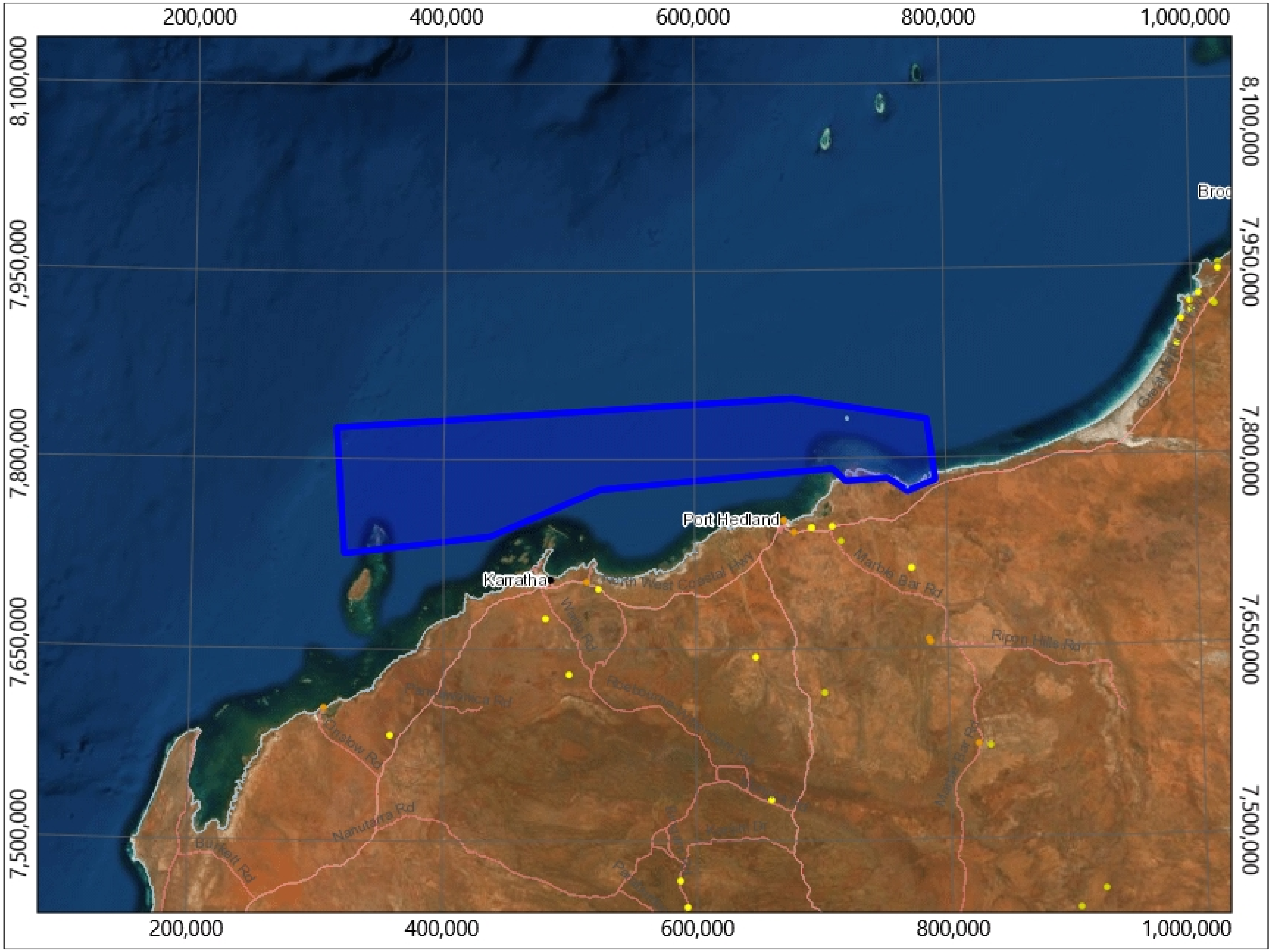


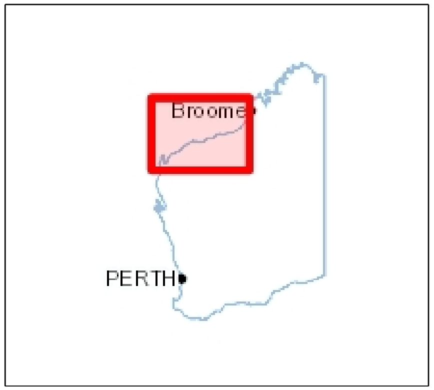
Legend

- Other Heritage Place
- Search Area
- Town
- Road
- River
- Local Government Authority

161.72 kilometres

Map Scale 1 : 4,900,000

MGA Zone 50 (GDA94)



Aboriginal Heritage Inquiry System

List of Other Heritage Places

Search Criteria

2 Other Heritage Places in Custom search area - Polygon - 119.760361138305°E, 19.9864120175203°S (GDA94) : 121.474228325805°E, 18.7829749126638°S (GDA94) : 121.606064263305°E, 18.6906385551274°S (GDA94) : 121.537399712524°E, 18.9233331588807°S (GDA94) : 121.559372368774°E, 19.0402084251818°S (GDA94) : 121.433029595337°E, 19.3540640674722°S (GDA94) : 120.684585991821°E, 19.8430923233986°S (GDA94) : 119.760361138305°E, 19.9864120175203°S (GDA94)

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Aboriginal Heritage Inquiry System

List of Other Heritage Places

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12963	CAPE KERAUDREN 1	No	No	No Gender Restrictions	Lodged	Midden / Scatter	*Registered Knowledge Holder names available from DAA	792040mE 7789156mN Zone 50 [Reliable]	K02264
14272	CAPE KERAUDREN	No	No	No Gender Restrictions	Lodged	Grinding Patches / Grooves, Skeletal Material / Burial	*Registered Knowledge Holder names available from DAA	804140mE 7790956mN Zone 50 [Reliable]	K00830

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

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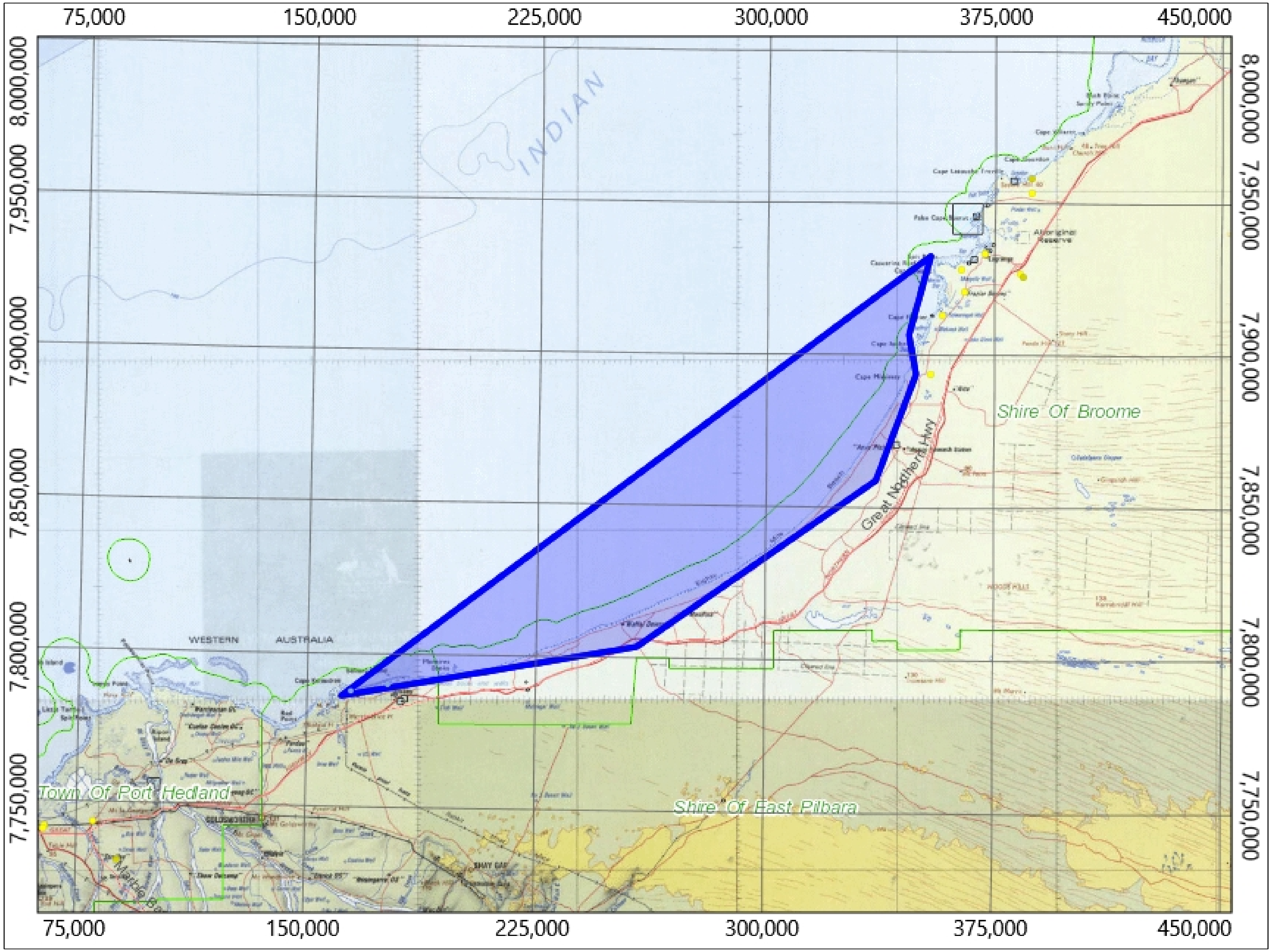


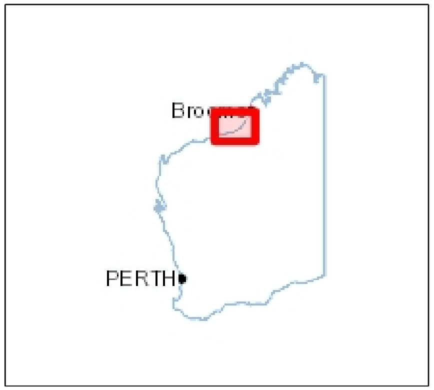
Legend

- Other Heritage Place
- Search Area
- Town
- Road
- River
- Local Government Authority

66.54 kilometres

Map Scale 1 : 2,020,000

MGA Zone 51 (GDA94)



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7 Other Heritage Places in Custom search area - Polygon - 121.585464898071°E, 18.6841601373409°S (GDA94) : 121.56074565979°E, 18.5878649672136°S (GDA94) : 121.102066460571°E, 16.8507341901069°S (GDA94) : 122.252884331664°E, 16.5955838135189°S (GDA94) : 121.901321831664°E, 18.4784909556029°S (GDA94) : 121.857376519164°E, 18.475885960121°S (GDA94) : 121.835403862914°E, 18.457649883944°S (GDA94) : 121.816177788696°E, 18.4837008278254°S (GDA94) : 121.832657280883°E, 18.5149567343999°S (GDA94) : 121.585464898071°E, 18.6841601373409°S (GDA94)

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Aboriginal Heritage Inquiry System

List of Other Heritage Places

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12465	BUNDABUNDA.	No	No	No Gender Restrictions	Lodged	Water Source	*Registered Knowledge Holder names available from DAA	367637mE 7945661mN Zone 51 [Unreliable]	K02769
12466	JUDIMULANBA.	No	No	No Gender Restrictions	Lodged	Camp, Water Source	*Registered Knowledge Holder names available from DAA	367293mE 7945164mN Zone 51 [Reliable]	K02770
12467	FALSE CAPE BOSSUT MIDDEN.	No	No	No Gender Restrictions	Lodged	Midden / Scatter, Camp, Water Source	*Registered Knowledge Holder names available from DAA	371637mE 7949661mN Zone 51 [Unreliable]	K02771
13731	PIDIRNGAPA.	No	No	No Gender Restrictions	Lodged	Mythological, Water Source	*Registered Knowledge Holder names available from DAA	367637mE 7945661mN Zone 51 [Unreliable]	K01382
13732	JIDAMUNGA.	Yes	Yes	No Gender Restrictions	Lodged	Mythological, Natural Feature	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K01383
13733	JINJAGURIN / NUNDUNARR.	Yes	Yes	No Gender Restrictions	Lodged	Mythological, Water Source	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K01384
14311	CAPE GOURDON	Yes	Yes	No Gender Restrictions	Lodged	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00816

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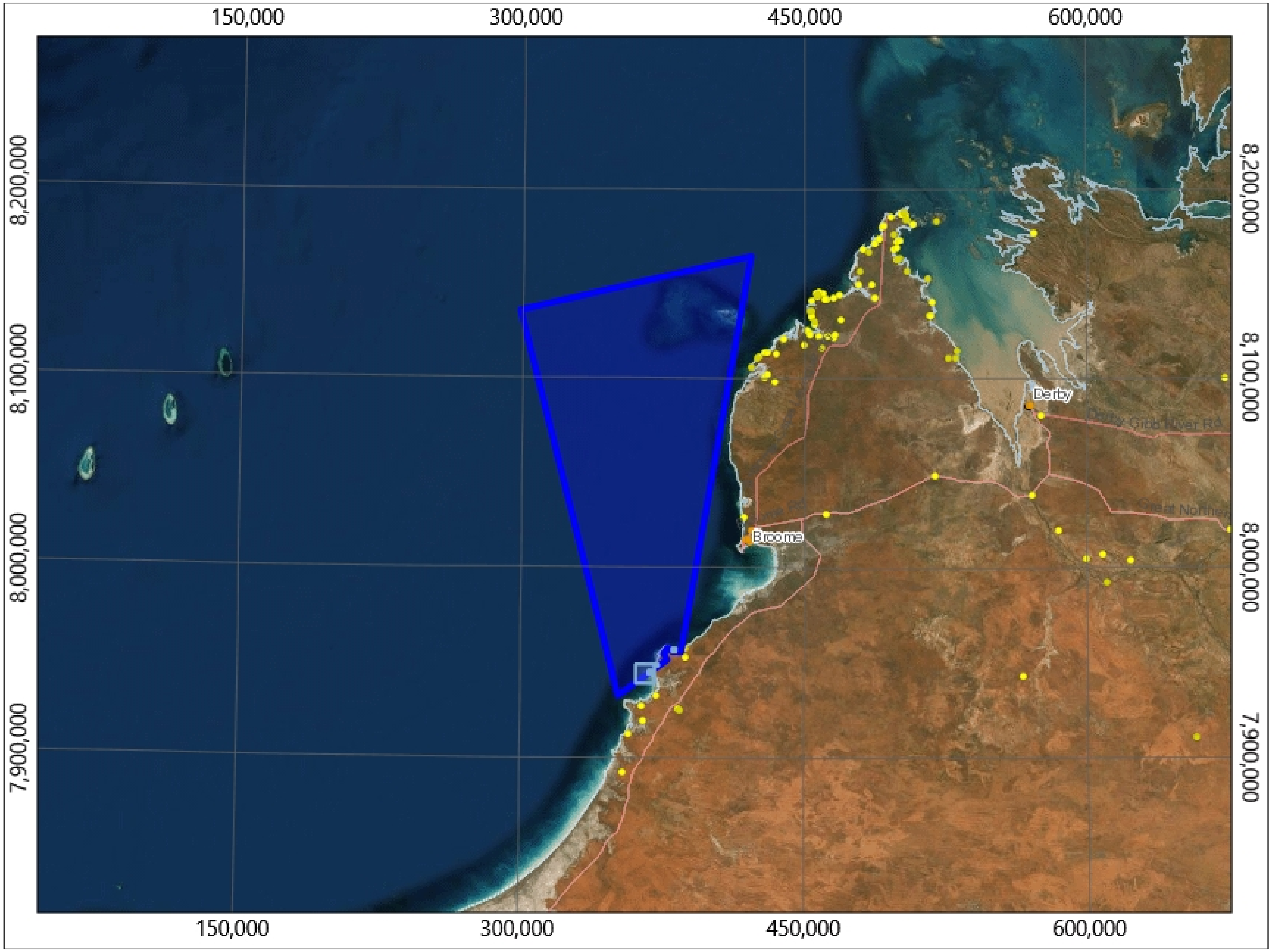

Legend

- Other Heritage Place
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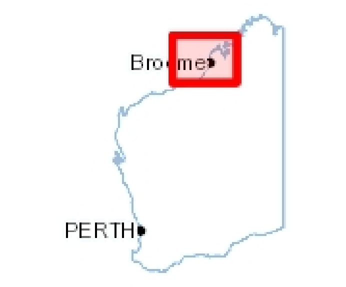
- Town
- Road
- River
- Local Government Authority

106.19 kilometres

Map Scale 1 : 3,220,000

MGA Zone 51 (GDA94)



Australian Government

Department of the Environment and Energy

EPBC Act Protected Matters Report

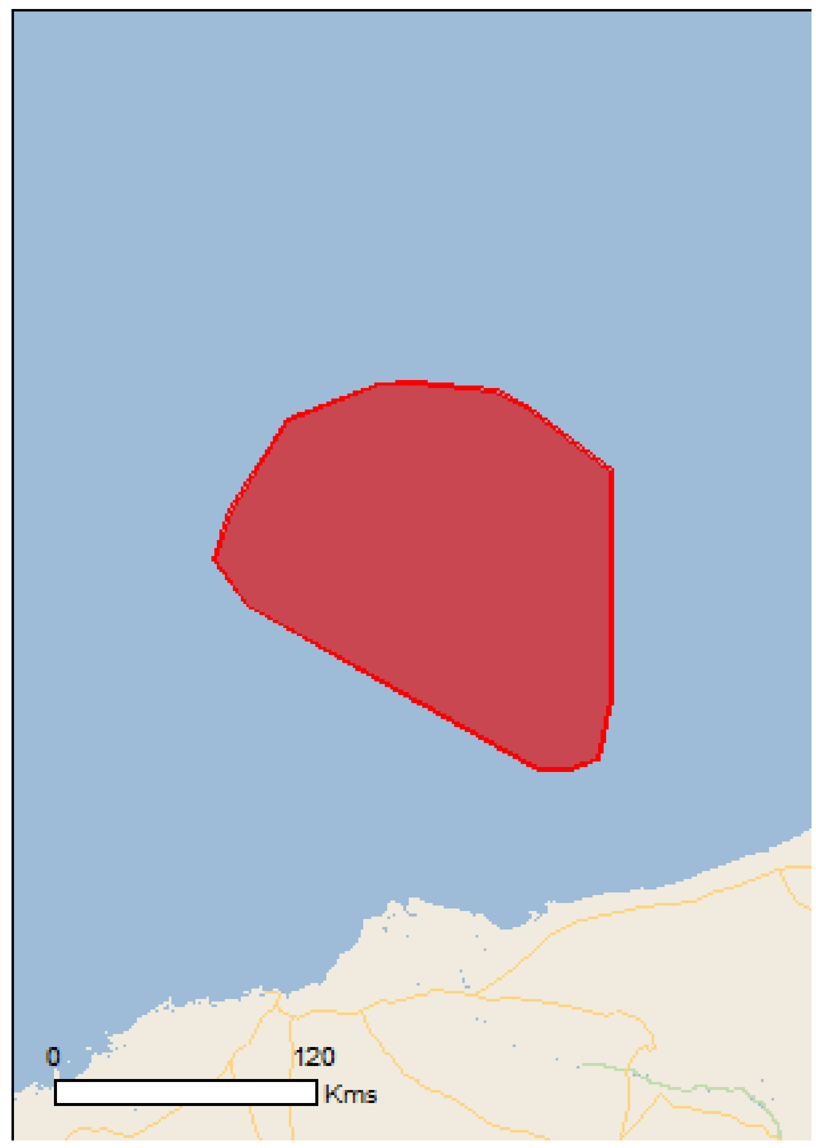
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

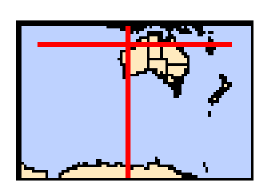
Report created: 08/10/19 18:03:24

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



Coordinates

Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	19
Listed Migratory Species:	37

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	74
Whales and Other Cetaceans:	26
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	1

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti		
Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis		
Australian Fairy Tern [82950]	Vulnerable	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area

Name	Threatened	Type of Presence
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat likely to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis		
Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus		
Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus		
Common Noddy [825]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans		[Resource Information]
Name	Status	Type of Presence
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species

Name	Status	Type of Presence
		habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-18.6324 118.3717,-18.8086 118.5075,-19.1252 119.1033,-19.4445 119.7064,-19.4451 119.8283,-19.4088 119.9443,-19.1753 120.0,-18.2889 120.0,-18.0478 119.6662,-17.9758 119.5315,-17.9456 119.184,-17.952 119.0504,-18.0885 118.6737,-18.4424 118.4347,-18.6324 118.3717

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Australian Government

Department of the Environment and Energy

EPBC Act Protected Matters Report

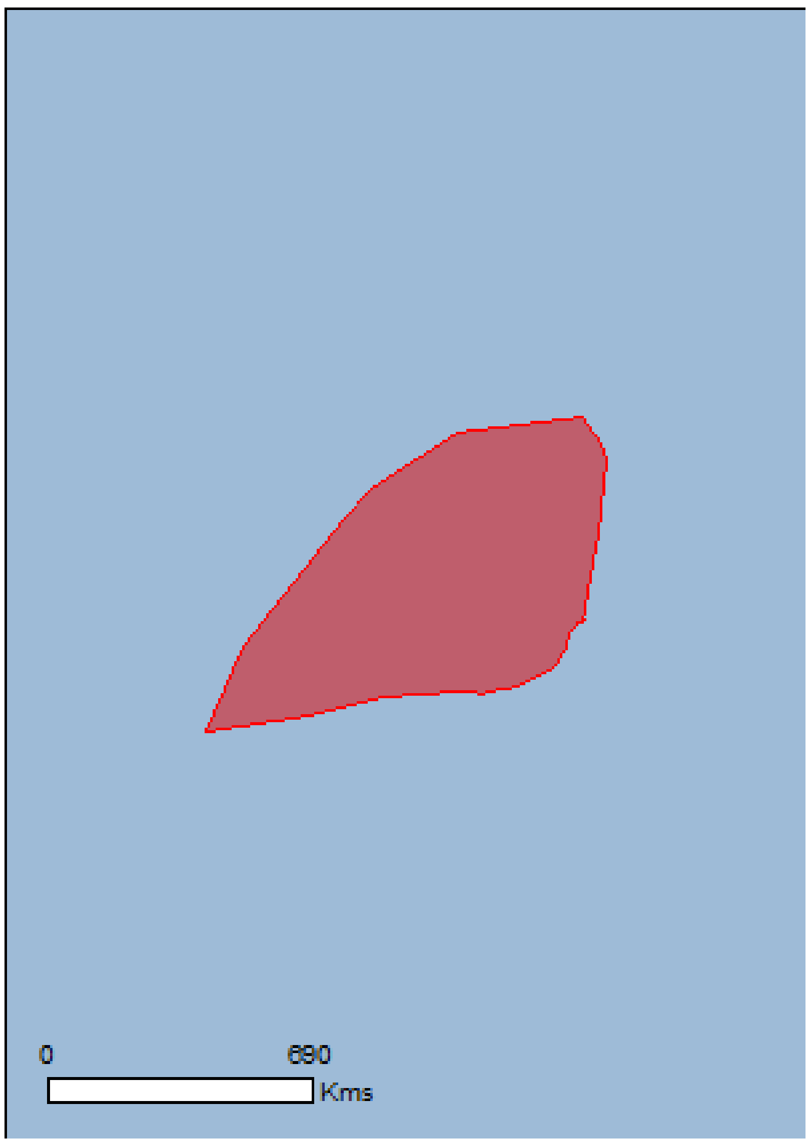
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

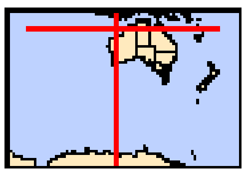
Report created: 01/11/19 11:32:56

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements



Coordinates

Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	1
Wetlands of International Importance:	2
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	42
Listed Migratory Species:	82

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	2
Listed Marine Species:	137
Whales and Other Cetaceans:	31
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	9

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	16
Regional Forest Agreements:	None
Invasive Species:	15
Nationally Important Wetlands:	3
Key Ecological Features (Marine)	7

Details

Matters of National Environmental Significance

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
The West Kimberley	WA	Listed place

Wetlands of International Importance (Ramsar) [Resource Information]

Name	Proximity
Eighty-mile beach	Within Ramsar site
Roebuck bay	Within 10km of Ramsar

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat known to occur

Name	Status	Type of Presence
		within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Polytelis alexandrae Princess Parrot, Alexandra's Parrot [758]	Vulnerable	Species or species habitat likely to occur within area
Rostratula australis Australian Painted-snipe, Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat likely to occur within area
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Translocated population known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Translocated population known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat known to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat may occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped	Vulnerable	Species or species

Name	Status	Type of Presence
Sheathtail Bat [66889]		habitat may occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Liasis olivaceus barroni Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Glyphis garricki Northern River Shark, New Guinea River Shark [82454]	Endangered	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat known to occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known

Name	Threatened	Type of Presence
		to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species habitat may occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat likely to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area

Name	Threatened	Type of Presence
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Mermaid Reef - Rowley Shoals	WA	Listed place
Scott Reef and Surrounds - Commonwealth Area	EXT	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris alba Sanderling [875]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat likely to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Roosting known to occur within area

Name	Threatened	Type of Presence
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Roosting known to occur within area
Chrysococcyx osculans Black-eared Cuckoo [705]		Species or species habitat known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Glareola maldivarum Oriental Pratincole [840]		Roosting known to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat known to occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limnodromus semipalmatus Asian Dowitcher [843]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting known to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area

Name	Threatened	Type of Presence
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Sula sula Red-footed Booby [1023]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Tringa totanus Common Redshank, Redshank [835]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus fuscus Dusky Seasnake [1119]		Species or species habitat known to occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnston's River Crocodile [1773]		Species or species habitat may occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area

Name	Status	Type of Presence
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat known to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks

[Resource Information]

Name	Label
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	National Park Zone (IUCN II)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Kimberley	National Park Zone (IUCN II)
Mermaid Reef	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Bedout Island	WA
Jarrkunpungu	WA
Jinmarnkur	WA
Jinmarnkur Kulja	WA
Karajarri	WA
Kujungurru Warrarn	WA
Kujungurru Warrarn	WA
Lacepede Islands	WA
Montebello Islands	WA
North Turtle Island	WA
Nyangumarta Warrarn	WA
Unnamed WA40828	WA
Unnamed WA41080	WA
Unnamed WA44672	WA
Unnamed WA52366	WA
Unnamed WA53015	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat may occur within area
Mammals		
Camelus dromedarius Dromedary, Camel [7]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Equus asinus Donkey, Ass [4]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Equus caballus		
Horse [5]		Species or species habitat likely to occur within area
Felis catus		
Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus		
House Mouse [120]		Species or species habitat likely to occur within area
Sus scrofa		
Pig [6]		Species or species habitat likely to occur within area
Vulpes vulpes		
Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris		
Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Parkinsonia aculeata		
Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Prosopis spp.		
Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus		
Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus		
Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
De Grey River	WA
Eighty Mile Beach System	WA
Mermaid Reef	EXT

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Canyons linking the Argo Abyssal Plain with the	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	North-west
Mermaid Reef and Commonwealth waters	North-west
Seringapatam Reef and Commonwealth waters in	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-16.1796 116.342,-18.9846 113.9659,-20.8968 113.1122,-20.5295 115.5458,-20.5262 115.5478,-20.1333 117.3207,-19.9921 118.9796,-20.0247 119.0556,-20.0232 119.1787,-20.0235 119.1792,-20.0232 119.2086,-20.0228 119.2165,-20.0141 119.3689,-20.0072 119.3972,-20.0231 119.4342,-20.0879 119.5706,-20.0249 119.7592,-19.9825 119.7644,-19.974 120.0271,-19.947 120.1303,-19.9307 120.1928,-19.8948 120.3297,-19.8092 120.5631,-19.7214 120.7794,-19.7197 120.7832,-19.7091 120.8065,-19.6122 121.0193,-19.5244 121.1585,-19.4922 121.2077,-19.3359 121.3469,-19.2695 121.3962,-19.1389 121.4968,-19.0575 121.5439,-19.0358 121.5416,-18.943 121.5487,-18.7928 121.5786,-18.7913 121.5789,-18.7567 121.5858,-18.706 121.5959,-18.5793 121.731,-18.5775 121.7329,-18.5772 121.7334,-18.5589 121.7715,-18.5104 121.81,-18.5058 121.8093,-18.5035 121.8089,-18.4999 121.8072,-18.4966 121.8057,-18.4802 121.798,-18.4526 121.8208,-18.454 121.8389,-18.4716 121.8592,-18.4754 121.8637,-18.4743 121.8821,-18.4735 121.8965,-18.4718 121.8991,-18.4492 121.9323,-18.4126 121.9864,-18.4105 122.0099,-18.3662 122.0441,-18.3629 122.0387,-18.3584 122.0315,-18.4028 122.0004,-18.4033 121.9975,-18.4043 121.9957,-18.4041 121.9944,-18.4046 121.9923,-18.4042 121.9905,-18.4097 121.9799,-18.4103 121.9799,-18.4104 121.9787,-18.4287 121.9602,-18.4393 121.9467,-18.4407 121.9432,-18.4407 121.9412,-18.4395 121.9402,-18.4395 121.9396,-18.4426 121.9354,-18.444 121.9344,-18.4485 121.929,-18.4488 121.9269,-18.4497 121.9245,-18.4526 121.9201,-18.4587 121.9121,-18.4607 121.9094,-18.4615 121.9084,-18.4641 121.9036,-18.4655 121.8998,-18.4662 121.898,-18.467 121.8941,-16.4813 122.2624,-14.8188 122.479,-14.4342 122.3735,-13.8473 121.8947,-14.2126 118.9638,-15.5107 116.9925,-16.1796 116.342

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-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
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-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
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-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
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-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

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Please feel free to provide feedback via the Contact Us page.

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Appendix D – RPS (2019) Ancient Coastline KEF Fish and Pearl Oyster Habitat Survey Report

Prepared for the Santos Keraudren 3D Marine Seismic Survey Environment Plan (2019)

Report

MARCH 2019

Ancient coastline KEF fish and pearl oyster habitat survey report

Keraudren marine seismic survey environment plan

RPS

Document status

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RPS

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1 Introduction

Santos WA Energy Limited (Santos) requires baseline ecological data to inform the Keraudren Marine Seismic Survey (MSS) Environment Plan (EP). Specifically, Santos requires information on 1) fish assemblages occurring at the ancient coastline at 125 m depth contour key ecological feature (KEF) and 2) potential pearl oyster and pearl oyster habitat values. To achieve these objectives, Santos commissioned RPS Australia West Pty Ltd (RPS) to undertake a KEF fish assemblage and pearl oyster and potential pearl oyster habitat survey within selected areas of the MSS operational area and predicted acoustic exposure zone. RPS selected the University of Western Australia (UWA) as a research partner for the SBRUVs component of this study.

1.1 Ancient coastline at 125 m depth contour key ecological feature

The proposed Keraudren MSS operational area is located on the Australian North West Shelf (NWS) and overlaps the KEF, which is formally located at 125 m depth and ranges between the 115 to 135 m depth contours (IMCRA v4.0). The NWS exhibits terrace and step features that reflect changes in sea level over the past 100,000 years. The most prominent of these is an escarpment feature that runs along the North West Shelf and Sahul Shelf at a depth of 125 m. The 'Marine bioregional plan for the North-west Marine Region' (DSEWPaC 2012a) describes this KEF as a "unique seafloor feature with ecological properties of regional significance. Parts of the ancient coastline, particularly where it exists as a rocky escarpment, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments. The topographic complexity of these escarpments may also facilitate vertical mixing of the water column, providing relatively nutrient-rich local environments".

The KEF does not have legislative status but must be considered in the EP impact assessment as an area of higher conservation value, in particular where it exists as rocky escarpment and biologically important habitat. However, the ecological and biodiversity values of the ancient coastline KEF are unlikely to be constant along its considerable spatial extent (>1500 km in length on the NWS), although there is little information on relative values of different sections of the KEF on which to base a reasoned impact assessment.

Given the recognised uncertainty in the relative values of different parts of the ancient coastline KEF, it is important to identify the key values (including fisheries resources) that occur in the small portion of the KEF that may be affected by the planned MSS operational area, in relation to unaffected components of the feature.

A key value of relevance to potential impacts from seismic survey is the possibility that the ancient coastline KEF provides important habitat for demersal fish assemblages, characterized by high species diversity and abundance. Qualitative information on the habitat in the field of view (FoV) of the survey equipment will also provide important contextual information on the ecological quality of the KEF in the MSS area. The target KEF fish assemblage survey Sites and Locations are presented in Figure 1.

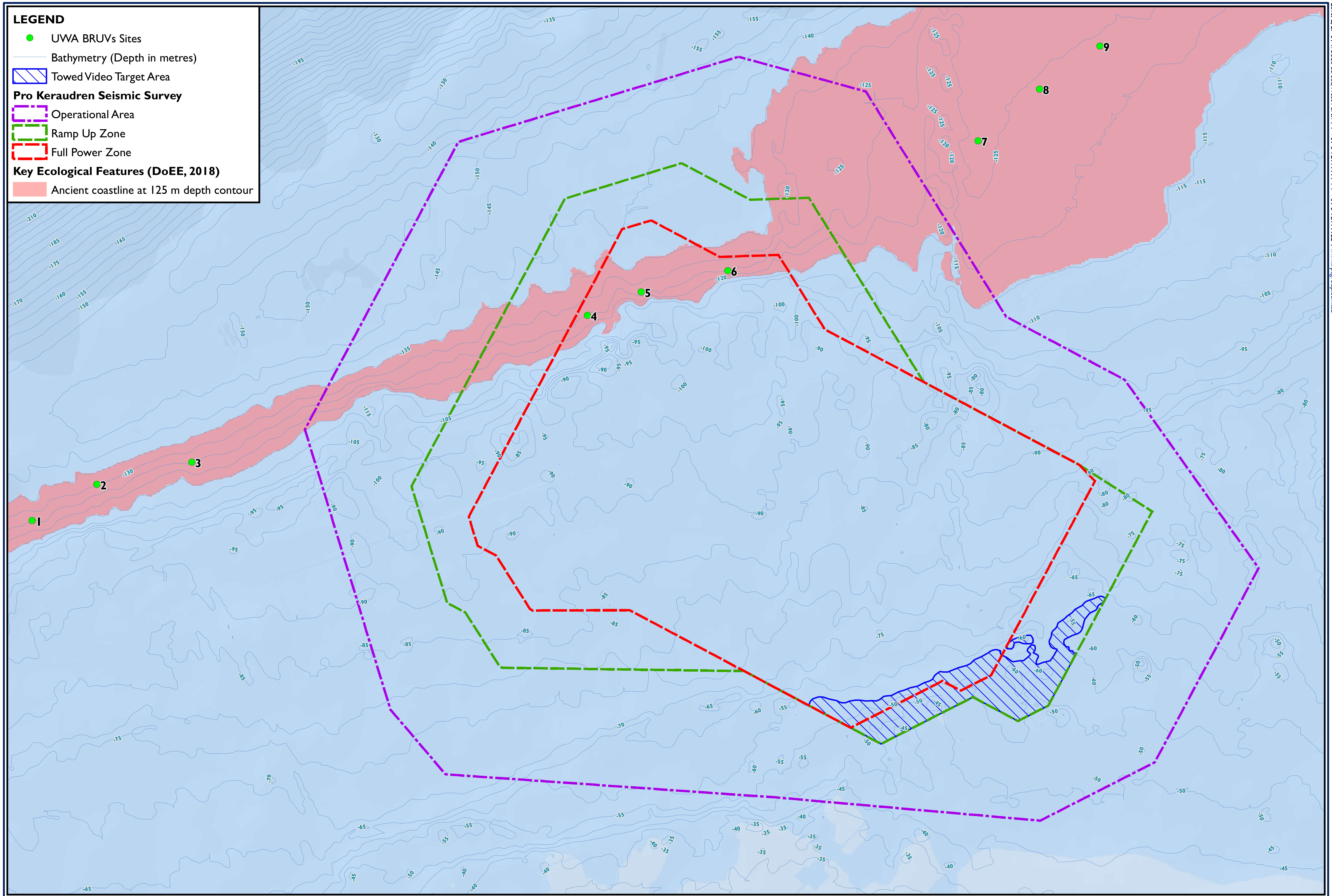

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Figure 1

Target fish assemblage BRUVs and towed video survey areas

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1.2 Pearl oyster and pearl oyster habitat values relevant to the seismic survey area

Historically, concerns have been raised by the pearling industry over the potential impact of seismic surveys on wild stocks of pearl oyster – primarily the silver-lipped pearl oyster, *Pinctada maxima*. This species is known to occur in water depths of 8 to 40 m in Western Australia, northwards of Dirk Hartog Island in Shark Bay. The highest abundances of *P. maxima* occur north of North-West Cape (114° 10' E), particularly in the vicinity of Eighty Mile Beach (Department of Fisheries 2016). Silver-lipped pearl oysters are commonly found in benthic habitats with relatively flat, rock substrate covered with a fine layer of sediment (veneer). 'Potato habitat' was named by pearl divers and is characterised by ascidians and sponges on hard bottom with a sediment veneer. 'Garden habitat' is characterised by assemblages of sponges, soft corals, hydroids, ascidians, sea pens and crinoids on hard bottom with crevices and covered by a fine veneer of sediment (Department of Fisheries 2016).

Feedback from the Pearl Producers Association (PPA) states that pearl oyster broodstock may be present out to 70 m water depths (from Santos stakeholder consultation). On the basis of Department of Fisheries information and PPA advice, the area targeted for the field study was within the MSS area in less than 60 m water depth.

1.3 Survey objectives

The primary objectives of the field study were to:

- compare fish assemblages on the ancient coastline KEF at Locations within the MSS operational area with those on nearby and unaffected parts of the KEF in the same depth range
- describe benthic habitats (in particular "garden" or "potato" potential pearl oyster habitat) within the area that may be ensonified by seismic noise within the full power and ramp-up zones of the MSS operational area in <60 m water depth.

Secondary objectives of the KEF fish assemblage survey were to:

1. Identify potential spatial differences in fish assemblages across the area of study.
2. Obtain imagery of the benthic habitat at the ancient coastline KEF sampling Locations.

Secondary objectives of the pearl oyster and potential pearl oyster habitat survey were to:

1. Identify the occurrence of *P. maxima* in the areas surveyed.
2. More broadly describe habitat types and features in the area surveyed.

This study provides descriptive information for assessing impacts from seismic surveys on fish assemblages associated with the coastline KEF and pearl oysters.

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2 Methods

2.1 Stereo baited remote underwater video systems (SBRUVs)

This section provides a brief summary of the Stereo Baited Remote Underwater Video system (SBRUVs) methods used in the KEF fish assemblage study . Refer to the UWA report in Appendix A for further detail.

2.1.1 Field deployments

The KEF fish survey was completed between 22 and 29 October 2018. The 6 m spring tides at the survey Location made collection of imagery with an acceptable level of quality challenging at times and the SBRUVs frames had to be heavily weighted and the drops scheduled around slack tides.

Five replicate SBRUVs were deployed at three Sites in three survey Locations along the ancient coastline KEF (n = 45) between the 120 and 130 m water depth contours. Two Locations were chosen to represent reference Locations adjacent to the planned MSS operational area (to the west and east) and the third Location was within the planned MSS operational area. Survey Locations were separated by minimum of 20 km. Sites within survey Locations were separated by 5–10 km, and replicates within Sites were separated by at least 400 m to minimise double-counting of individual fish.

Re-survey of multiple Sites (i.e. 1 to 4) due to spring tidal conditions ensured that all nine KEF fish assemblage Locations were successfully surveyed. SBRUVs were also opportunistically deployed at three 'Exploratory' Sites in the 97–114 m depth range (LAT), to the south of Sites 1 to 3. These were referred to as Sites 0.1 to 0.3 and were used to survey an area identified from the vessel's sounder during a transect from 135 m water depth to 90 m water depth. These Sites targeted an area where a sudden change in bathymetry was observed, from a relatively flat, soft substrate seabed to a high relief hard substrate seabed with potentially abundant fish and epibiota assemblages, potentially representing terrace and step features described in the bioregional plan for the north-west marine bioregion (DSEWPaC 2012a). Bathymetry (presented in Figure 1) indicates that similar features occur in the MSS operational area, just south of Sites 4 to 6. KEF fish assemblage survey Locations are presented in Figure 1.

The UWA SBRUV systems are specifically designed to optimise sampling efficiency in the field and to minimise damage to fragile benthic environments (see Appendix A). Each SBRUV unit comprised a pair of high definition (hi-def) Canon Legeria HFG25 video cameras set to record at 30 frames per second. These cameras have a proven ability in low light conditions. The cameras were inwardly converged at a 7° angle to provide an overlapping field of view, and fixed to a galvanised steel bar within a trapezium-shaped frame (Langlois et al. 2018). A third camera, a GoPro Hero 3+, was mounted on the rear of the frame to obtain imagery of the benthos behind the SBRUV at each Site. To maximise calibration stability, the systems used a purpose-built, tri-housing mounted on a base bar designed to minimise camera movement within the housing and between the cameras (Appendix A). For surveys at these depths, two LED lights were attached to each SBRUV with one facing in either direction; this light source provides sufficient illumination of the field of view while having minimal impact on fish behaviour (Fitzpatrick et al. 2012). A rope riser with four surface buoys was fixed to the SBRUVs frame and was used to mark the deployment Location for retrieval.

A bait bag containing ~1 kg of crushed fresh pilchards (*Sardinops neopilchardus*), attached to a stainless steel arm, was mounted in front of the pair of hi-def cameras. Each SBRUVs frame was deployed by trailing the surface buoys and riser behind the vessel while approaching the deployment Site, then lowering the frame to the water surface using guidelines. The frame was then released once on Site and allowed to free-fall to the seabed. Position, time and water depth were recorded for each deployment. Five replicate SBRUV frames were deployed at each Site, then recovered in order of deployment following a minimum of 1 hour of immersion (commonly referred to in literature as the 'soak time'). Recovery was achieved by grappling for the riser rope, then hauling the SBRUVs frames back on board using the vessel deck winch and A-frame. Further details are provided in Appendix A.

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2.1.2 Analysis

2.1.2.1 Image analysis

Following conversion of video footage (see Appendix A), the left camera footage was analysed using EventMeasure™ software (SeaGIS 2011) and calibrated with the right camera footage for stereo measurements (using CAL™ software – SeaGIS 2011). All fish were identified to their lowest taxonomic level and the maximum number per species per image frame (MaxN) recorded. Fish lengths (fork length) were measured at the same time as MaxN to avoid duplicating measurements of the same individual. MaxN fish lengths were measured and converted to weight using length-weight relationships, and summed for each species. In-water visibility and water velocity were also measured/ranked (Appendix A). Habitat composition was obtained from both forward and rearward-facing cameras using EventMeasure™ (SeaGIS 2011). Habitats were classified using the CATAMI habitat classification scheme (Althaus et al. 2013) with a visual estimate of relief and classification of bedforms. A full description of methods is described in Appendix A.

2.1.2.2 Statistical analysis

Datasets of fish abundance and of biomass were derived from survey imagery. Multivariate statistical analysis was undertaken using PRIMER v6 with PERMANOVA+. Box and whisker plots were used to present univariate environmental and fish assemblage metrics. All data formatting, plotting and univariate statistical analysis were undertaken in the R language for statistical computing (R Core Team 2017).

Multivariate statistical routines used were distance-based redundancy analysis (dbRDA), DISTLM, CLUSTER analysis (dendrogram), Similarity Percentage (SIMPER), Principal Coordinate Analysis (PCA), Canonical Analysis of Principal coordinates (CAP), PERMANOVA and PERMANCOVA. These routines were used to characterise fish assemblages, and to investigate variability in fish assemblages and potential environmental drivers of fish assemblage composition across the ancient coastline KEF Sites.

Univariate analytical techniques included Generalised Additive Mixed Models (GAMMs), which are often used to reveal non-linear relationships between dependant and continuous predictor variables. The GAMMs models were validated using independent and supporting PERMANOVA/PERMANCOVA tests.

A detailed description of the statistical analyses undertaken and identification of the R packages used are presented in Appendix A.

2.2 Pearl oyster and potential pearl oyster habitat surveys

2.2.1 Field survey

The subsea towed video survey was undertaken between 29 and 31 October 2018. Transects of benthic habitats were recorded between the 43 and 60 m LAT water depths, within the planned MSS operational area (Figure 2). The towed video system used comprised the following:

- HDR CX690E HD video camera fitted with a Raynox ×5 wide-angle adaptor in underwater housing (2000 m depth-rated)
- LED lights (× 2)
- green lasers (× 2)
- camera sled, ballast and fittings
- GPS receivers and antennae (× 2) for video overlay and navigation software
- laptop computers (× 2) with ArcPad navigation software and LANC camera software (v2.1).

Two complete additional video camera systems were also mobilised aboard the RV Warrego for redundancy should the first system fail.

As survey of the seabed would be undertaken over the full tidal range (during springs), and with the understanding that the vessel would need to drift to maintain a speed of <2 knots, transects were not pre-identified. The survey plan required that transects be undertaken in water depths of between 40 and 60 m within the MSS operational area. Transects would start as soon as the seabed was clearly visible and biota identifiable (when the camera was 'on bottom'), until the camera 'left bottom' – the point at which the lead marine ecologist considered that the video transect had (where possible) adequately represented the range of habitat types at the survey Location. On a number of occasions during the survey, the vessel was put into gear at minimum speed to determine whether control over speed and direction could be attained. However, the cumulative effect of current speed and vessel speed (and transiting across currents rather than drifting with currents) reduced video quality, and so drifting with the current was found to be the preferred technique during spring tides.

Prior to deployment, the video system was powered up and the date and transect number was recorded. Recording was stopped only once the camera system was on its way back up to the surface following completion of each transect. The navigation tracklog was started once the camera system was in the water. Positions were set to record in ArcPad every two seconds. The point capture feature in ArcPad was used to mark the positions on and off the seabed of any features of interest, any changes in habitat, or where photos were taken.

The camera system was deployed via deck winch with carabiners used to secure the umbilical to the winch rope (to reduce billowing of the cable and reduce physical stress on the umbilical and deck personnel). During deployment the vessel was allowed to drift with the current, with drift speed monitored throughout the duration of the deployment. The maximum speed-over-ground for adequate video quality is considered to be <2 knots. The length of the transect and direction travelled was therefore a function of current speed, direction of drift, and the duration of deployment. The duration of deployment was determined by the point at which the video imagery captured was considered to be sufficiently representative of the habitats at the deployment Location. This assessment was based on the types and distribution of seabed habitat observed throughout the deployment.

The live video feed was viewed throughout each deployment, with the following information recorded on data sheets:

- deployment date
- transect reference details (transect number and deployment number)
- position references
- time
- water depth (m)
- description of seabed relief and seabed features (e.g. sand waves, ripples)
- sediment descriptions
- descriptions of biota (including estimate of total % coverage)
- changes in habitat
- potential features of interest (e.g. potential pearl oysters).

Classification of seabed relief, features, seabed substrate and conspicuous biota was broadly based on AIMS classifications but was expanded to include biota that would be expected to be found on seabed habitats in the target depth range in the north-west shelf. A finer-scale classification of the habitat types present was required to prevent bias in any potential assessment due to differences with defined pearl oyster habitat in shallower waters. Other potentially relevant components in this category were considered likely to be common to ubiquitous (e.g. 'non-coral benthic invertebrate', 'coral -soft' and 'unvegetated' categories), and hence would add little value to the assessment. For simplicity, category components were revised following the survey to only represent those habitat components that were actually recorded during the survey (Table 1). The abundance scale used by AIMS was modified to allow classification of rare (<1%) and sparse (1–5%) distributions of biota that can be characteristic of sediment habitats. Other classifications were also defined: 5–9% (Low), 10–24 % (Low), 25–39% (Moderate), 40–75% (High) and >75% (Very High). The 25–75% scale used in the AIMS classifications was considered too coarse to be used in this instance. The term ‘no conspicuous epibiota’ was used to highlight that although no epibiota was evident, infaunal and/or unclassified/motile epibiota were likely to occur (e.g. evidenced by the occurrence of burrows, mounds or tracks). Abbreviations were used to record observations on data sheets during the survey to allow more efficient data capture. Point capture information (reference number and reason for point capture) were recorded on additional data sheets. Video files were recorded to the control unit, with stills images recorded onto a memory card in the video camera itself. Video and stills image files were backed up to a laptop and external hard drive at regular intervals.

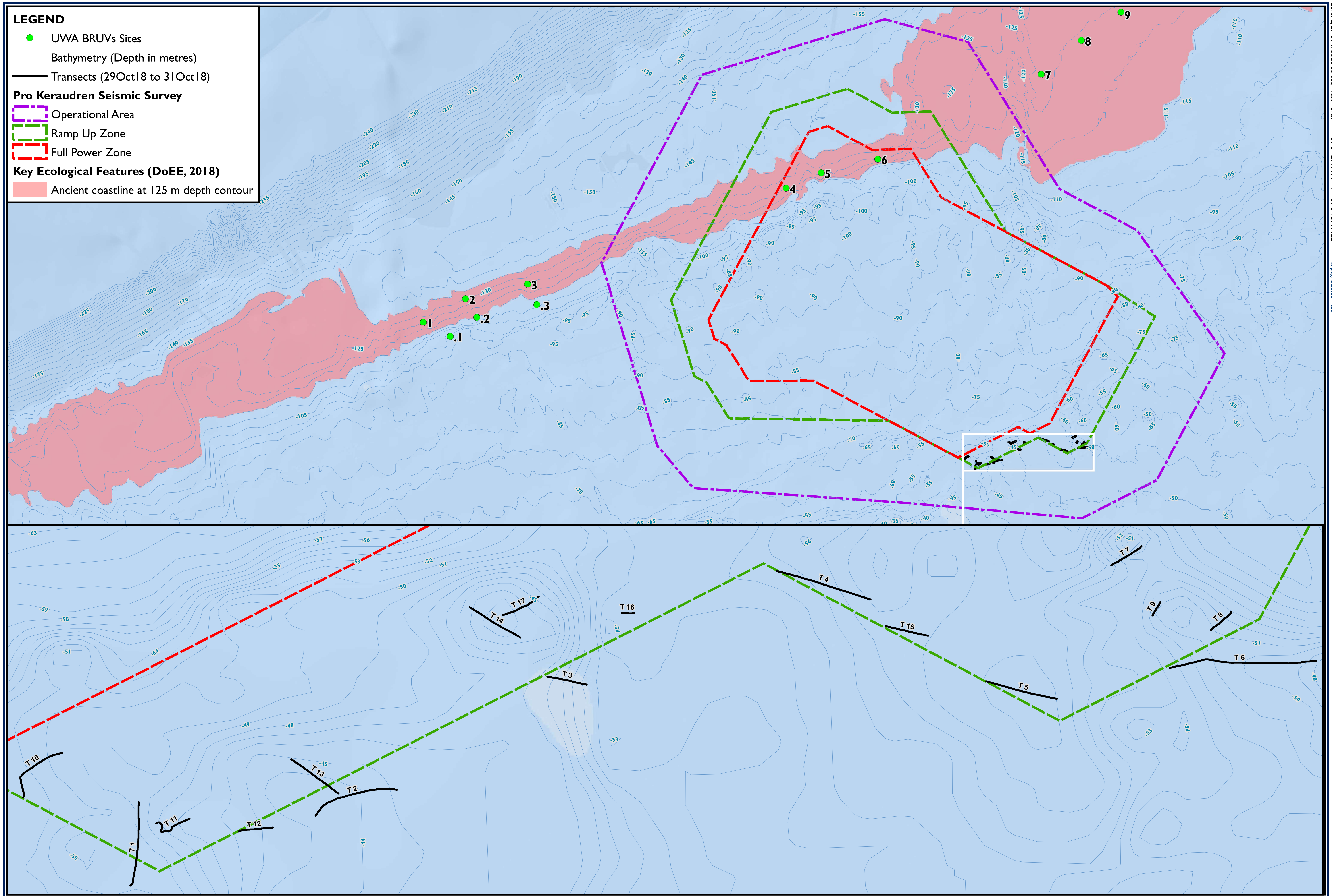

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Figure 2

KEF fish SBRUVs sites and towed video transects surveyed

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Table 1 Habitat classification sub-units used in the pearl oyster and potential pearl oyster habitat survey

Abbr.	Relief	Abbr.	Substrate	Abbr.	Feature	Abbr.	Conspicuous biota
F	Flat	Sa	Sand	R2	Ripples 2D	Ane	Anemones (true/flytrap/tube/colonial)
GS	Low; gently sloping (5–35°)	SaSh	Sand/shell	R3	Ripples 3D	Asc	Ascidians
SS	Steeply sloping (35–70°)	SaGr	Sand/gravel	W2	Waves 2D	B	Bryozoans
V	Vertical wall	Gr	Gravel	W3	Waves 3D	C	Crustacean
		P/C	Pebbles/cobbles	Bu	Burrows	CSo	Coral – soft – growth form (e.g. branching)
		CCo	Consolidated cobbles	ShFr	Shell fragments	CoRA	Coralline red algae
		B	Boulders			Cri	Crinoids
		BCo	Consolidated boulders	ShGr	Shell gravel	Ech	Echiurans
		Lp	Limestone pavement	Wt	Worm tubes	Gast	Gastropod (Mollusca)
		Bed	Bedrock			Gor	Gorgonians (i.e. octocorals) and growth form
		SaV	Veneer – sand			Hol	Holothuria
						HBt	Hydro-bryo turf
Abundance scale (adapted from AIMS)						H	Hydroids (growth form, e.g. Lo = Long, prone form)
Estimated total coverage			Description used as part of habitat classification			Biv	Bivalve (Mollusca)
No conspicuous epibiota			No conspicuous epibiota			Oph	Ophiuroids
<1%			Rare			PO	Possible pearl oyster
1–5%			Sparse			SP	Sea pens
5–9% and 10–24%			Low			Star	Sea stars (inc. e.g. cushion stars = StarCu)
25–39%			Moderate			Sp	Sponges (growth form, e.g. Bra = branching)
40–75%			High			Wc	Whip corals
>75%			Very high				

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2.2.2 Analysis

2.2.2.1 Pearl oysters

Potential pearl oyster specimens were identified from video captured during the survey and during a post-survey review of the videos. Identifications were made by qualified and experienced marine ecologists from RPS and UWA. ‘Screen grabs’ of potential specimens were then captured for further identification if they were considered to be a pearl oyster (high confidence), or a bivalve in the right size range (low confidence). The transect number, time, date and GPS position for each specimen were recorded.

2.2.2.2 Potential pearl oyster habitat

Data recorded on field record sheets were transferred into MS Excel. Navigation tracklog data were downloaded into ArcGIS and each transect surveyed was mapped as being between the point at which the video camera reached the seabed and the point at which the camera left the seabed.

A hierarchical habitat classification scheme was used to define different seabed habitat based on the modified AIMS structure (consistent with CATAMI; Althaus et al. 2013) (Table 1) but in a way that was designed to allow relationships between seabed structural components (substrate/features) and epibiota to be identified (consistent with e.g. Mount et al. 2007, Hooper et al. 2011a,b, JNCC 2015). The approach used herein was seen as advantageous for this specific project, as a single (continuous) hierarchical structure can be defined to demonstrate how biological and environmental components of the habitat are linked. This makes the process more sensitive, which is important when discussing the range of habitat types (‘biotopes’ – see Appendix B) and their variants that are likely to be represented within a higher-level category – e.g. ‘Garden’ or ‘Potato’ habitat – and their relative ecological value as part of an appropriate assessment within the MSS EP. This type of approach has been assessed and considered to be robust for classification and mapping, and also for research and assessments based on functional marine ecology and coastal zone management approaches (Olenin & Ducrotoy 2006). Further detail on the habitat classification approach used herein is provided in Appendix B.

The classification process essentially characterises the habitat by moving from left to right in Table 1, and providing multiple descriptors from columns were necessary (e.g. ‘soft’ and ‘hard’ substrate types). The abbreviations in Table 1 have been used to code habitat classifications, using full stops to delimit individual abbreviations (which equate to individual habitat components). Due to the nature of the analysis (i.e. video, rather than stills), conspicuous epibiota within an identified habitat were recorded as ‘present’ and a cumulative list of size classes (see below, this section) used to define each habitat.

This approach was designed to allow comparison of observed habitat types with potential pearl oyster habitat (as defined in Department of Fisheries 2016). The present study adapted the AIMS approach for classifying habitat components for use in this survey. The AIMS approach was modified to:

1. Increase the range of biota and features found in the range of depths surveyed in the planned Keraudren MSS operational area.
2. Adapt the abundance scale categories to allow adequate differentiation between low-abundance epibiota assemblages, which are characteristic of the habitat types (e.g. particulate sediment habitats) likely to be found in the water depths surveyed.

As described above, the codes used for each habitat classification comprised full-stop delimited lists of abbreviations used in Table 1. This structure provided a code as a ‘top down’ description of the habitat (i.e. starting at the top tier and working down the classification hierarchy), as described in Figure 3. The following terms have been used in the classification but have not been previously been defined herein:

- Mixed sediments (Mx): particulate sediment comprising a mixture of silt, sand, gravel (including broken shell fragments) and pebbles
- Sand Veneer (SaV): a thin layer of sand (usually with gravel/shell) overlying consolidated rock or bedrock

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- Bedrock (BR): continuous bedrock; often emergent (= outcropping) or covered by a sediment veneer
- Consolidated Rock (CoR): cobbles and/or boulders and/or broken bedrock part-buried in particulate sediment habitat
- Waves (W): particulate sediment bedform features >10 cm in height. All waves observed were two-dimensional (2D) (i.e. orientated in the same direction)
- Ripples (R): particulate sediment bedform features <10 cm in height. Although three-dimensional ripples (i.e. orientated in multiple directions at the same Location) were observed during the survey, these were rare, and the majority were two-dimensional (i.e. orientated in the same direction). Therefore a 2D/3D component has not been defined in the classification in this case
- Patchy: discontinuous occurrence of substrate and/or epibiota
- Burrowing (Bur) assemblage component: Comprises epibiota that have a component growing within/through the substrate, e.g. burrowing sponges, burrowing anemones
- Encrusting (Enc) assemblage component: epibiota that grow as thin layer along the top of seabed substrates (at the substrate/seawater interface), e.g. encrusting sponges, encrusting bryozoans, coralline red algae
- Turf (Turf) assemblage component: generally comprised a dense, small stature (~1–5 cm) mixed hydroid and bryozoan assemblage, which may also include short branching sponge growth forms. Due to the nature of this assemblage, it is very difficult to distinguish individual components (such as hydroids from branching forms of bryozoan) in the towed video footage and has therefore been referred to as a “hydro-bryo turf” (e.g. Plate 4)
- Meadow (Mead) assemblage component: epibiota generally within a ~5–30 cm height range, e.g. hydroids, sponges (multiple growth forms) and soft corals. Motile fauna, such as crinoids and holothurians, may be found on epibiota in “meadow” assemblages
- Massive (Mass) assemblage component: epibiota generally >30 cm in height, and often more structurally robust, such as barrel sponges, fan sponges and octocorals (fan corals). Motile fauna, such as crinoids and holothurians, may be found occurring as epibiota on “massive” sessile epibiota.

These terms have been used to classify habitats to allow direct comparison with descriptions of shallower-water habitat types considered to be pearl oyster habitat (i.e. ‘Garden’ and ‘Potato’ habitat) (Department of Fisheries 2016).

The Department of Fisheries (2016) identified that the substrate components of potential pearl oyster habitat comprised relatively flat hard rock substratum with small crevices, covered with a fine layer of sediment. The ecological component of potential pearl oyster habitat (i.e. conspicuous epibiota) varied between ‘Potato’ and ‘Garden’ habitats, namely:

1. “Potato” habitat was characterised by ascidians and sponges.
2. “Garden” habitat was characterised by hydroids, sponges, ascidians, soft corals, sea pens and crinoids.

By applying information provided in Department of Fisheries (2016) (including from imagery provided therein) to the framework presented in Figure 4, habitat classifications for ‘Potato’ and ‘Garden’ habitats were identified (Figure 4). Broken bedrock, boulders and cobbles may also provide suitable habitat and hence both classifications identified in Figure 4 may have consolidated rock variants (rather than bedrock).

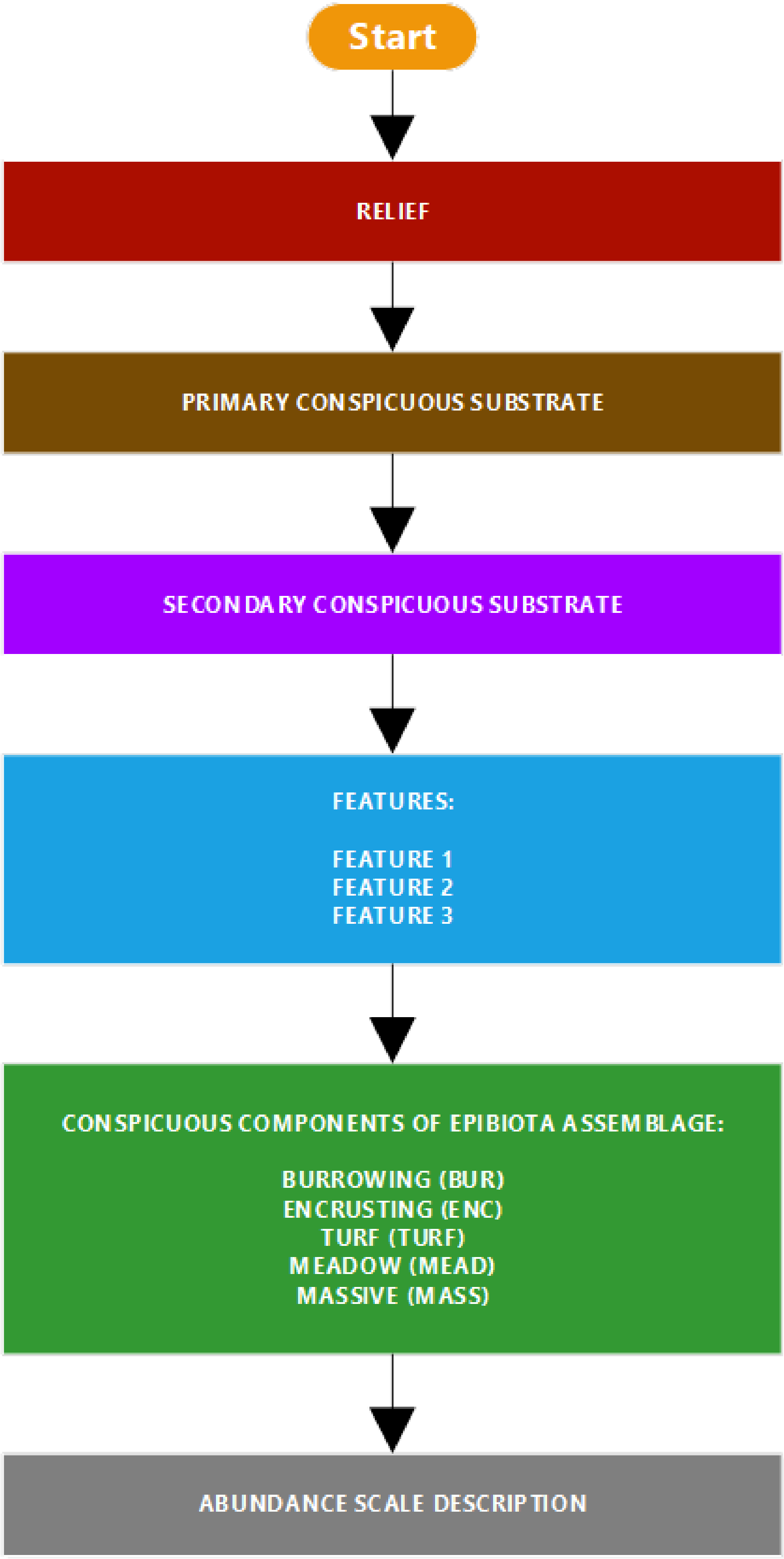

Figure 3 Habitat classification hierarchical framework

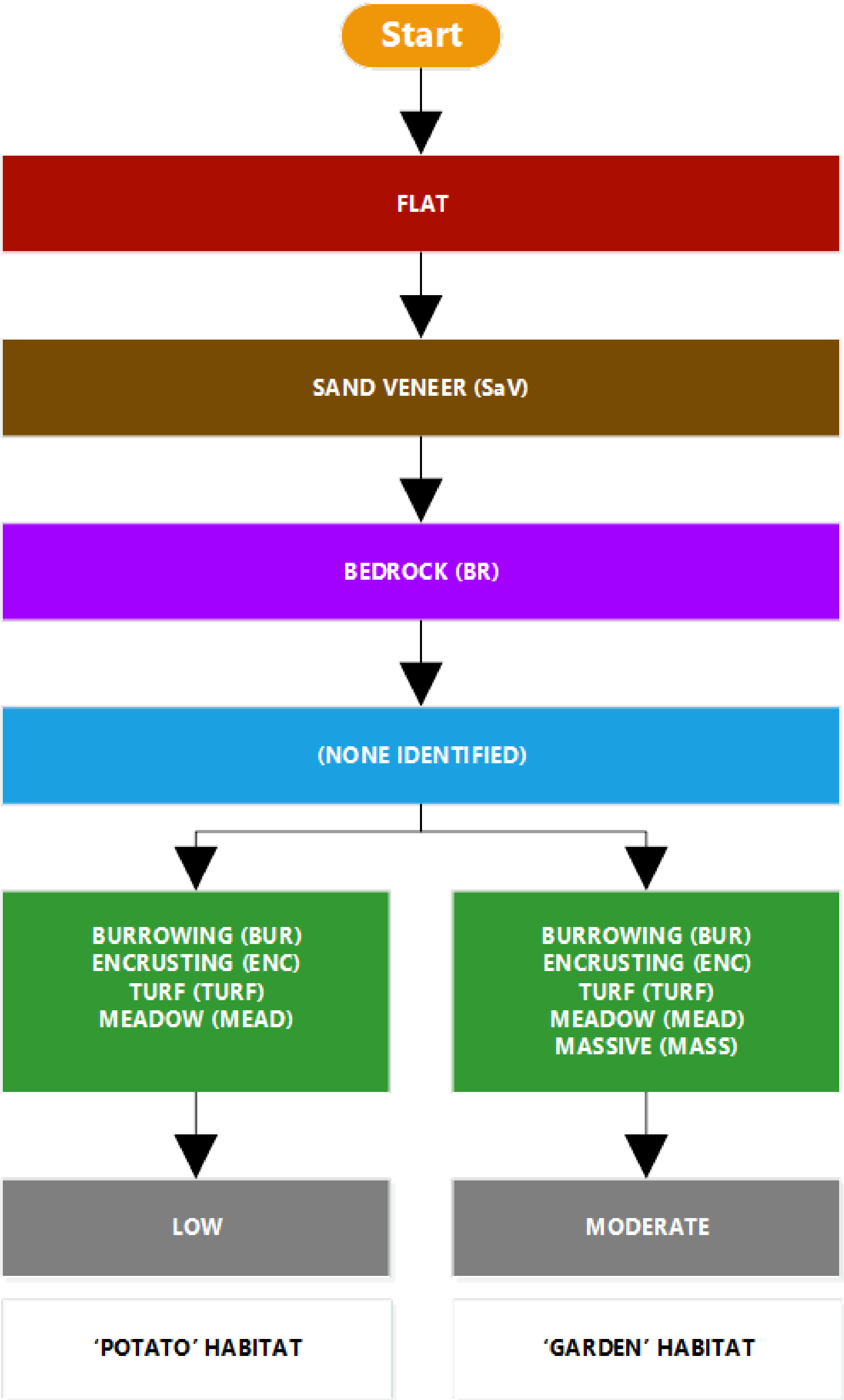

Figure 4 Classification of "Potato" and "Garden" habitats

3 Results

3.1 SBRUVs fish assemblage surveys

This section provides a brief summary of the results of the SBRUVs fish assemblage survey. Refer to Appendix A (the detailed report prepared by UWA) for further information.

3.1.1 Planned study sites

A total abundance of 643 fish from 39 species and 17 families were recorded across the three KEF survey Locations (comprising nine study Sites). The goldband snapper, *Pristipomoides multidens*, and the yellowspotted rockcod, *Epinephelus areolatus*, were the only commercially important species observed at these Locations. The four most ubiquitous species were the lunartail pufferfish, *Lagocephalus lunaris* (72% of deployments), the threadfin bream, *Nemipterus spp.* (67%), the longnose trevally, *Carangoides chrysophrys* (59%), and the giant trevally, *Caranx ignobilis* (47%). At Locations 1 and 2, the most abundant species was the longnose trevally (97 and 47 individuals respectively). At Location 1 (Sites 1 to 3) the next three most abundant species were threadfin bream (22), lunartail pufferfish (22), and giant trevally (14), and at Location 2 (Sites 4 to 6) scad, *Decapterus spp*. (35), lunartail pufferfish (35), and threadfin bream (28). At Location 3 (Sites 7 to 9), three of the four most abundant species were the same as those at Locations 1 and 2, threadfin bream (54 individuals), lunartail pufferfish (16) and longnose trevally, however the second most abundant species was the commercially important goldband snapper (20). Refer to Figure 3 in Appendix A for further information.

3.1.2 Exploratory study sites

At the exploratory Location (Sites 0.1 to 0.3), a total of 388 fish from 38 species and 20 families were recorded across the three Sites. In contrast to the planned Locations seven commercially important species were observed at the Exploratory Location including the red emperor, *Lutjanus sebae* (30 individuals), goldband snapper (26) and the saddletail snapper, *Lutjanus malabaricus* (5). The four most ubiquitous species were longnose trevally (100% of deployments), the giant catfish, *Netuma thalassina* (73%), and giant trevally and goldband snapper (67% each). The four most abundant species were longnose trevally (76 individuals), and the three commercially important species, the frypan bream, *Argyrops spinifer* (31), red emperor (30) and goldband snapper (26).

3.1.3 Spatial patterns in fish assemblages

A significant effect of Location for both the total abundance of all individuals and species richness was correlated with a trend of greater values within the Exploratory Sites and with both metrics decreasing across the planned study Locations, with the lowest values at Location 3. Pairwise comparisons found the total abundance of all fish within the Exploratory Sites was significantly higher than at all other Locations, whereas Location 3 consistently had lower abundances. Significant differences in species richness between Locations followed a similar (but less pronounced) pattern to total abundance. CLUSTER analysis of fish assemblages for the planned and Exploratory Locations identified a significant grouping of replicates in the Exploratory Location (Figure 5). This figure also showed the relative consistency in fish assemblage across the KEF study area at all three KEF Locations.

3.1.4 Seabed habitat

Analysis of ancient coastline KEF habitats from the KEF fish assemblage survey imagery indicated that Sites were either unconsolidated (Sand/rubble) or octocoral broad CATAMI habitat classifications (Althaus et al. 2013). The unconsolidated classification was further sub-divided into 'coarse' and 'fine' variants. Similarly, the octocoral classification was subdivided into three groups, characterised by 'whip', 'fan' and 'branching' octocorals. Octocoral cover ranged from 0 to 7.5% across the survey Locations.

Multivariate analysis identified a change in substrate from west to east, which appeared to correlate with bathymetry. The BRUVs replicates deployed on areas with the most complex bathymetry (Exploratory Sites 0.1 and part of 0.2) were different from the other Sites due predominantly to the occurrence of octocorals, bioturbated sediments and fine/sandy substrate. The rest of the Exploratory Site deployments (part of Site 0.2 and Site 0.3), and Sites 1 to 6 were more characterised by finer sediments, and were deployed on relatively flat seabed areas within approximately 8 km of more complex benthic morphology (e.g. see Figure 6). Location 3 (Sites 7 to 9) were characterised by coarser sandy/gravel substrates with no bedforms, and were correlated with a broad, relatively flat sea bed.

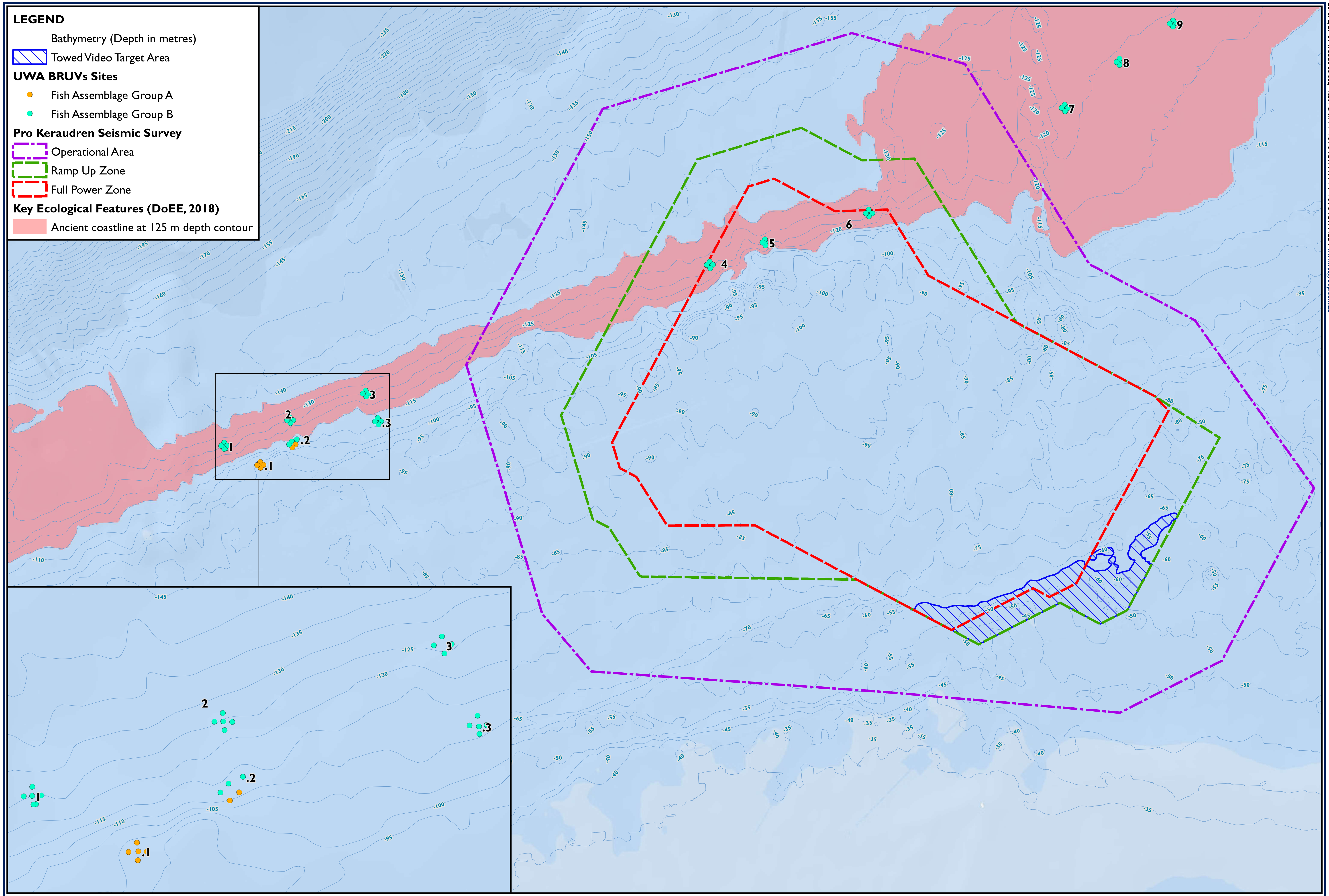

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Figure 5
Spatial distribution of fish assemblage groupings from the KEF and exploratory locations

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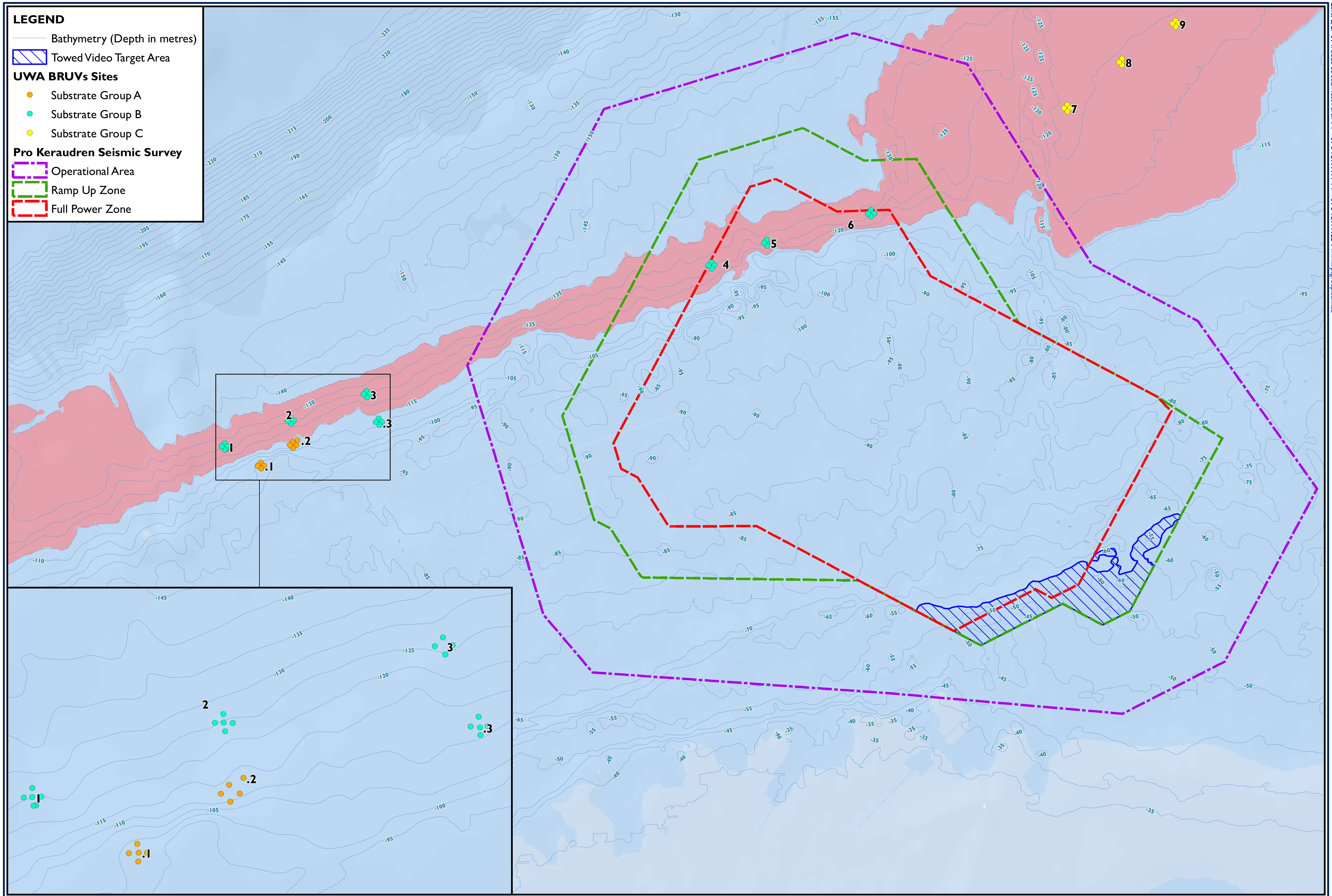

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Figure 6
Spatial distribution of substrate environmental variable groupings from the KEF and exploratory locations

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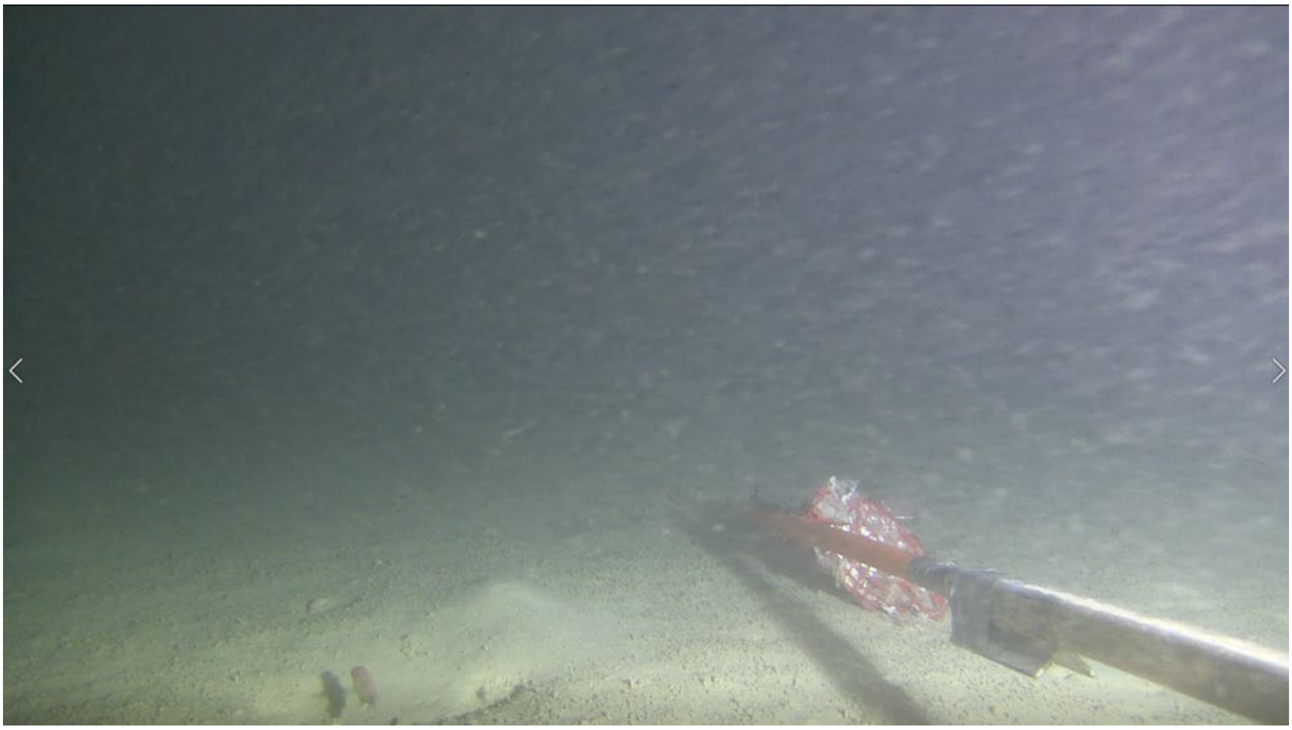

Plate 1 Benthic habitat at the ancient coastline KEF within the planned MSS operational area

3.2 Pearl oyster and potential pearl oyster habitat survey

Seventeen towed video transects were successfully completed, with around 21.9 km total length of seabed imaged across the target area.

3.2.1 Pearl oysters

A number of features were classified for further assessment during the survey. Following review of video imagery, only three of these were considered to be likely to be large bivalves. Plate 2 and Plate 3 were considered 'high confidence' matches (i.e. likely to be pearl oysters) whereas Plate 4 was considered to be a 'low confidence' match (i.e. bivalve of appropriate size, but considered unlikely to be a pearl oyster).

The potential pearl oyster identified on transect 10 (Plate 2) was associated with a flat substrate of mixed sediments with sand ripples over consolidated rock, in a water depth of 54 m (LAT). The ecological assemblages characterising this habitat were comparable with a low-abundance 'Garden' habitat, namely hydroids, sponges, octocorals, soft corals, ascidians and crinoids. The potential pearl oyster recorded on transect 11 (Plate 3) was observed at 50 m water depth (LAT) and was associated with a similar substrate to the transect 10 pearl oyster, with waves and ripples, and a patchy distribution of sparse 'Garden' habitat. The ecological components of this habitat comprised sponges, hydroids, octocorals, soft corals, ascidians and crinoids.

Using the distance between lasers points for scaling (measured on deck at 205 mm), the individual from transect 10 was estimated to be >170 mm in length (Plate 2) and the individual from transect 11 was likely to be >200 mm in length (Plate 3).

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Plate 2 **Potential pearl oyster observed on transect 10 in 54 m water depth (centre right of the image)**

Plate 3 **Potential pearl oyster observed on transect 11 in 50 m water depth (centre right of the image)**

Plate 4 Bivalve observed on transect 17 (centre bottom of the image) and patchy "hydro-bryo" turf on rock (indicated by arrow)

3.2.2 Potential pearl oyster habitat

Common epibiota observed throughout the survey included sponges, hydroids, whip corals, soft corals, echinoderms (crinoids, starfish, ophiuroids and holothurians), octocorals (gorgonians) and ascidians. The abundance and growth forms of certain epibiota such as hydroids, sponges and octocorals were often a characteristic of specific habitat types. For example, habitats characterised by low abundance short, turf-like forms were often also characterised by mobile sand habitats with consolidated gravel/rock occurring in patches or troughs that were likely to be prone to periodic inundation by sand wave features. Large and potentially more sensitive growth forms (e.g. fans, barrel sponges) in high density assemblages were generally associated with consolidated hard substrate or bedrock, which was often covered with a sand or sandy gravel veneer. Most transects comprised several different habitat types (Figure 7), and high abundance, diverse assemblages were commonly found in patches interspersed by lower abundance/diversity biota in sand or sandy gravel habitats.

Abundance estimates in habitat classifications represent the abundance of meadow and massive growth forms (for comparability with AIMS and CATAMI classifications). Inclusion of turf growth forms (which were generally more abundant) tended to over-represent epibiota coverage, and may lead to misinterpretation of results. Overall abundance estimates used in the thirteen main habitat classifications were representative of the most common or median abundance derived from the range of individual habitats used to characterise that main classification.

Thirteen main habitat types were defined across the survey area ([I] = comparable to 'garden' habitat; [L] = Low comparability 'garden' habitat - inconsistent/patchy or low abundance/diversity 'garden' habitat with sand waves or ripples and thick sand veneer

Figure 8). These represented flat and gently-sloping seabeds, comprising mainly sand/gravel, mixed and rock (with sediment veneer) substrates. No 'Potato' habitat was observed or defined, but a range of variants of 'Garden' habitat were identified. The two likely pearl oysters identified during the survey were both found within potential 'Garden' habitat variants.

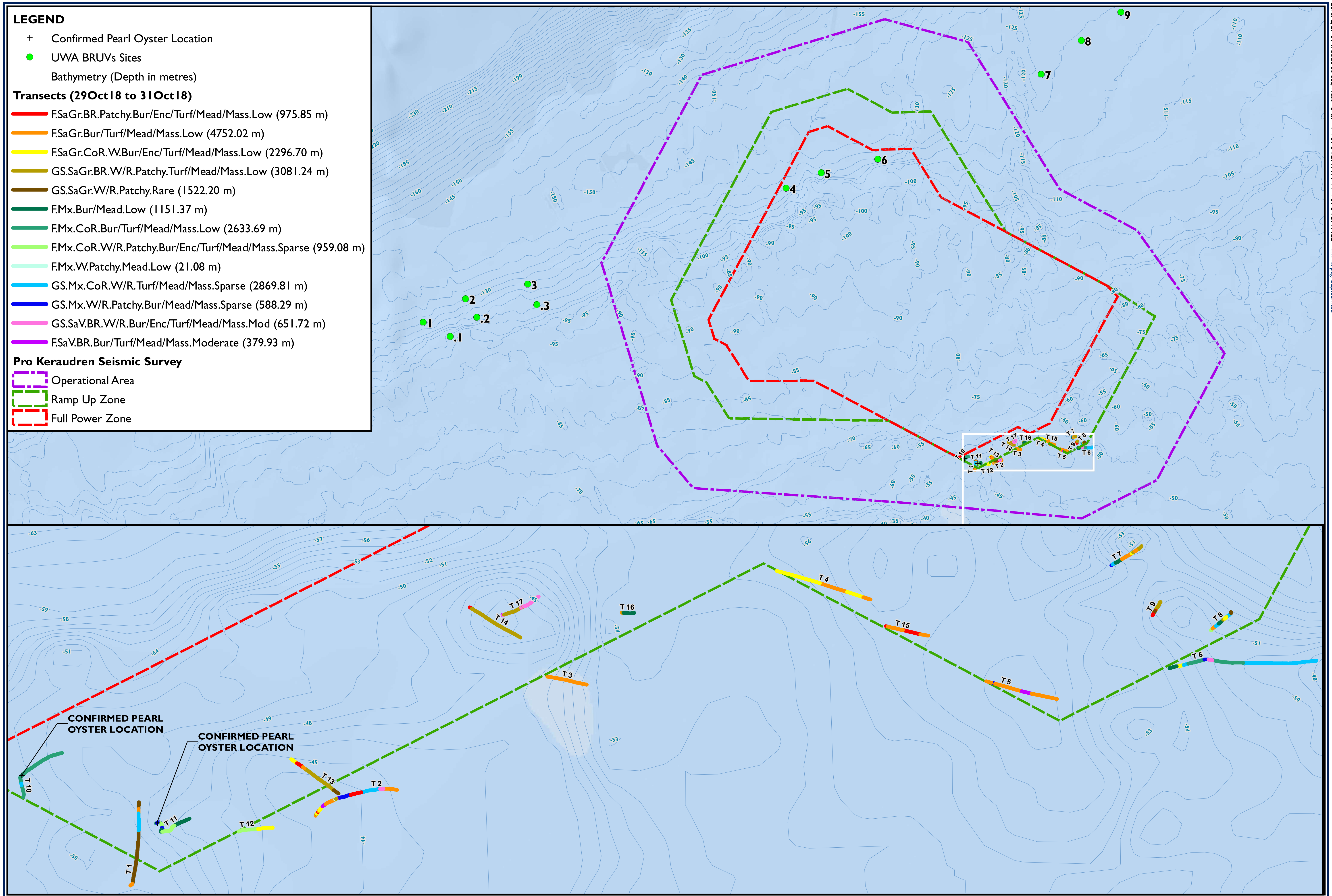

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Figure 7
Location of SBRUVs deployment sites and towed video transects, showing distribution of habitat types along transects

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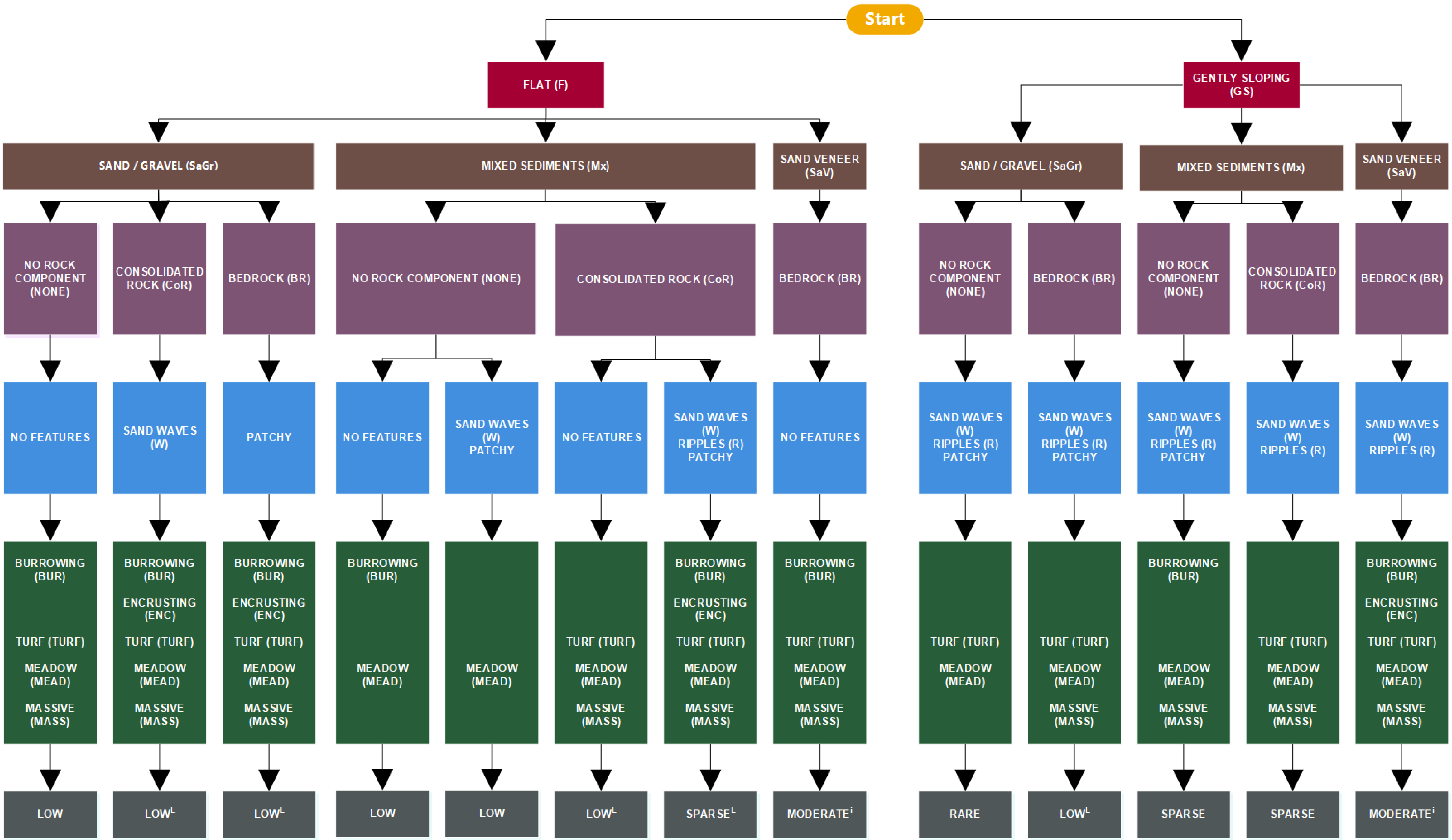

[i] = comparable to 'garden' habitat; [L] = Low comparability 'garden' habitat - inconsistent/patchy or low abundance/diversity 'garden' habitat with sand waves or ripples and thick sand veneer

Figure 8 Final habitat classification hierarchy for habitats identified from the pearl oyster and potential pearl oyster habitat survey

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One observed difference of note between the ‘Garden’ habitat defined by the Department of Fisheries (2016) and the present survey, was that the thickness of the veneer was generally greater in the Keraudren MSS operational area whereby veneers were commonly several centimetres thick, rather than a ‘fine layer of sediment’.

The pearl oyster identified in transect 10 was associated with a flat substrate comprised mixed sediments over consolidated rock (rather than bedrock). No features were identified and the ecological assemblage comprised burrowing, turf, meadow and massive growth forms at low abundances (between ~5 and 24% total coverage). This habitat type (F.Mx.CoR.Bur/Turf/Mead/Mass.Low) comprised 2634 m (12%) of the 21,883 m of total video transects recorded. In transect 11, the pearl oyster was associated with a flat substrate comprised mixed sediments over consolidated rock (rather than bedrock) with waves and ripples, and a patchy distribution of substrate and ecological components. Burrowing, encrusting, turf, meadow and massive growth forms were all represented but at sparse abundances (~1 to 5% total coverage). This habitat type (F.Mx.CoR.W/R.Patchy.Bur/Enc/Turf/Mead/Mass.Sparse) comprised 959 m (4.4%) of the total seabed surveyed.

Habitats identified as fitting the Department of Fisheries (2016) description of ‘garden’ habitat in Figure 4 included:

- GS.SaV.BR.W/R.Bur/Enc/Turf/Mead/Mass.Mod
- F.SaV.BR.Bur/Turf/Mead/Mass.Mod.

A number of other habitats also included habitat components broadly fitting the description of ‘Garden’ habitat (including those in which pearl oysters were observed):

- F.SaGr.BR.Patchy.Bur/Enc/Turf/Mead/Mass.Low
- F.SaGr.CoR.W.Bur/Enc/Turf/Mead/Mass.Low
- F.Mx.CoR.Bur/Turf/Mead/Mass.Low
- F.Mx.CoR.W/R.Patchy.Bur/Enc/Turf/Mead/Mass.Sparse
- GS.SaGr.BR.W/R.Patchy.Turf/Mead/Mass.Low.

Potential variants of ‘garden’ habitat therefore occupied a total of 10,978 m (or 50.2%) of the total transect lengths surveyed. Transects were then classified as either ‘mostly pearl oyster habitat’, ‘patchy pearl oyster habitat’ or ‘mostly not pearl oyster habitat’ to facilitate interpretation of the distribution of potential pearl oyster habitat:

- mostly pearl oyster habitat: T9, T10, T11, T12, T13, T14 and T17
- patchy pearl oyster habitat: T1, T3, T5, T7, T8 and T16
- mostly not pearl oyster habitat: T2, T4, T6 and T15.

This identified that potential pearl oyster habitat was most commonly distributed in the south-west and western central sections of the area surveyed within the 40 to 60 m depth range, with limited distribution in the central and eastern sections.

Over half of Transect 17 was considered to be the most similar habitat observed to the ‘garden’ habitat description in the Department of Fisheries report (2016); namely an assemblages of sponges, soft corals, hydroids, ascidians, sea pens and crinoids on hard bottom with crevices and covered by a fine veneer of sediment (e.g. Plate 5 and Plate 6). This habitat was classified as GS.SaV.BR.W/R.Bur/Enc/Turf/Mead/Mass.Mod in this study. A mesophotic gorgonian sea fan (octocoral) forest was found with a ‘garden’ habitat understorey in large areas this transect (e.g. see Plate 7, Plate 8 and Plate 9), but was not observed in any other transect surveyed. Sea fans at this Location were generally estimated to be 1–1.8 m high (based on laser scaling, with lasers measured at a distance of 205 mm apart, e.g. Plate 10), with much smaller colonies also present (potentially recruits, approximately 10–30 cm high). This habitat is also of note as it is a potentially suitable habitat for pearl oysters, but individuals would be more difficult to observe here if obscured by taller epibiota. The ‘Garden’ habitat at this Location was characterised by hydroids, sponges, ascidians, soft corals, octocorals (fan corals, branching corals and whip corals) and crinoids.

Due to the nature of the habitat, the video system was generally kept above the height of the epibiota to avoid ecological impact but was lowered to near-seabed at regular intervals in an attempt to identify any pearl oysters. None were recorded at this Location.

Plate 5 “Garden” habitat between gorgonians on transect 17, with a seabed of bedrock with a gravelly sand veneer

Plate 6 “Garden” habitat between gorgonians on transect 17

Plate 7 Mesophotic gorgonian (octocoral) forest, found in approximately 45 m water depth (LAT) on transect 17

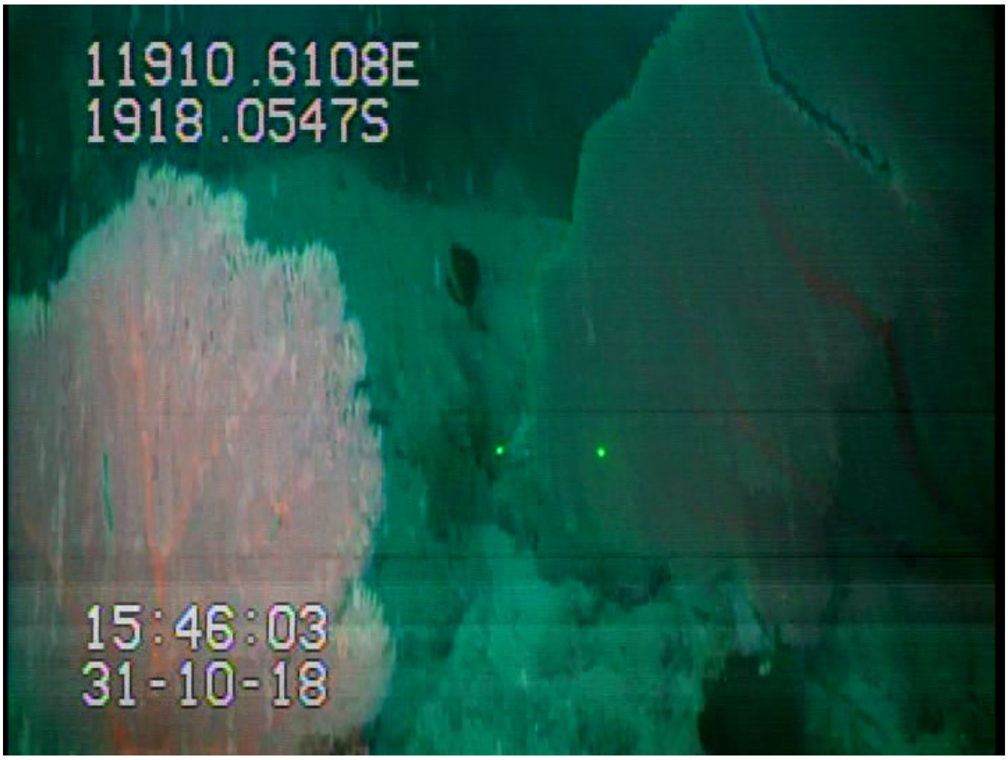

Plate 8 Close-up of octocorals (gorgonian fan corals) on transect 17 with "garden" habitat understorey

Plate 9 **Gorgonian forest on transect 17, interspersed by areas of sand/gravel and "garden" habitat**

Plate 10 **Octocoral (gorgonian fan coral) on transect 17**

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4 Discussion

4.1 KEF fish assemblage values

The ancient coastline KEF fish survey Sites were found to be broadly comparable in terms of measured environmental variables, yet patterns in the fish assemblage abundance and biomass composition revealed a longitudinal trend in the assemblage correlated with west-east gradients in various derived environmental variables, in particular turbidity.

The only commercially important species within the planned survey Sites was the goldband snapper, *Pristipomoides multidens*. However, it was rare, and despite being completely absent from the KEF Sites in the proposed MSS operational area, this pattern was not significantly different between Locations, likely due to the high level of site-to-site variability found throughout the remaining Sites. Goldband snapper is a demersal species (Newman et al. 2000), likely to be associated with high relief habitats. Its absence within the KEF in the proposed MSS operational area suggests a lack of suitable habitat in the vicinity of the sampling Sites. No escarpment, complex relief, emergent bedrock or complex epibiota assemblages were recorded on video or observed on the vessel sounder at the KEF survey Locations. There was also limited variation in the fish assemblages at these KEF survey Locations (including those within and outside of the MSS operational area).

High within-site variability should not be considered as conferring low confidence in study outcomes. These results identified that abundances (and most likely density) of fish species were low in the area, comprising relatively mobile demersal fish species (see discussion of site attachment of fish in Appendix A).

The Exploratory Sites adjacent to Location 1, at a shallower water depth of 95-115 m, may represent terrace and step features resulting from changes in sea level over the past 100,000 years, as identified by DoEE (2017). They fall within the broader definition of the ‘ancient coastline between 90 and 120 m depth’ KEF defined in the Marine Bioregional Plan for the South-west Marine Region (DSEWPaC 2012b). Within the Exploratory Sites 0.1 and 0.2 higher relief emergent habitat with a significant increase in the percentage cover of octocoral compared to other sites. However, Exploratory Site 0.3 was more similar to the Planned survey locations (in terms of environmental variables), suggesting that while more structurally complex habitats exist in adjacent shallower (95-115 m) locations, they are not consistently distributed across this depth range (e.g. see bathymetry in Fig. 19). In addition, visibility at the Exploratory sites was approximately twice that of the study sites, presumably due to lower cover of soft-sediments, which at the study sites were observed to be readily stirred up by fish activity and near-seabed water currents around the stereo-BRUV. The contrast between Planned and Exploratory sites was also clearly demonstrated in the spatial representation of CLUSTER groupings based on substrate and benthos composition (Fig. 18). A similar pattern was evident in the fish data with Exploratory sites 0.1 and 0.2 having greater occurrence and abundance of commercially important species such as the red emperor *Lutjanus sebae*, and the yellowspotted rockcod *Epinephelus areolatus*, and a greater abundance of goldband snapper, and Exploratory Site 0.3 being more similar (in terms of fish composition) to the Planned survey locations. Again, this trend was supported in the spatial representation of CLUSTER groupings based on fish composition (Fig. 19). Goldband snapper, red emperor and yellowspotted rockcod are very important target species across the Indo-Pacific (Cappo et al. 2009) and are typically closely associated with higher relief habitat (Pistorius and Taylor 2009) as also found in the current study.

Understanding the life-history characteristics of a fish species, especially those of commercial importance, is necessary for understanding how individuals may relate to the environment or respond to anthropogenic or environmental disturbance (Claudet et al. 2010) . For demersal species, home range size and movement patterns can be strongly correlated with body-size (Harasti et al. 2015) , but also be strongly influenced by ontogenetic variation in habitat usage changing between different life stages (Kimirei et al. 2011, Parsons et al. 2014) . Telemetry studies provide the most direct approach to study and quantify home range size and habitat use in demersal fishes, and such studies have frequently provided surprising insights into hitherto unknown behavioral modality in highly studied coastal water and commercially important demersal species (e.g. the pink snapper Pagrus auratus; Willis et al. 2001, Parsons et al. 2003, Egli and Babcock 2004) . Both Parsons et al. (2003) and Willis et al. (2001) found that pink snapper had relatively restricted home ranges (< 1 km) and that they can exhibit long-term (>3 years; Willis et al. 2001) site fidelity, however, the sample size with these studies, as with many telemetry studies, was small so the generality of these results should be viewed with caution. Parsons et al. (2003) also suggested that for pink snapper, some individuals may relocate their home range over time, but again, due to a small sample size (n = 4) these results should be viewed with caution. To our knowledge there have been no telemetry studies of home range and habitat use conducted for the commercially important species more typical of mesophotic reefs and sampled in the current study, likely due to the challenges of conducting acoustic telemetry at the typical depths (50-150 m) at which these species occur.

It is worth noting that the bathymetry presented in Figure 1 indicates that an escarpment feature may occur in this area in the 145 to 240 m water depth range, which is >12 km from the MSS operational area at its closest point.

4.2 Pearl oyster and pearl oyster habitat values

4.2.1 Pearl oysters

Transects within the 40 to 60 m depth range were surveyed to identify potential silver-lipped pearl oysters, *Pinctada maxima*, occurring outside the 8 to 40 m water depth range of the species defined by the Department of Fisheries (2016), and which therefore might occur in areas subject to ensonification during the proposed MSS.

Only two pearl oysters were identified from a total of 21.9 km of seabed surveyed. Both individuals were observed growing vertically attached to consolidated rock substrates with a relatively thick veneer of shelly/gravelly sand, in water depths of 50–54 m (LAT). This indicated that although potential pearl habitat was likely to occur in the depth range surveyed, the habitat did not support a high density of pearl oysters (only a few individuals).

The pearl oyster on transect 10 was estimated to be >170 mm long, while the individual on transect 11 was likely to be >200 mm long. By the time an oyster has reached 170 mm in length, about half of the age cohort will have changed from male to female, with most oysters >190 mm being female. Individuals that are 200 mm in length are likely to be 15–20 years old (Department of Fisheries 2016), with this species reaching lengths of up to 270 mm. This means that at least one of the two individuals identified was likely to be female, and hence there is the potential that a low abundance of reproductive adults may occur in these habitats. However, reproductive success would be dependent on the availability of male gametes, which is reliant on the proximity of male pearl oysters along with suitable local hydrographic conditions to deliver male gametes to females at the right time. At the low densities observed, reproductive output in this area would be correspondingly low.

The silver-lipped pearl oyster (*P. maxima*) can be cryptic and difficult to see, and therefore it is possible that other individuals occurred in potential pearl oyster habitat. However, the results from this study support the Department of Fisheries' (2016) statement that the silver-lipped pearl oyster (*P. maxima*) are generally found in water depths of 40 m or less.

4.2.2 Pearl oyster habitat

Benthic habitats were surveyed across the southern end of the MSS operational area in water depths from 43.8 to 59.4 m (LAT). Depths of less than ~43 m were surveyed as they were not identified in the target survey area (see Figure 2). Of the 21.9 km of transects, approximately 50% was identified as being potential pearl oyster habitat (considered variants of 'Garden' habitat). No 'Potato' habitat was identified. Cross-referencing the spatial distribution of potential pearl oyster habitat from survey transects in Figure 3 revealed that the majority of potential pearl oyster habitat was found on the western side of the MSS operational area; specifically from transect 17 westwards, and across the full range of depths surveyed. Only one transect was identified as ‘mostly potential pearl oyster habitat’ in the eastern part of the pearl oyster and potential pearl oyster habitat survey area.

Thirteen overarching habitat types were described, with up to seven being considered variants of potential ‘Garden’ habitat. Habitat classifications were developed using on an adapted AIMS classification system. The components used in the classification system also align with CATAMI (Althaus et al. 2013), and were comparable with other classification schemes (e.g. EUNIS, NISB). The classification system developed for this study was designed to allow links between the environmental component and the composition and abundance of the biological component to be identified. This was an important aspect in correlating habitat types in the ramp up zone with shallower water ‘Garden’ habitat (as described by Department of Fisheries 2016). Although ‘potential pearl oyster habitat’ was identified as being recorded along ~50% of the transects, the two closest matches only represented ~1 km (4.7%) of total seabed habitat assessed (F.SaV.BR.Bur/ Turf/Mead/Mass.Mod and GS.SaV.BR.W/R.Bur/Enc/Turf/Mead/Mass.Mod). The other habitats classified as being ‘potential pearl oyster habitat’ were considered to be a weaker match to the Department of Fisheries (2016) description (e.g. due to reduced composition or abundance of epibiota, lack of continuous bedrock, and thickness of sediment veneer) but were recognised as being sufficiently similar to be considered under the broad term ‘Garden’ habitat. The two pearl oysters identified in this survey were associated with these ‘weaker match’ habitats. This suggests that although these habitats may be considered as ‘potential pearl oyster habitat’, benthic habitats in this area appear to be sub-optimal for the silver-lipped pearl oyster, *Pinctada maxima*.

Habitats recorded in transect 17 were considered to be most similar to the ‘garden’ habitat description provided in Department of Fisheries (2016). It was deemed appropriate to characterise one of the habitats observed in transect 17 as mesophotic gorgonian forest, as similar habitats have been identified in Malaysia (at Layang Layang, which were found associated with high relief) and the Mediterranean (Cerrano et al. 2010, Ponti et al. 2018), with gorgonian forests also known from shallower waters in Western Australia. The gorgonian forest habitat was not observed in any other transect surveyed but may be represented in shallower waters inshore of the MSS area.

The comparability of habitat recorded in the 45–47 m depth range on transect 17 with ‘garden’ habitat suggests that this is likely to be considered suitable pearl oyster habitat. The presence of a filter-feeding bivalve of similar size attached to hard substrate (Plate 4) on transect 17 also indicates that conditions may be suitable for pearl oyster survival; however, no pearl oysters were recorded on this transect.

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RPS

Appendix A

UWA KEF fish survey report

Characterisation of the fish assemblages associated with the ancient coastline key ecological feature within a proposed marine seismic survey operational area and reference locations on the North West Shelf of Australia

REPORT ON RESEARCH FINDINGS

Prepared for Santos

By

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Introduction

This study characterised the fish assemblage abundance and biomass composition within a proposed marine seismic survey (MSS) operational area and adjacent western and eastern locations within the ancient submerged coastline at 125 m key ecological feature (KEF) of the North West Shelf (NWS) of Australia. KEFs are parts of the marine ecosystem that are considered to be important for a region's biodiversity or ecosystem function (Hayes et al. 2015) and are defined as regionally or nationally important due to their ecological role or high levels of biodiversity, endemism, faunal aggregations, biological productivity or unique sea-floor features (DSWEPaC 2011). One of the most prominent of these features is thought to occur as an escarpment along the NWS and Sahul Shelf at a depth of 125 metres; however the spatial boundary of this KEF as defined in the Conservation Values Atlas (https://www.environment.gov.au/sprat-public/action/kef/view/9; accessed on 29/11/18), has a depth range of 115-135 metres in the NWS Province and Transition provincial bioregions. Despite being a biodiverse region coexisting with globally significant petrochemical and mineral industries, knowledge of the spatial distribution and abundance of fish, invertebrate and benthic communities on the NWS is limited (Moore et al. 2016).

Globally, the eastern sides of ocean basins tend to be highly productive ecosystems. However, the Western Australian coast is an exception, which has important biogeographic implications for its characteristically endemic fish assemblages (Langlois et al. 2012). On the NWS, the upwelling of deeper more nutrient-rich waters is typically suppressed by the dominance of the Indonesian Throughflow and Leeuwin Current. However, the shelf break (~100 m) is an area where significant mixing of water bodies is known to occur, and the frequency of this mixing is influenced by a range of factors including tidal forcing. Despite our limited understanding of the nature and spatial distribution of biological productivity in the region it has been hypothesized that evidence of localised mixing, such as surface turbidity, can be indicative of biological productivity in deeper waters of the shelf break, as surface waters mix with deeper, more nutrient-rich waters (Brewer et al. 2007).

Mesophotic reef habitats, such as those found within the depth range of the old coastline KEF, are characterised by middle to low light levels (Kahng et al. 2010, Turner et al. 2017). In these mesophotic zones, hard substrata is often dominated by sponges and octocorals, and is usually interspersed with unconsolidated soft sediment habitats (Harris et al. 2008, Monk et al. 2017). Such mesophotic reefs promote habitat heterogeneity by increasing the physical complexity of the ecosystem (Buhl-Mortensen et al. 2010, Baillon et al. 2012, Monk et al. 2016). The prevalence of suspension feeders in the sessile communities associated with these mesophotic reefs are known to be important in the transfer of energy and biomass from the pelagic to the benthic zone by recycling particulate organic matter (POM) sinking from the upper photosynthetic regions (Gili and Coma 1998, de Goeij et al. 2013). These mesophotic reefs are not only of crucial importance to the overall functioning of the ecosystem (Ribes et al. 2003, Gori et al. 2014), but can also provide 'refuge' habitat for fishery targeted species (Lindfield et al. 2016). There is also some evidence that mesophotic reefs, such as those found within the depth range of the old coastline KEF, support unique species assemblage (Sih et al. 2017).

Stereo-BRUVs are increasingly being adopted as a standard method for characterising fish assemblages and investigating the impact of marine spatial planning (Langlois et al. 2018, Hill et al. 2018), and provide a cost-effective, non-destructive remote methodology suited to deeper photic zones (100-150m) (Langlois et al. 2010) that enables repeat sampling of assemblages to track change through time (Bornt et al. 2015). Recently, stereo-BRUV imagery has also been recognised as a useful source of benthic habitat information, both for investigating fish distributions (McLean et al. 2016, Collins et al. 2017) and measuring change in habitat composition (Vergés et al. 2016).

In this report we aim to;

1. Characterise the fish assemblages occurring at 125 m depth at sites along the ancient coastline KEF within and outside of a proposed marine seismic survey area.
2. Identify potential spatial differences in fish assemblages across the area of study.
3. Obtain imagery of the benthic habitat at the ancient coastline KEF sampling locations.

Materials and methods

Study area and sampling design

This study took place in the lower mesophotic zone (~120-130 m), within the area identified as the ancient submerged coastline key ecological feature (KEF) of the North West Shelf (NWS) of Australia (Fig. 1). Over eight days in October 2018, a total of 45 stereo-BRUVS were deployed at nine predetermined sites across three locations designed to characterise the ancient submerged coastline KEF, one within the area of a proposed marine seismic survey (proposed MSS) and two outside of the survey area (five BRUVS per Site, 3 sites per Location, Fig. 1). BRUVS were deployed in depths of 121 to 128 metres (standardised to lowest astronomical tide [LAT]). Opportunistically, an additional 15 BRUVS were deployed at three Exploratory sites in seabed identified during the survey to have high relief emergent reef habitat using boat sounder imagery in water depths of 97-114m (LAT; Fig. 1). These sites were located adjacent to sites 1, 2 and 3, however the bathymetry associated with these high relief emergent reef features suggests comparable features may also exist adjacent to sites four, five and six. These sites will be referred to herein as the 'Exploratory sites'.

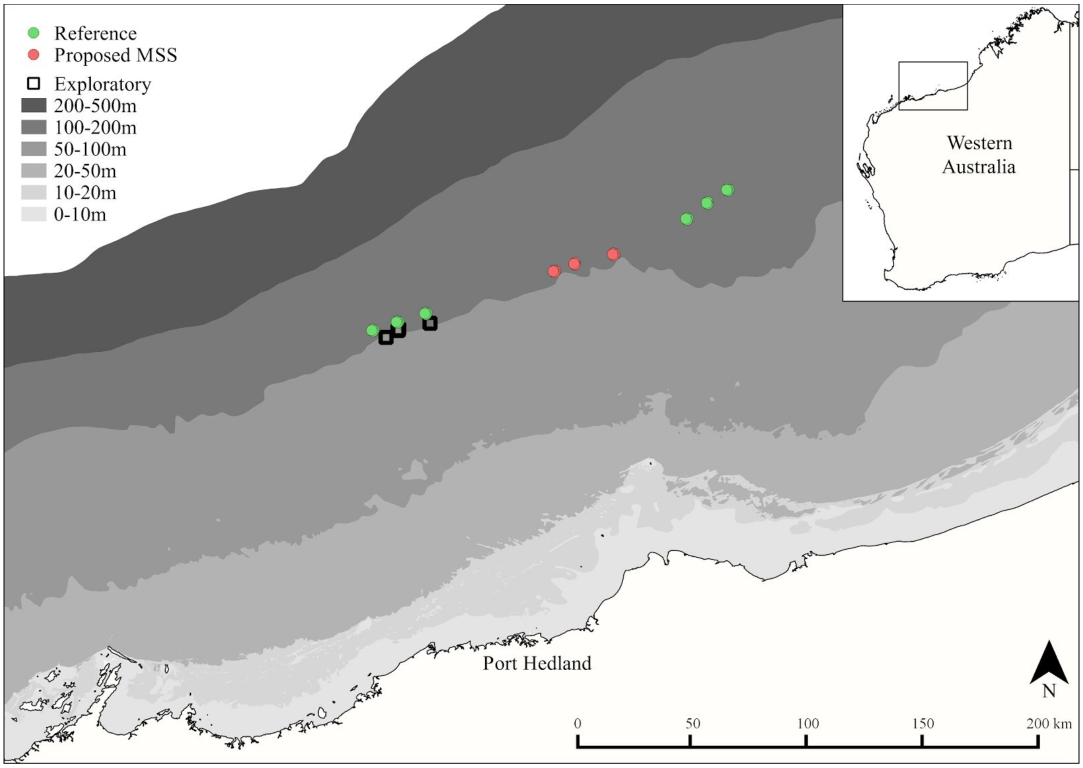

Figure 1. Three study locations and the nine sampling sites, three in the proposed marine seismic survey area (Location 2) and six in two western and eastern reference locations (Location 1 and Location 3). An additional three Exploratory sites are indicated on the map.

Each stereo-BRUVS consisted of two Canon Legria HF G25 cameras set to a fixed focus point of three metres to prevent the cameras from focusing on individual fish or habitat in the near field of view. The cameras were positioned in waterproof housings fixed to a bar, with a base separation of 65cm and an inward facing angle of 7°, which allows for the accurate identification and stereo-photogrammetric measurement of individual fish from 0.5 to 7 metres in front of the BRUVS (Fig. 2A). The stereo-video systems were calibrated in a pool to synchronise the cameras prior to and post deployment in the field. Further information on the design and calibration of these systems can be found in Harvey and Shortis (1995, 1998).

In the field each base bar was mounted on a trapezium frame and four lead weighted bars (and additional heavy-duty steel shackles) were added to stop the frames overturning in strong currents. In addition to the stereo camera setup a single rearward facing GoPro Hero 3+ in a waterproof housing was positioned facing backwards in the centre of the base bar to record additional habitat information (Fig. 2B). The GoPro was set to record in a 127° medium field of view at 30 frames per second with 1080 pixel resolution to maximise video quality in low visibility environments. Forward and rearward white LED lights were also attached to the base bar to illuminate the field of view in front of the forward-facing stereo cameras and rearward facing habitat camera (Fig. 2C). A plastic mesh bait bag containing 1 kg of fresh crushed pilchards (*Sardinops neopilchardus*) was attached to each BRUVS system using a 1.2 m conduit rod bait arm centred between the stereo cameras.

Each stereo-BRUV was attached to 200 m of cray rope and identified on the water surface by one large orange Norwegian float and three smaller polystyrene floats. Work was carried out from research vessel Warrego (Gun Marine Services, Exmouth) during daylight hours, and stratified to slack water only due to spring tides in the region during the sampling period resulting in strong currents that prevented stereo-BRUV deployment. Slack mean low and high water spring tide levels were identified using tide predictions from the Phoenix and Roc Wells buoy (18° 50' 23" S; 118° 51' 30" E) provided by RPS Australia West Pty Ltd (RPS). At each Site five replicate BRUVS were deployed in a cross formation with a minimum of 500 m between each one and a minimum time on sea bed of 60 minutes.

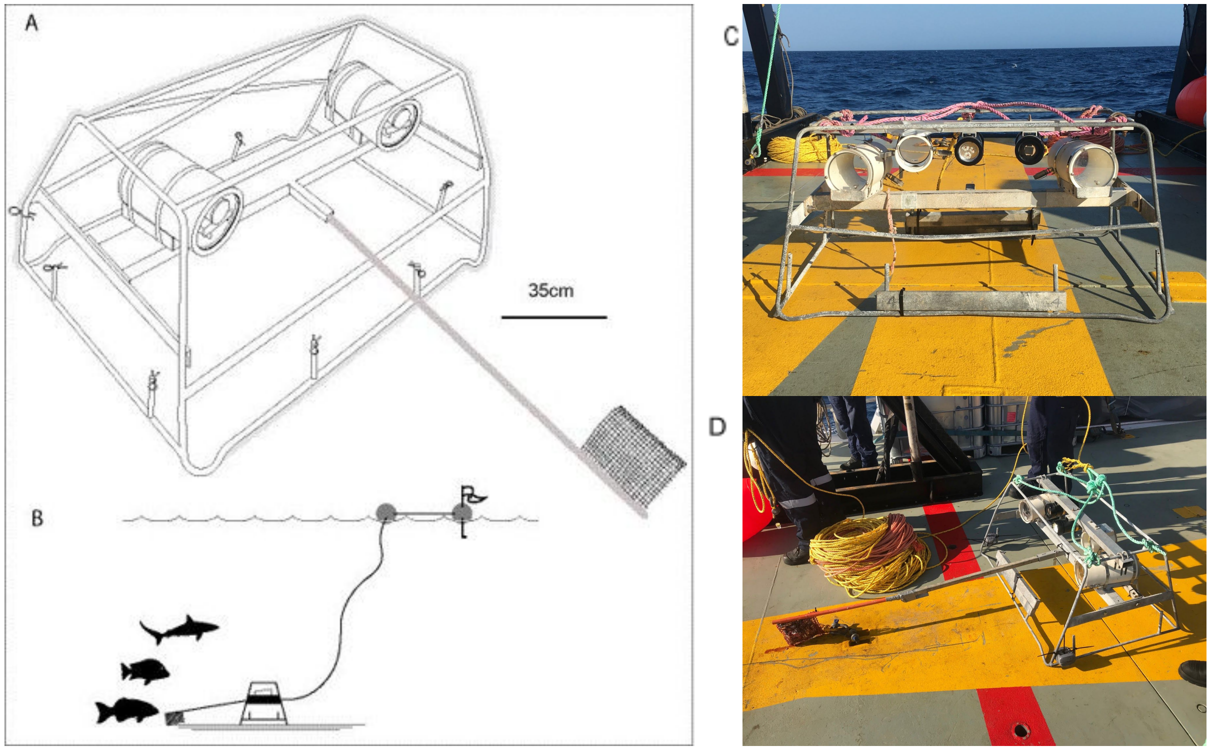

Figure 2. Line drawing of stereo- BRUVS set up including bait arm (A) and the whole submerged deployment set up (B). Photographs show the additional rearward facing GoPro camera for habitat imagery and both forward and rearward facing lights (C) and the whole set up before deployment (D).

Image analysis

Prior to analysis all the video footage was converted to audio-video-interleaved (AVI) format. The left camera of each video was analysed using EventMeasure™ software (SeaGIS 2011) and calibrated with the right camera for stereo measurements using CAL™ software (SeaGIS 2011). During analysis all fish were identified to their lowest possible taxonomic level. The maximum number of individuals of a single species in one frame (MaxN) at each stage was recorded and the fish lengths (Fork length [L_F]) taken at the corresponding MaxN to avoid making repeated measurements of the same individuals. The length of each fish occurring at the MaxN for each species were measured and converted to weight using length-weight relationships obtained from local fisheries reports, where available, or Fishbase (Froese and Pauly 2011), and summed for each species.

For each sample, in water visibility (m) was measured at 5 time points every 15 minutes, beginning when the BRUVS landed on the seabed until the 60 minute deployment elapsed. A single estimate of water velocity was taken for each sample and ranked on a scale from 0-5, zero being low and five being high (Table 1). Habitat composition was obtained from video footage from both the forwards and backwards cameras at the time the BRUVS landed on the seabed using TransectMeasure™ (www.seagis.com.au). The percentage composition of habitat, was recorded from a 5 x 4 grid overlay following methods developed in McLean et al. (2016) and Collins et al. (2017) and applying a modified version of the CATAMI habitat classification scheme (Althaus et al. 2013) with the addition of a visual estimate of relief complexity (0-5, Wilson et al. 2007). Based on the CATAMI scheme broad habitat types included unconsolidated (sand/rubble) and octocoral. Unconsolidated substrates were further divided into two groups; coarse and fine sand. Octocorals were further divided into three groups; whip, fan and branching. Grid rectangles that were orientated to open water were excluded from analyses. Bedforms were classified as either two-dimensional, three-dimensional, bioturbation (burrows and/or tracks) or flat (none). The two-dimensional and three-dimensional bedforms were both further split, based on size; ripples (<10 cm height) and waves (>10 cm height). A further five environmental variables were derived from existing datasets (MODIS 2011; [sediment type] Content Across the Australian EEZ) and calculated for each sample position or site depending on the spatial scale available (see supplementary Table 3; henceforth called 'derived' environmental variables). These derived variables include a long term mean monthly average measure of surface turbidity for each sample, which was derived from MODIS satellite imagery (Supplementary Table 3). It is possible that such broad-scale long-term mean variables are representative of gradients in other variables that have not been measured or derived. For example, although distance from hard reef was not a derived environmental variables in the current study, both broad-scale (Fig. 1) and detailed (Fig. 20) bathymetry indicate a gradient in distance to reef or higher relief substrate from Locations 1 to 3, which would correlate with the pattern in the derived variable turbidity across the locations (Fig. 5A).

Table 1. Velocity rating scale for imagery, from 0-5 (low to high velocity). Each scale increment is supported by a detailed description of the expected fish behaviour, sediment and habitat movement at that velocity intensity, and enables a standardised classification of velocity from imagery.

Velocity Rating	Intensity	Description of habitat and fish assemblage behaviour
0	Low	Water direction not obvious. Particles in the water are sitting in suspension or with slight vertical or 'bobbing' movements. Very minor movement or sway in vegetation. Fish not affected by current.
1	↓	Water direction obvious. Particles in the water are sitting in suspension but the majority are moving in a clear horizontal direction with a stop-start motion. Vegetation swaying slightly but not uniformly. Fish not affected by current.
2		Small (~1 mm) particles in the water are in suspension and are moving uniformly horizontally in the water. Vegetation is clearly swaying, and/or partially leaning in a uniform direction. Fish not affected by current.
3		Particles (> 1mm) and very small bits of vegetation (1-5 mm) are in suspension and moving uniformly horizontally in the water. Vegetation is swaying strongly and is uniformly/ or partially leaning in one direction with the current. Some fish may be affected by current.
4		Particles and larger bits of vegetation (6-30mm) are in suspension and moving uniformly horizontally in the water. Vegetation is leaning uniformly in one direction at a 45° angle with the current. Fish are affected by current.
5	High	Particles and large pieces of vegetation (>30mm) are in suspension and moving uniformly horizontally in the water. Very fast current. Vegetation is uniformly horizontally flattened to the substrate. Current has a significant effect on fish.

Statistical analysis

Two fish assemblage datasets were generated from image analyses, one for abundance (MaxN of each species per sample) and one for biomass (mass of each individual at MaxN of each species summed per sample). Environmental variables were tested for correlation with each other ($|R| > 0.9$ led to exclusion), their distributions examined, and transformations applied where necessary to reduce the influence of outliers before further analysis and comparison with the fish assemblage. The overall experimental design consisted of two factors: Location (three levels; 1, 2, 3; fixed), and Site (9 levels; random; nested in Location).

All multivariate and supporting univariate analyses were undertaken using appropriate dissimilarity measures and transformations in PRIMER v6 and the PERMANOVA+ add-on package (using 4999 permutations, Anderson et al. 2008). All P-values for PERMANOVA and analyses were calculated using 9999 permutations and Monte Carlo simulations where appropriate. Significant terms and interactions were investigated using a posteriori pairwise comparisons with the PERMANOVA *t* statistic and 4999 permutations (see Anderson 2001a). All data formatting and plotting were conducted in the R language for statistical computing (R Core Team 2018), using the following additional packages: tidyr (Wickham and Henry 2017), dplyr (Wickham et al. 2018), and ggplot2 (Wickham 2009) and their dependencies.

Description of the data

The fish assemblage data and environmental variable data were visualised first to explore for patterns and trends in the data. To investigate effects on environmental variables, the experimental design was analysed using permutational multivariate analysis of variance (PERMANOVA, Anderson 2001b, McArdle and Anderson 2001). Analyses were undertaken on square-root transformed data using a Euclidean dissimilarity measure.

Fish abundance and biomass compositional differences between locations

The relationship between the environmental variables and the fish assemblage for both abundance and biomass was investigated using distance-based redundancy analysis (dbRDA, Legendre and Anderson 1999, McArdle and Anderson 2001). The DISTLM model was fitted using stepwise selection, and the most parsimonious model was chosen using a direct multivariate analogue to Akaike's information criterion (AICc, see Anderson et al. 2008). To visualise the resulting model, dbRDA (RDA, Legendre and Anderson 1999) was used, where the ordination axes are linear combinations of the environmental variables that maximised the biotic variation. Analyses were undertaken on Log x 2 (abundance) and Log x10 (biomass) transformed data.

To investigate effects on the fish assemblage abundance and biomass composition as a whole, the experimental design was analysed using permutational multivariate analysis of variance (PERMANOVA, Anderson 2001b, McArdle and Anderson 2001). Analyses were undertaken on square-root transformed data using a Euclidean dissimilarity measure.

To visualize patterns in the abundance and biomass composition across the proposed MSS Location and western and eastern reference locations principal coordinate analysis (PCO) of the abundance and biomass composition of the fish assemblage was performed. A constrained ordination using canonical analysis of principal coordinates (CAP) was used to investigate any patterns in the assemblage and individual species correlated with the environmental variables indicated to be significant in the DISTLM (Anderson and Robinson 2003, Anderson and Willis 2003). Analyses were undertaken on Log x 2 (abundance) and Log x10 (biomass) transformed data.

Hierarchical CLUSTER analysis, which identifies naturally occurring groupings in abundance data, was used to further characterise the benthos and fish abundance assemblage to investigate any spatial distribution gradients across all sites. Subsequent groupings were then plotted spatially over bathymetric data for context. Subsequent one-way SIMPER analysis, which characterises the top 90% of benthos and fish driving the groupings identified in CLUSTER analysis, was used to indicate benthos and fish species which characterised the groupings to identify those correlated with, and unique to groups.

Patterns in total abundance, species richness, and the abundance and biomass of prominent taxa

Univariate permutation analysis of variance was performed on measures of species richness, total abundance; and the abundance and biomass of species of interest. Where tests of factors of interest were significant ($p > 0.05$), pairwise tests were used to further investigate any patterns.

Results

Description of data from Planned study sites

Description of fish assemblage

A total abundance of 643 fish were recorded across the three Planned locations and nine sites from 39 species and 17 families. The goldband snapper, *Pristipomoides multidens,* and the yellowspotted rockcod, *Epinephelus areolatus*, were the only commercially important species observed (Fig. 3A & C). The four most ubiquitous species were the lunartail pufferfish, *Lagocephalus lunaris* (72% of deployments), the threadfin bream, *Nemipterus spp* (67%), the longnose trevally, *Carangoides chrysophrys* (59%), and the giant trevally, *Caranx ignobilis* (47%). At locations 1 and 2 the most abundant species was the longnose trevally (97 and 47 individuals respectively; Fig. 3A & B). At Location 1 the next three most abundant species were threadfin bream (22), lunartail pufferfish (22), and giant trevally (14 Fig. 3A), and at Location 2 scad, *Decapterus spp.* (35), lunartail pufferfish (35), and threadfin bream (28; Fig. 3B). At Location 3, three of the four most abundant species were the same as those at locations 1 and 2, threadfin bream (54 individuals), lunartail pufferfish (16) and longnose trevally, however the second most abundant species was the commercially important goldband snapper (20, Fig 3C). Two species ranked as endangered by the International Union for Conservation of Nature (IUCN) were also recorded across the three Planned locations, the greater hammerhead shark *Sphyrna mokarran* and the scalloped hammerhead shark *Sphyrna lewini* (See Supplementary Table 1). The greater hammerhead is not listed in the Environment Protection and Biodiversity Conservation Act (1999), however the scalloped hammerhead was recently classified (2018) as conservation dependent (http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl; accessed on 08/01/19). At the Exploratory Location a total of 388 fish were recorded across the three sites from 38 species and 20 families. In contrast to the Planned locations seven commercially important species were observed at the Exploratory Location including the red emperor, *Lutjanus sebae* (30 individuals), goldband snapper (26) and the saddletail snapper, *Lutjanus malabaricus* (5) (Fig. 3D). The four most ubiquitous species were longnose trevally (100% of deployments), the giant catfish, *Netuma thalassina* (73%), and giant trevally and goldband snapper (67% each). The four most abundant species were longnose trevally (76 individuals), and the three commercially important species, the frypan bream, *Argyrops spinifer* (31), red emperor (30) and goldband snapper (26) (Fig. 3D).

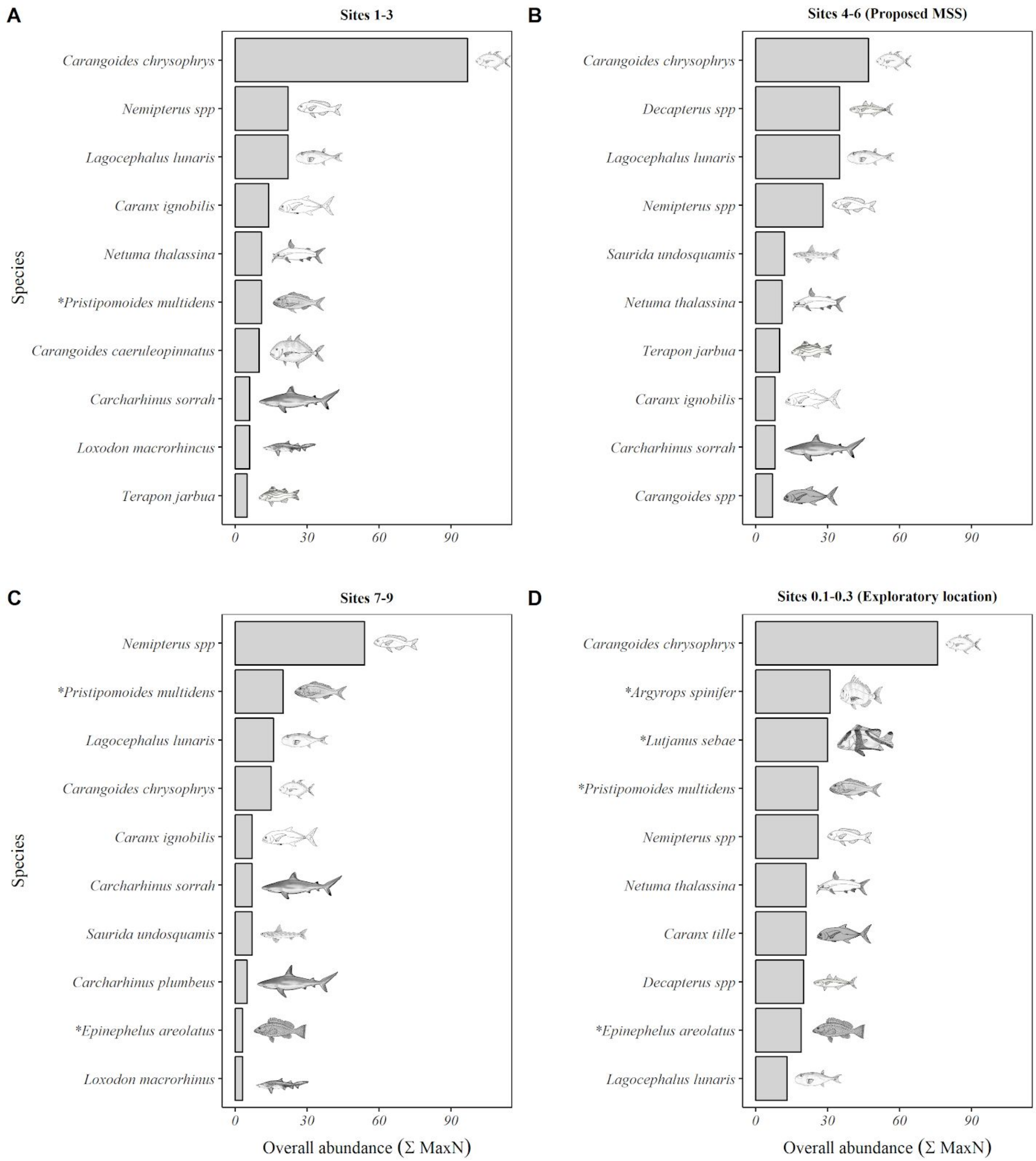

Figure 3. The overall abundance of the top 10 most abundant species at each of the three main study locations (A: western Location 1, B: Proposed MSS Location & C: eastern Location 3) and the opportunistically sampled Exploratory sites (D). Species with an asterix (*) are considered commercially important.

Description of environmental variables

There were no significant effects of Location for any measured environmental variable of interest tested by univariate permutational analysis of variance (PERMANOVA, Table 2, Fig 4). An apparent west-east gradient was seen in the derived environmental variables across sites and locations including mean turbidity (Fig. 5A), and percentage cover of mud (Fig. 5D). For mean turbidity significant differences were found between Location 3 and locations 1 and 2, and for percent cover of mud, between Location 1 and locations 2 and 3 (Table 3).

Table 2. Results of permutational multivariate analysis of variance (PERMANOVA) of environmental variables in response to the factors Location, and Site (Location). Significant results ($p < 0.05$) are shown in bold.

	Variable	Source	*df*	MS	*F*	*p*
Measured Variables	Depth (LAT)	Location	2	0.02	0.47	0.64
		Site (Location)	6	0.05	29.46	**0.0001**
	SD Relief	Location	2	0.02	0.28	0.79
		Site (Location)	6	0.06	0.50	0.8
	Octocoral	Location	2	0.01	0.57	0.27
		Site (Location)	6	0.01	1.35	0.14
	Bioturbated bedforms	Location	2	0.27	4.34	*0.08*
		Site (Location)	6	0.06	1.76	0.14
	Mean visibility	Location	2	0.15	0.83	0.59
		Site (Location)	6	0.18	3.08	**0.02**
	SD visibility	Location	2	0.19	1.65	0.27
		Site (Location)	6	0.12	1.29	0.29
Derived variables	Mean turbidity	Location	2	0.0004	32.27	**0.01**
		Site (Location)	6	0.000006	7.90	**0.0002**
	Gravel	Location	2	2.67	1.71	0.2
		Site (Location)	6	1.55	164.08	**0.0001**
	Mud	Location	2	11.58	3.53	**0.02**
		Site (Location)	6	3.31	6.28	**0.0001**
	Sand	Location	2	0.02	0.55	0.59
		Site (Location)	6	0.39	30.87	**0.0001**

Table 3. Pairwise comparisons for environmental variables and the effect of Location. Significant results ($p < 0.05$) are shown in bold.

	Variable	Location	*t*	*p*
Measured Variables	Bioturbated bedforms	1, 2	1.90	0.13
		1, 3	2.77	**0.05**
		2, 3	0.80	0.47
Derived variables	Mean Turbidity	1, 2	1.3	0.26
		1, 3	14.28	**0.0003**
		2, 3	5.15	**0.006**
	Mud	1, 2	1.96	**0.03**
		1, 3	2.29	**0.02**
		2, 3	0.71	0.77

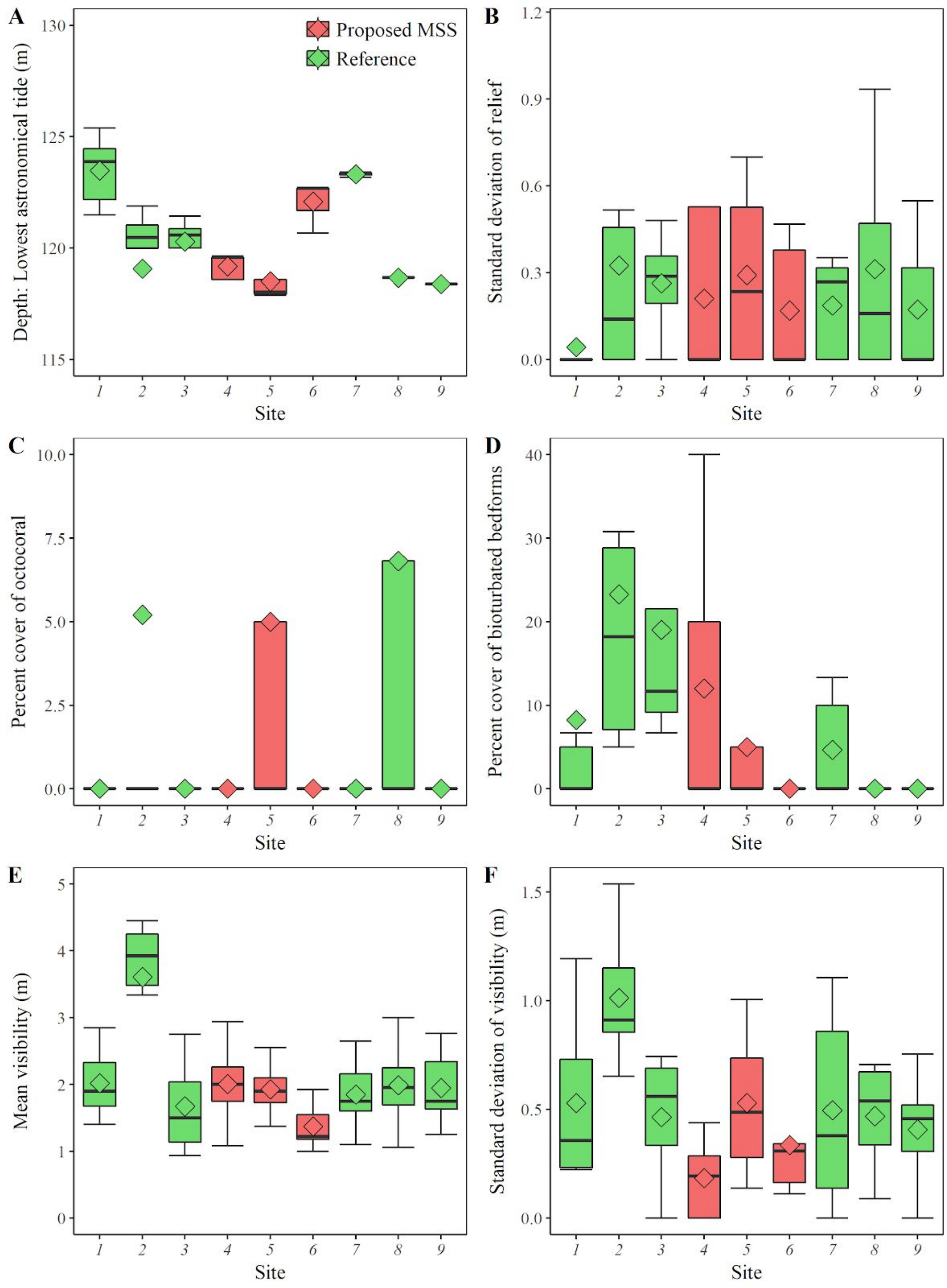

Figure 4. Measured environmental variables of interest across all planned study sites. Diamonds indicate the mean value. Sites 1-3 are from Location 1, Site 4-6 are from the Proposed MSS Location and Site 7-9 are from Location 3. See Supplementary Table 2 for representative images of stereo-BRUV field of view from which measured environmental variables were obtained.

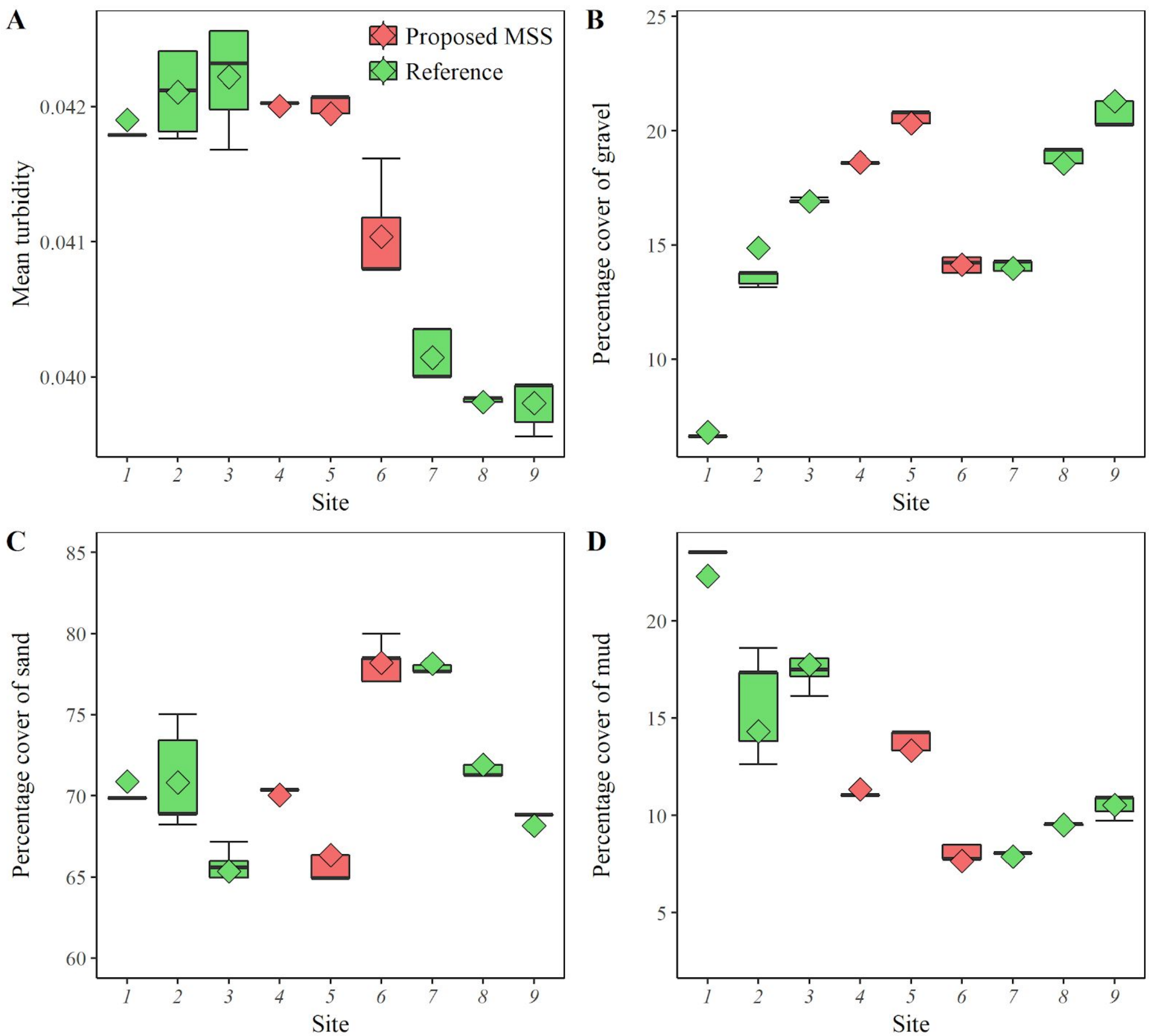

Figure 5. Derived environmental variables of interest across all study sites. Diamonds indicate the mean value. Sites 1-3 are from Location 1, Site 4-6 are from the Proposed MSS Location and Site 7-9 are from Location 3. See Supplementary Table 3 for a description of the derived variables.

Fish abundance and biomass compositional differences between Planned study sites

Potential confounding by environmental variables

The most parsimonious model of the fish assemblage abundance composition included two significant environmental predictor variables, mean turbidity and longitude (Table 4), and the constrained ordination indicated a clear clustering of sites between locations and a consistent gradient between these locations (Fig. 6A). The most parsimonious model for fish assemblage biomass composition also contained two significant environmental predictors, mean turbidity and percent cover of sand (Table 4) and a clear clustering and consistent gradient between locations was observed in the dbRDA ordination, however sites four and five within the proposed MSS Location were somewhat dispersed within the cluster of sites in reference Location 1 (Fig. 6B). These analyses and ordinations indicate that variation in environmental variables likely correlates with variation in the fish abundance and biomass composition between sampled locations.

Table 4. Most parsimonious model from DISTLM analysis of all covariates of interest for both fish abundance and biomass. Significant results ($p < 0.05$) are shown in bold.

	Abundance				Biomass			
Variable	AICc	*F*	*p*	Prop.	AICc	*F*	*p*	Prop.
Mean turbidity	-18.32	6.72	**0.001**	0.14	49.56	4.25	**0.001**	0.10
Longitude	-18.55	2.44	**0.004**	0.05				
Sand					49.54	2.24	**0.005**	0.05

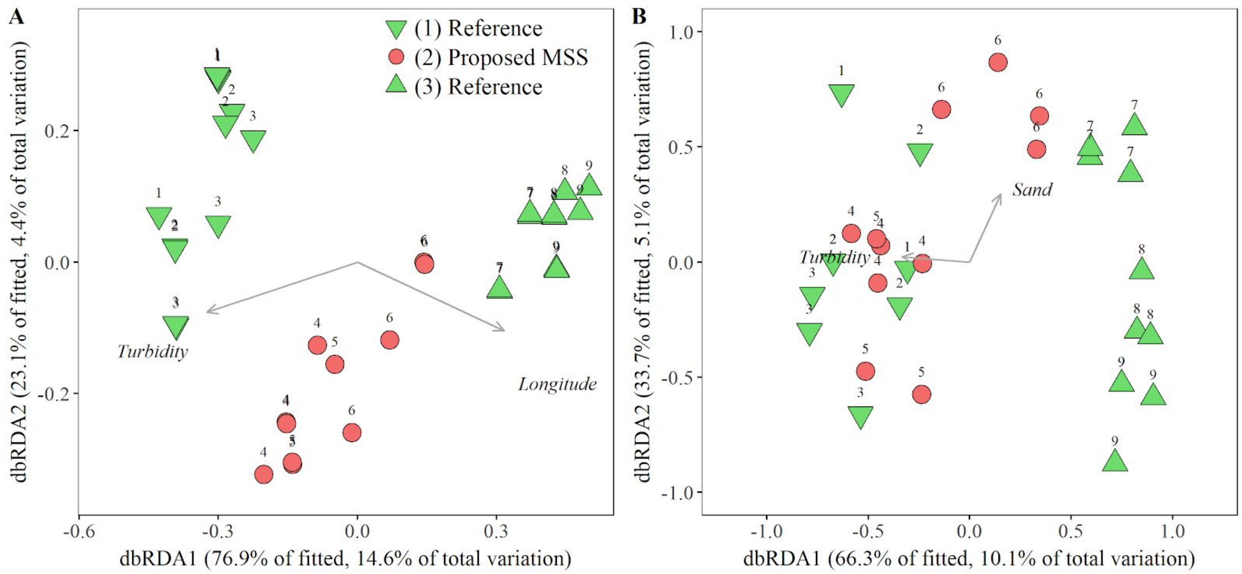

Figure 6. Distance-based RDA ordination relating the environmental variables to the fish assemblage abundance composition data (A) and fish assemblage biomass composition data (B). Biplot projections are given for the environmental variables found to be significant in the DistLM. Vectors are plotted showing the correlations of environmental variables with RDA axes, with the length and direction of the vector representing the strength and direction of the relationship.

The principal coordinate ordination (PCO) indicated that both the fish assemblage abundance and biomass composition (Fig. 7A & B) at reference Location 3 was somewhat distinct from both reference Location 1 and the proposed MSS Location (2), which were relatively interspersed. Whereas, the canonical correlation analysis of principal components (CAP) found a strong separation between all the locations in the assemblage abundance composition (Fig. 7C). For both the abundance and biomass composition, the proposed MSS Location was correlated with lunartail pufferfish, reference Location 1 was correlated with longnose trevally, and reference Location 3 was correlated with threadfin bream (Fig. 7C & D). However, the low delta^2 values suggested that these correlations are not, overall, a strong structuring feature of the assemblage.

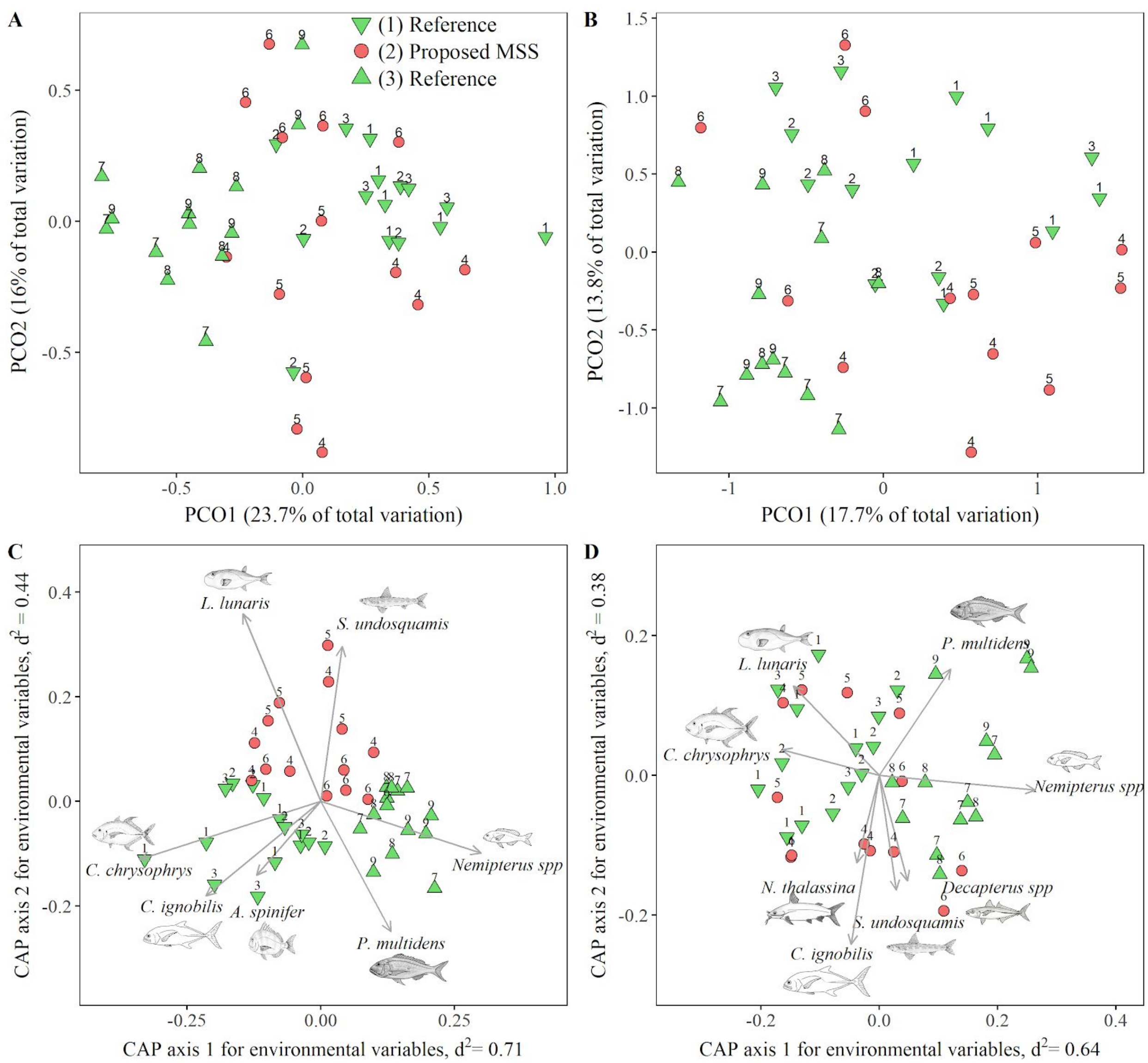

Figure 7. The top two panels show principal coordinate ordination (PCO) and the bottom two panels show canonical analysis of principal components (CAP) plots of the abundance composition (A & C) and biomass (B & D) of the fish assemblage. The CAP plots explore the influence of environmental variables found to be significantly correlated with the abundance and biomass composition in the DistLM, for (C) abundance the CAP explore the influence of longitude and turbidity whereas for (D) biomass the CAP explore the influence of sand and turbidity. Delta^2 correlation coefficients for each CAP is given (d^2).

Assemblage composition

For both the fish assemblage abundance and biomass composition there was a significant effect of Location in the multivariate permutational analysis of variance (PERMANOVA, Table 5). In the abundance composition there were significant differences between all three locations but only between locations 1 and 3 in the biomass composition (Table 6).

The canonical discriminant analysis of principal components (CAP) found a strong separation between the locations for the abundance composition (Fig. 8A). For both abundance and biomass longnose trevally was correlated with Location 1, whereas threadfin bream and the commercially important goldband snapper were correlated with Location 3 (Fig. 8). For the assemblage abundance lunartail pufferfish, was correlated with the Proposed MSS Location but was not strongly correlated with any Location in the biomass composition data.

Table 5. Results of permutational multivariate analysis of variance (PERMANOVA) of the (a) abundance; and (b) biomass composition in response to the factors Location, and Site (Location). Significant results ($p < 0.05$) are shown in bold.

	Abundance				Biomass			
Variable	*df*	MS	*F*	*p*	*df*	MS	*F*	*p*
Location	2	3.16	2.98	**0.007**	2	77.62	2.04	**0.02**
Site (Location)	6	1.06	2.16	**0.0001**	6	38.42	1.97	**0.0001**

Table 6. Pairwise comparisons for abundance and biomass of the fish assemblage and the effect of Location. Significant results ($p < 0.05$) are shown in bold.

	Abundance		Biomass	
Location	*t*	*p*	*t*	*p*
1, 2	1.38	**0.09**	1.24	0.16
1, 3	2.36	**0.001**	1.76	**0.01**
2, 3	1.57	0.38	1.34	0.10

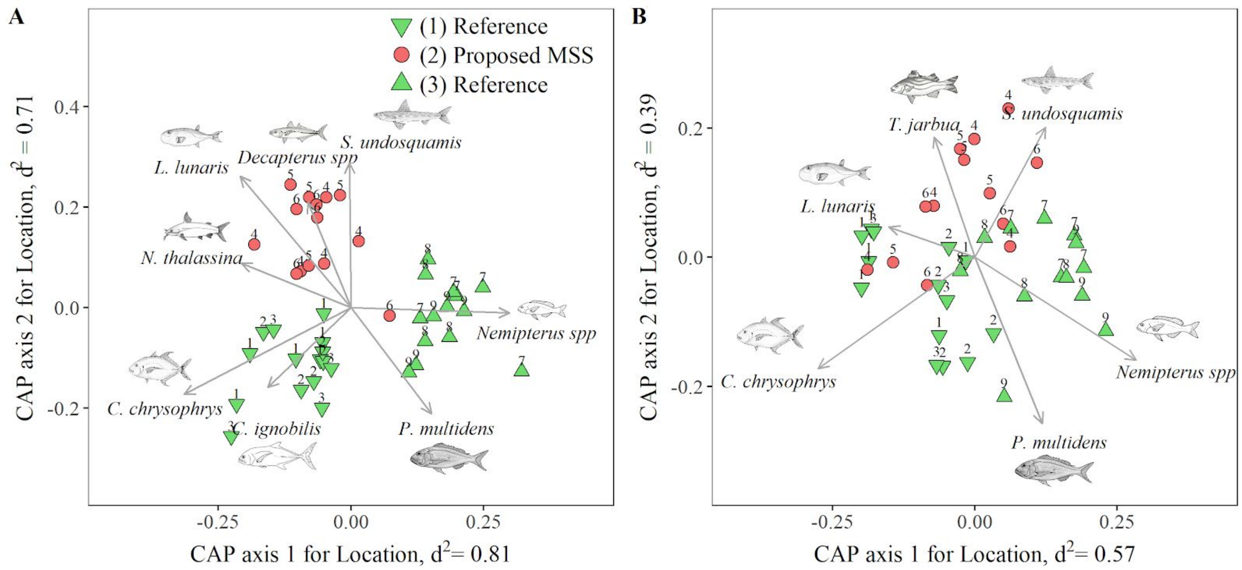

Figure 8. Canonical discriminant analysis of principal components (CAP) plots of the abundance composition (A) and biomass (B) of the fish assemblage. The CAP plots explore which species are correlated with which Location. Delta^2 correlation coefficients for each CAP is given (d^2).

Patterns in assemblage metrics and the abundance and biomass of prominent taxa

Both the total abundance of all fish (Fig. 9A) and species richness (Fig. 9B) appeared to be lower at Location 3, however Location was only found to be approaching significance (Table 7, $p < 0.1$). Only longnose trevally was found to be significantly different between locations (Table 7, Fig. 10A), for both abundance and biomass, with greater abundance in Location 1 than Location 2, and greater biomass in Location 1 versus both Location 2 & 3 (Table 8). There was some evidence of further differences, with the abundance of lunartail puffer and the biomass of threadfin bream both approaching significance for Location (Table 7, Fig. 10B & C). However, despite visual trends in the abundance of other species between locations, in particular goldband snapper which was completely absent from the proposed MSS locations (Fig. 7D), no further significant differences were found (Table 5).

Table 7. Results of permutational multivariate analysis of variance (PERMANOVA) of the total abundance and species richness, and the abundance and biomass of the three most abundant species and the most abundant commercially important species in response to the factors Location, and Site (Location). Significant results (p < 0.05) are shown in bold and results approaching significance are show in italics.

		Abundance				Biomass			
Taxa	Source	*df*	MS	*F*	*p*	*df*	MS	*F*	*p*
Total abundance	Location	2	2.87	5.45	*0.07*	-	-	-	-
	Site (Location)	6	0.53	1.04	0.41	-	-	-	-
Species richness	Location	2	0.56	5.19	*0.07*	-	-	-	-
	Site (Location)	6	0.11	0.59	0.73	-	-	-	-
C. chrysophrys	Location	2	11.43	6.22	**0.05**	2	3080.80	22.57	**0.04**
	Site (Location)	6	1.85	3.65	**0.01**	6	135.97	0.84	0.55
L. lunaris	Location	2	1.45	4.28	*0.06*	2	137.44	0.69	0.47
	Site (Location)	6	0.34	3.70	**0.005**	6	202.50	4.22	**0.005**
Nemipterus spp.	Location	2	2.28	3.29	0.16	2	1538.90	4.45	*0.07*
	Site (Location)	6	0.69	2.31	*0.06*	6	350.40	2.75	**0.03**
P. multidens	Location	2	2.91	2.33	0.15	2	837.72	1.76	0.23
	Site (Location)	6	1.25	4.46	**0.002**	6	485.25	7.20	**0.0001**

Table 8. Pairwise comparisons for taxa found to have an effect of Location. Significant results (p < 0.05) are shown in bold and results approaching significance are show in italics.

		Abundance		Biomass	
Taxa	Location	*t*	*p*	*t*	*p*
C. chrysophrys	1, 2	1.95	0.13	6.20	**0.002**
	1, 3	3.72	**0.02**	5.20	**0.005**
	2, 3	1.48	0.21	0.50	0.65

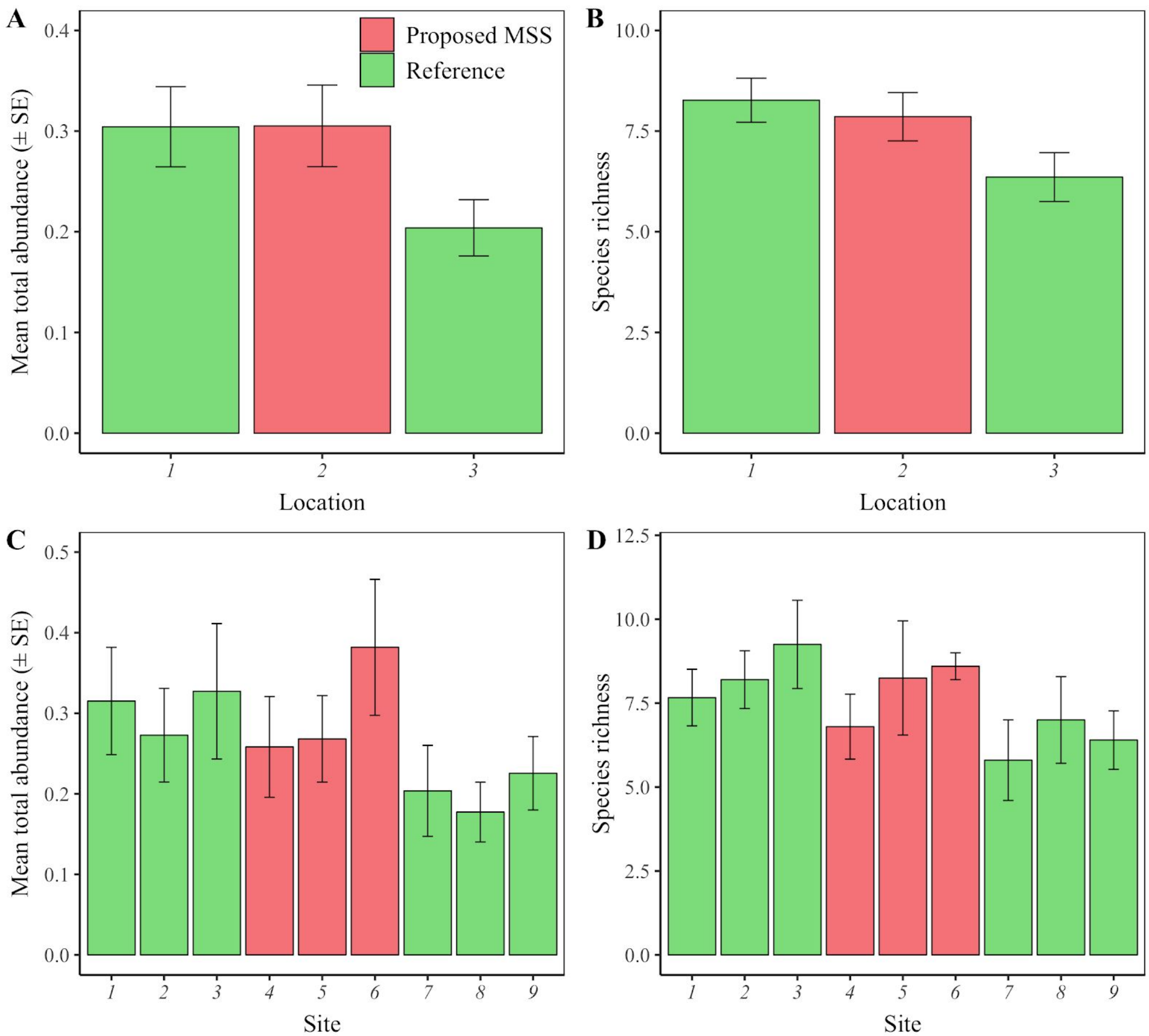

Figure 9. Mean total abundance and species richness across locations (A & B) and sites (C & D). Sites 1-3 are from Location 1, Site 4-6 are from the Proposed MSS Location and Site 7-9 are from Location 3.

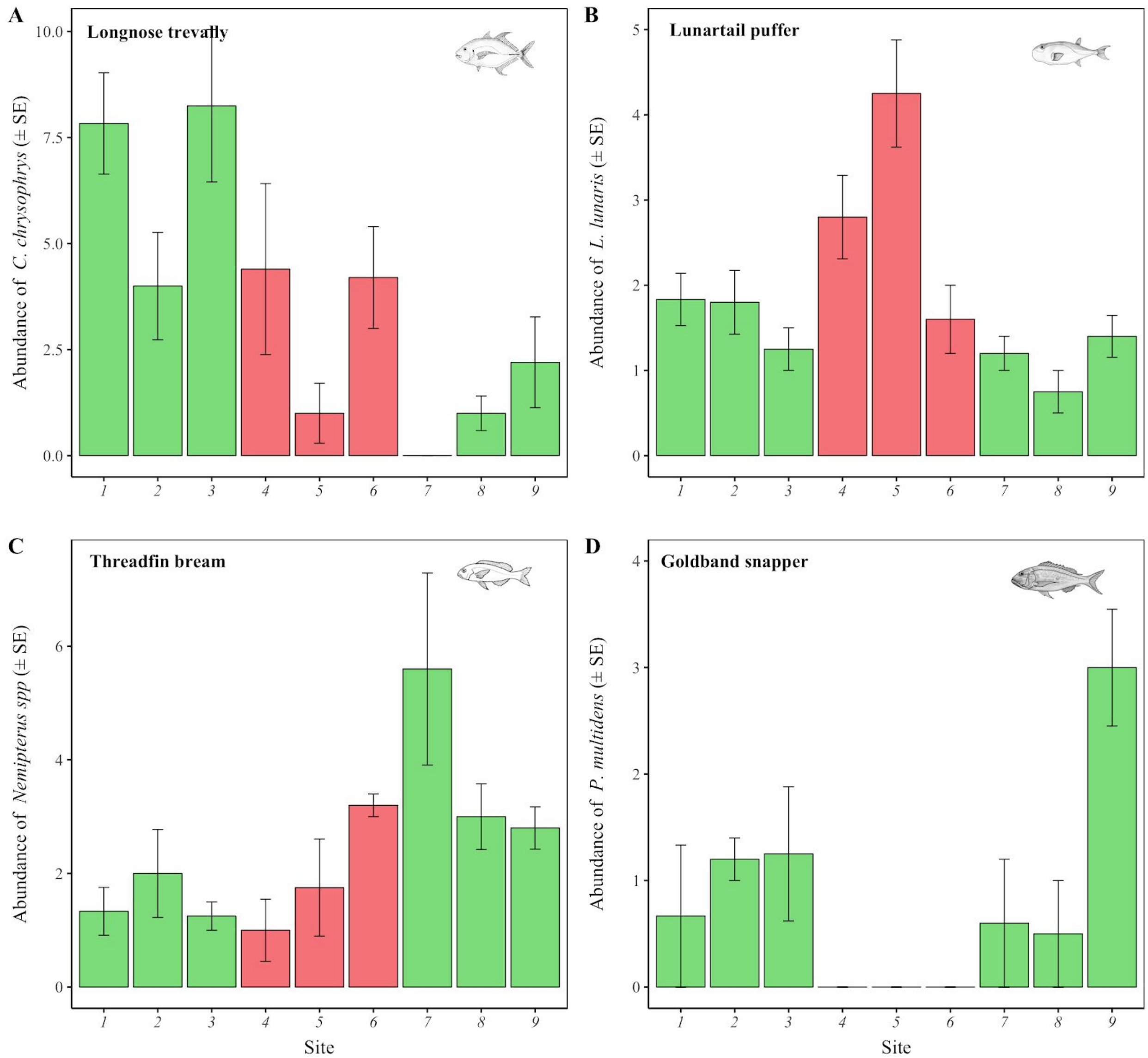

Figure 10. Mean abundance of the three most abundant species (A, B & C) and the most abundant commercially important species (D). Sites 1-3 are from Location 1, Site 4-6 are from the Proposed MSS Location and Site 7-9 are from Location 3.

Description of data from Exploratory versus Planned study sites

Description of environmental variables

There was a stronger significant effect of Location for the measured environmental variables in the multivariate permutational analysis of variance (PERMANOVA) with the inclusion of the Exploratory sites (Table 9). In contrast to the less distinct patterns between the measured environmental variables across the Planned locations (Fig. 4), significant differences were found between the Exploratory sites and the Planned locations for depth (LAT), bioturbated bedforms and visibility (Table 10, Fig. 11A & D-F). The Exploratory sites were ~20 m shallower (Fig. 11A), more structurally complex (Fig. 11D), and had typically twice the mean visibility (Fig. 11E & F). However, despite visual trends in measures of standard deviation of relief and percent cover of octocoral at the Exploratory sites (Fig 11B & C), no further significant differences were found (Fig. 11B & C). Significant differences were found between the Exploratory sites and the Planned locations for the derived environmental variables mean turbidity and mud. An apparent west-east gradient was again seen in mean turbidity (Fig. 12A) across sites and locations. Turbidity was higher at the Exploratory Location however significant differences were only found between Location 3 and the Exploratory Location.

Table 9. Results of permutational multivariate analysis of variance (PERMANOVA) of the environmental variables in response to the factors Location, and Site (Location). Significant results ($p < 0.05$) are shown in bold.

	Variable	Source	*df*	MS	*F*	*p*
Measured Variables	Depth (LAT)	Location	3	2.71	19.91	**0.01**
		Site (Location)	8	0.13	20.84	**0.0001**
	SD Relief	Location	3	0.35	0.91	0.46
		Site (Location)	8	0.39	3.45	**0.005**
	Octocoral	Location	3	0.22	2.67	0.12
		Site (Location)	8	0.08	4.25	**0.001**
	Bioturbated bedforms	Location	3	0.60	6.50	**0.02**
		Site (Location)	8	0.09	2.22	**0.04**
	Mean visibility	Location	3	1.30	4.50	**0.03**
		Site (Location)	8	0.29	3.90	**0.001**
	SD visibility	Location	3	0.45	3.13	**0.06**
		Site (Location)	8	0.14	1.70	0.12
Derived variables	Mean turbidity	Location	3	0.0001	14.52	**0.003**
		Site (Location)	8	0.00001	23.83	**0.0001**
	Gravel	Location	3	1.78	1.46	0.28
		Site (Location)	8	1.23	18.72	**0.0001**
	Mud	Location	3	7.51	5.08	**0.02**
		Site (Location)	8	1.49	10.09	**0.0001**
	Sand	Location	3	0.52	1.17	0.39
		Site (Location)	8	0.44	37.97	**0.0001**

Table 10. Pairwise comparisons for environmental variables and the effect of Location. Significant results ($p < 0.05$) are shown in bold.

	Variable	Location	*t*	*p*
Measured Variables	Depth (LAT)	0, 1	5.26	**0.01**
		0, 2	4.74	**0.01**
		0, 3	4.58	**0.01**
		1, 2	1.06	0.35
		1, 3	0.73	0.51
		2, 3	0.10	0.93
	Bioturbated bedforms	0, 1	1.34	0.25
		0, 2	2.98	**0.04**
		0, 3	3.71	**0.02**
		1, 2	1.90	0.13
		1, 3	2.77	**0.05**
		2, 3	0.80	0.47
	Mean visibility	0, 1	1.71	0.16
		0, 2	2.97	**0.04**
		0, 3	2.87	**0.04**
		1, 2	1.02	0.37
		1, 3	0.78	0.48
		2, 3	0.73	0.50
Derived variables	Mean Turbidity	0, 1	1.26	0.28
		0, 2	1.79	0.14
		0, 3	5.25	**0.01**
		1, 2	1.30	0.27
		1, 3	14.28	**0.0002**
		2, 3	5.15	**0.01**
	Mud	0, 1	2.95	**0.04**
		0, 2	1.01	0.37
		0, 3	0.70	0.53
		1, 2	3.25	**0.03**
		1, 3	5.22	**0.01**
		2, 3	0.72	0.51

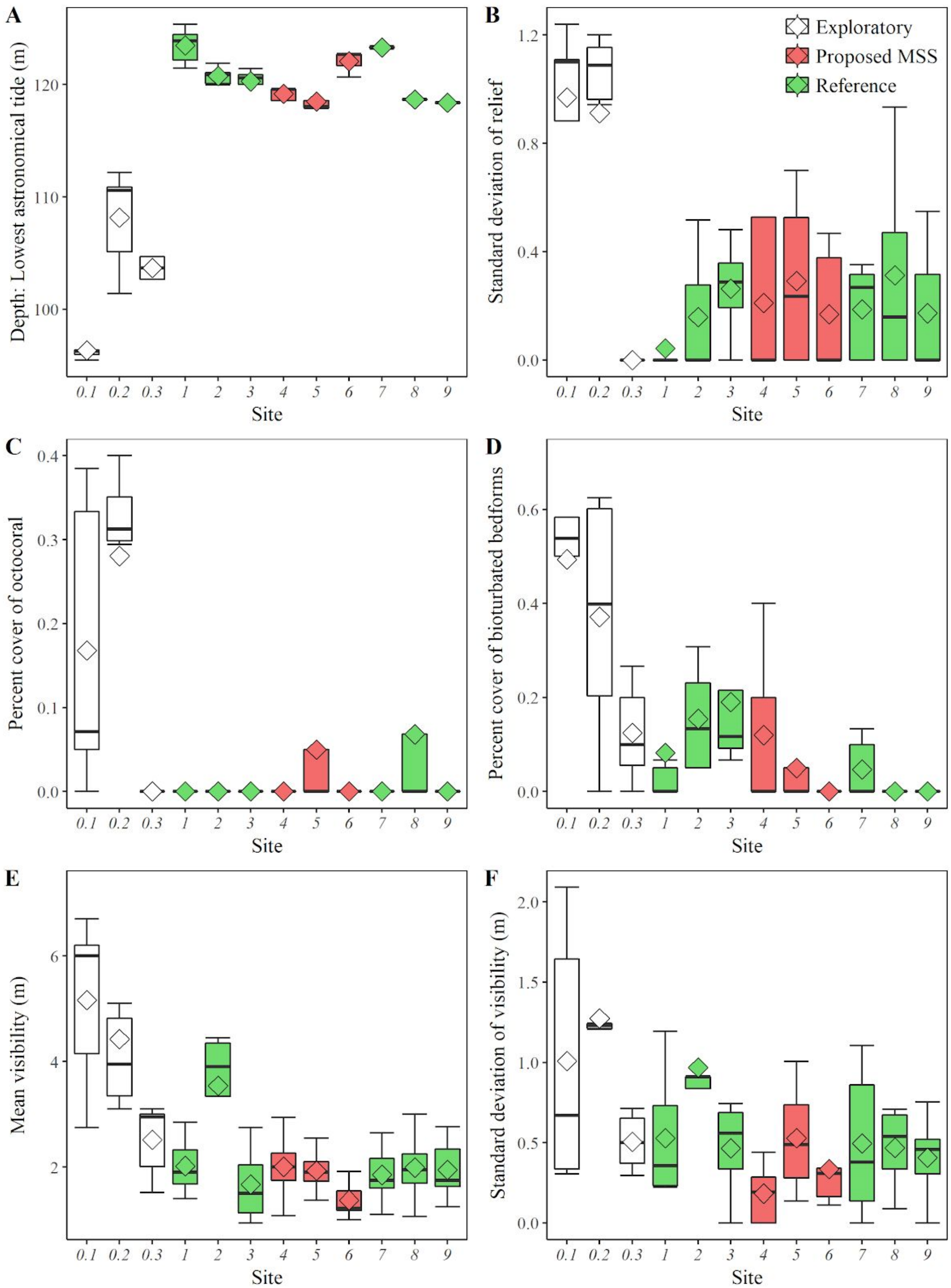

Figure 11. Measured environmental variables across Exploratory sites (0.1-0.3) and study sites (1-9). Sites 0.1-0.3 are from the Exploratory Location, sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3.

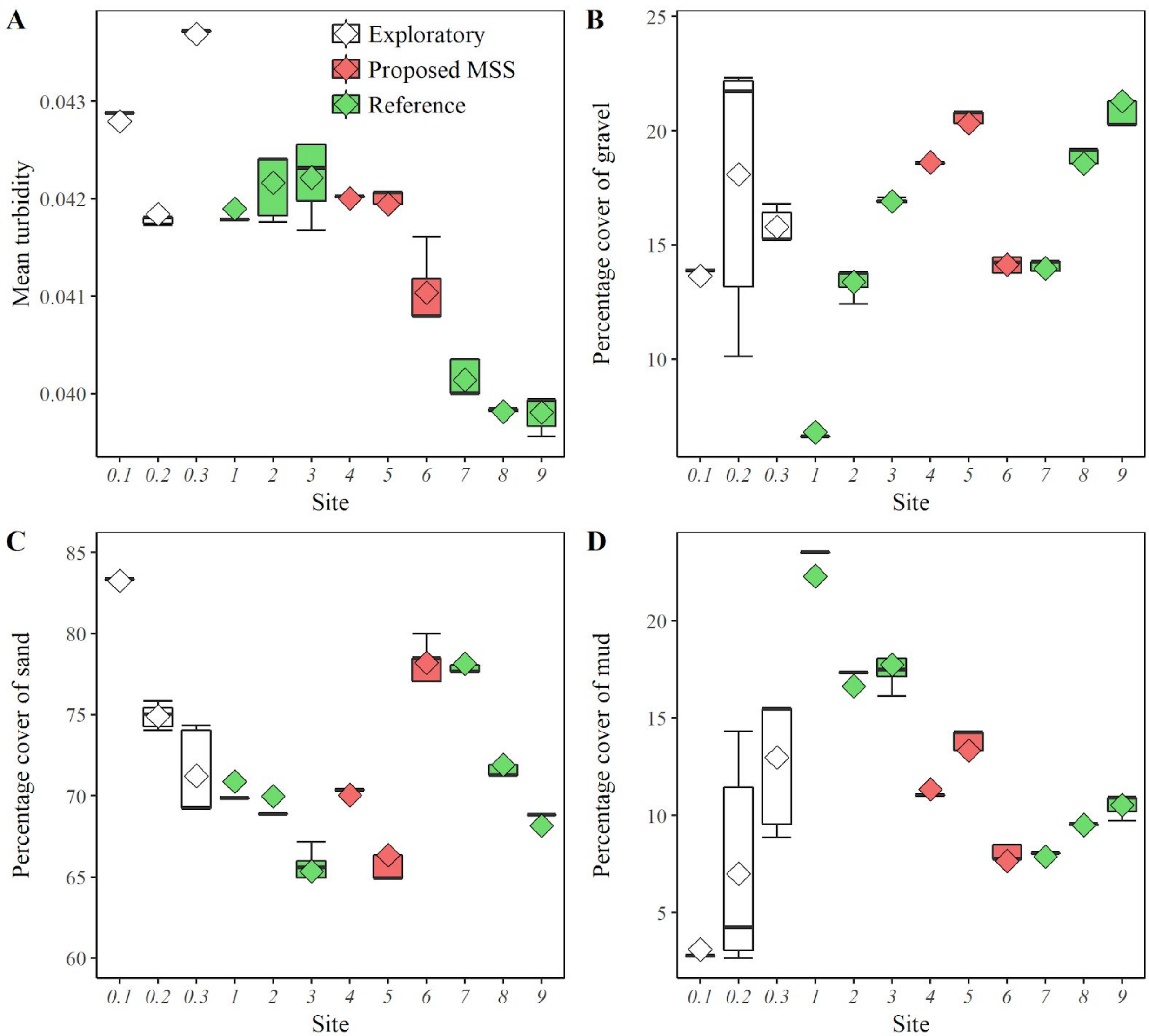

Figure 12. Derived environmental variables of interest across Exploratory sites (0.1-0.3) and study sites (1-9). Sites 0.1-0.3 are from the Exploratory Location, sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3. See Supplementary Table 3 for a description of the derived variables.

Fish abundance and biomass compositional differences between Planned and Exploratory sites

Potential confounding by environmental variables

With the inclusion of the Exploratory sites, the most parsimonious model for fish assemblage abundance composition from DISTLM analysis contained three significant environmental predictor variables, longitude, mean turbidity and depth, and the most parsimonious model for assemblage biomass also contained three significant environmental predictors, mean turbidity, standard deviation of relief and percent cover of sand (Table 11). Constrained ordinations relating environmental variables to the fish assemblage for both abundance and biomass composition clearly showed clustering of sites within locations and in particular Exploratory sites 0.1 and 0.2 were clustered apart from the Planned locations (sites 1-9), whereas Exploratory Site 0.3 appears more comparable to sites within the Planned locations (Fig 13). In particular for biomass, the constrained ordination indicated sites 0.1 and 0.2 were positively correlated with standard deviation of relief (Fig 13B).

Table 11. Most parsimonious model from DISTLM analysis of all covariates of interest for both fish abundance and biomass across the Planned locations and Exploratory sites. Significant results ($p < 0.05$) are shown in bold.

	Abundance				Biomass			
Variable	AICc	*F*	*p*	Prop.	AICc	*F*	*p*	Prop.
Longitude	14.21	7.30	**0.0001**	0.12				
Mean turbidity	-19.61	4.16	**0.0001**	0.06	71.49	5.29	**0.0001**	0.09
Depth (LAT)	-20.44	3.04	**0.0004**	0.04				
SD relief					68.76	4.92	**0.0001**	0.08
Sand					67.95	3.00	**0.0005**	0.05

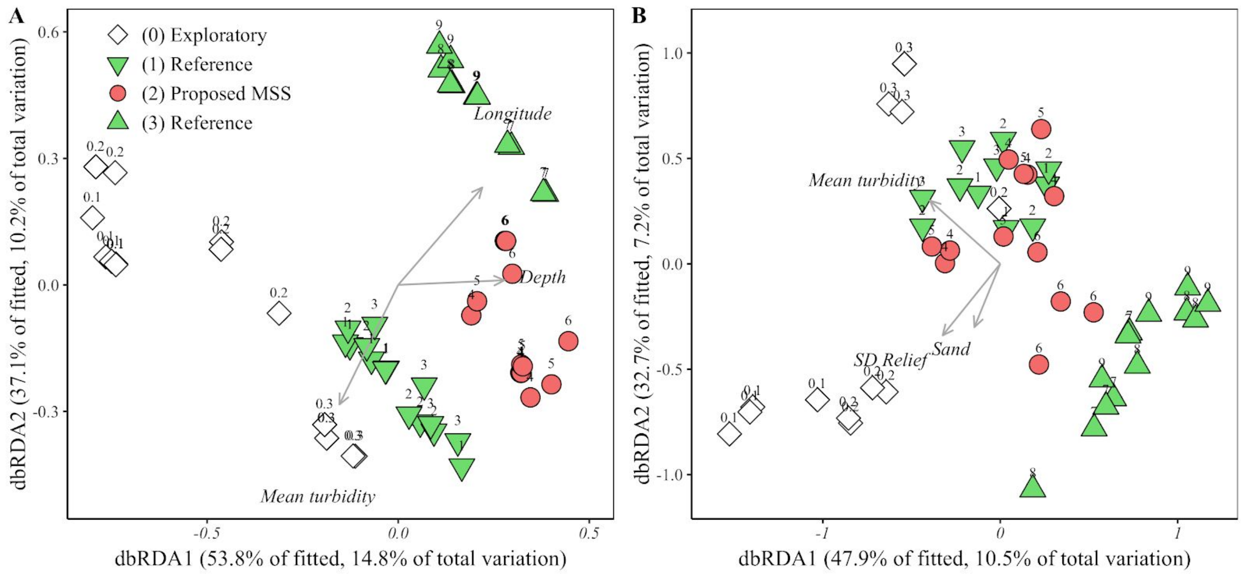

Figure 13. Distance-based RDA constrained ordination relating the environmental variables to the fish assemblage abundance composition data (A) and fish assemblage biomass composition data (B) for Exploratory sites 0.1-0.3 and survey sites 1-9. Biplot projections are given for the environmental variables found to be significant in the DistLM. Vectors are plotted showing the correlations of environmental variables with RDA axes, with the length and direction of the vector representing the strength and direction of the relationship. Sites 0.1-0.3 are from the Exploratory Location, sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3.

The unconstrained principal coordinate ordination (PCO) indicated that both the fish assemblage abundance and biomass composition (Fig. 14A & B) at the Exploratory sites 0.1 and 0.2 were somewhat distinct from both the reference Location 1 and 3 and proposed the MSS Location (2), which were relatively interspersed in comparison. Whereas Exploratory Site 0.3 was interspersed with both survey Location 1 and Location 2 (Fig. 14A & B). Further investigation of the influence of environmental variables found to be significantly correlated with the abundance and biomass composition in the DistLM found a strong separation was evident between the Exploratory sites 0.1 and 0.2 versus Exploratory Site 0.3 and the Planned locations in canonical correlation analysis of principal components (CAP) for abundance and biomass composition. For both the abundance and biomass composition, Exploratory sites 0.1 and 0.2 were strongly correlated with commercially important species, including red emperor, the brownstriped snapper *Lutjanus vitta* and saddletail snapper. Overall the high delta^2 (d^2) values suggested that differences between the Planned locations and Exploratory sites were strong.

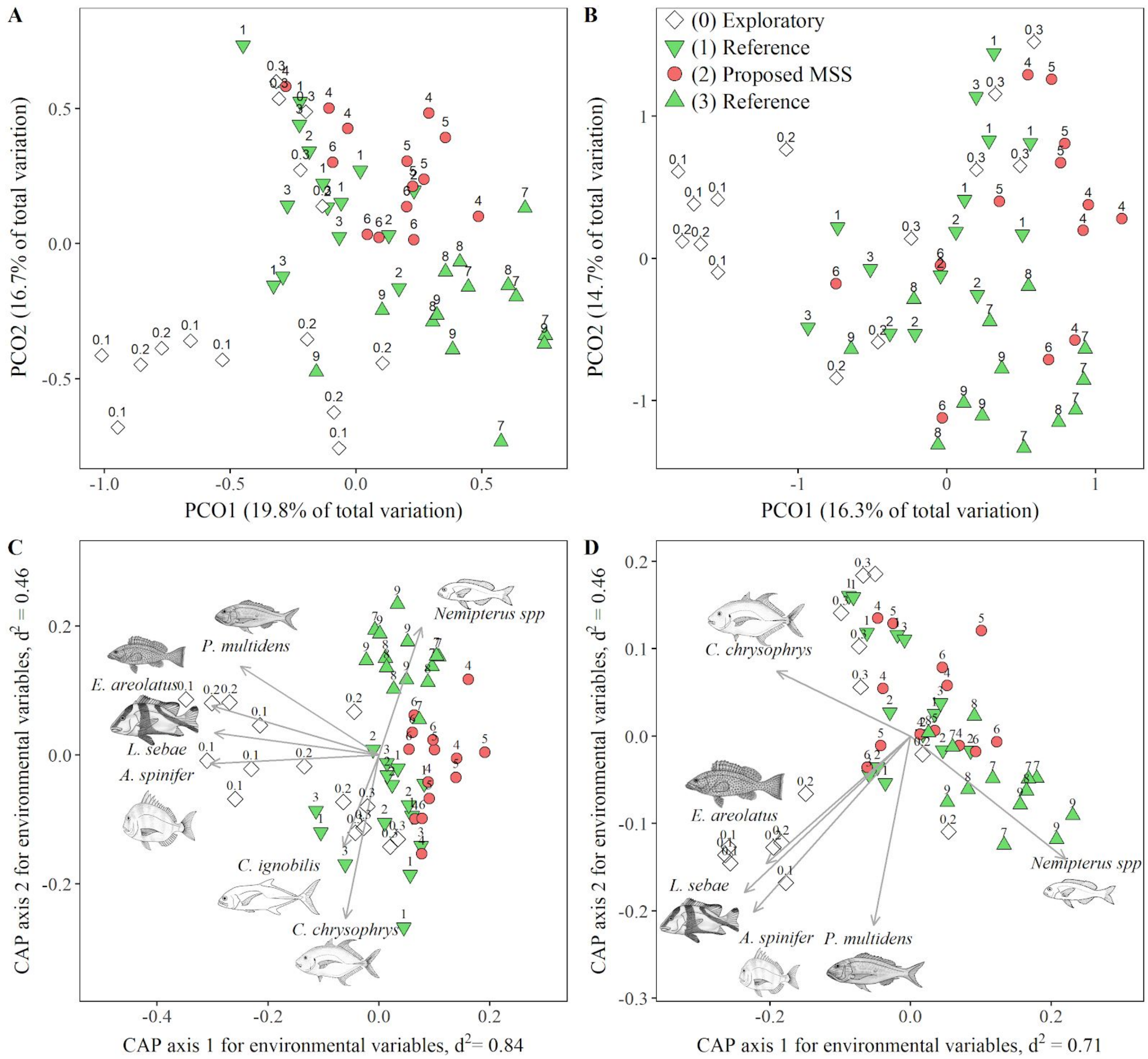

Figure 14. The top two panels show principal coordinate ordination (PCO) and the bottom two panels show canonical correlation analysis of principal components (CAP) plots of the abundance composition (A,C) and biomass (B,D) of the fish assemblage. Sites 0.1-0.3 are from the Exploratory Location, sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3. The CAP plots explore the influence of environmental variables found to be significantly correlated with the abundance and biomass composition in the DistLM, for (C) abundance the CAP explore the influence of longitude and turbidity whereas for (D) biomass the CAP explore the influence of sand and turbidity. Delta^2 correlation coefficients for each CAP are given (d^2).

Assemblage composition

Again, for both assemblage abundance and biomass composition there was a significant effect of Location in the multivariate permutational analysis of variance (PERMANOVA, Table 12). For both the assemblage abundance and biomass composition there was a trend of the Exploratory Location being most similar to Location 1 and least similar to Location 3 (Table 13).

The canonical discriminant analysis of principal components (CAP) found distinct separation between the locations in particular for abundance composition, but for both abundance and biomass assemblage composition commercially important species were found to be strongly correlated with the Exploratory Location (Fig. 15B).

Table 12. Results of permutational multivariate analysis of variance (PERMANOVA) of the (a) abundance; and (b) biomass composition in response to the factors Location, and Site (Location). Significant results ($p < 0.05$) are shown in bold.

	Abundance				Biomass			
Variable	*df*	MS	*F*	*p*	*df*	MS	*F*	*p*
Location	3	3.65	2.53	**0.001**	3	12.77	1.89	**0.01**
Site (Location)	8	1.45	2.65	**0.0001**	8	6.84	2.52	**0.0001**

Table 13. Pairwise comparisons for abundance and biomass of the fish assemblage and the effect of Location. Significant results ($p < 0.05$) are shown in bold and results approaching significance ($p < 0.1$) are show in italics.

	Abundance		Biomass	
Location	*t*	*p*	*t*	*p*
0, 1	1.28	0.14	1.09	0.31
0, 2	1.41	*0.08*	1.25	0.15
0, 3	1.78	**0.02**	1.62	**0.02**
1, 2	1.38	*0.09*	1.25	0.16
1, 3	2.36	**0.001**	1.74	0.01
2, 3	1.57	**0.04**	1.33	0.11

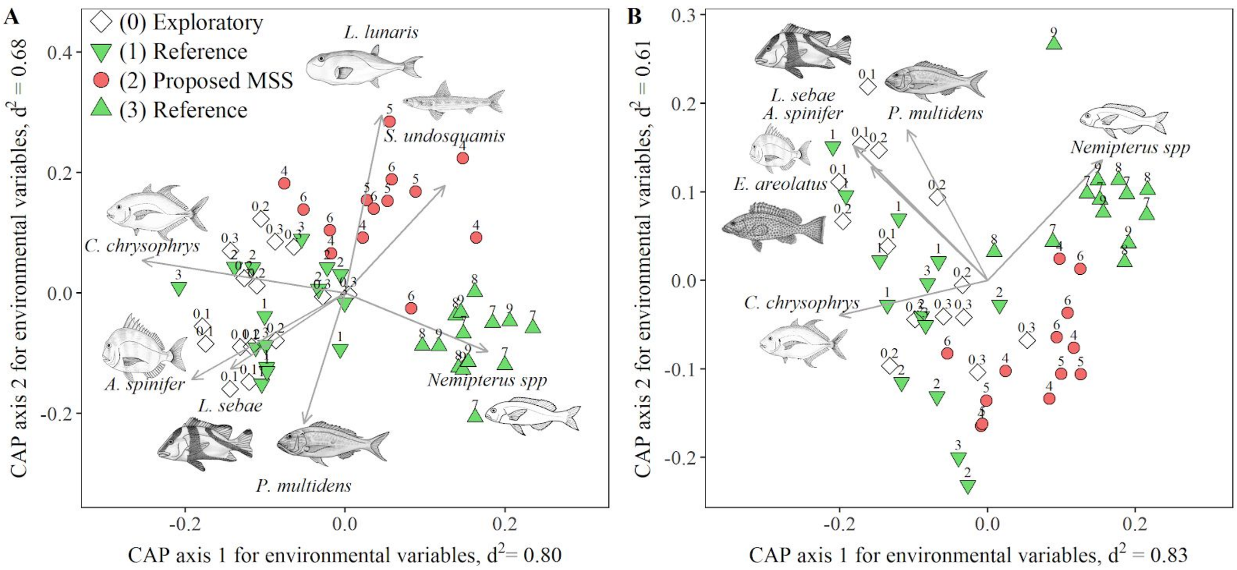

Figure 15. Canonical discriminant analysis of principal components (CAP) plots of the abundance composition (A) and biomass (B) of the fish assemblage. The CAP plots explore which species are correlated with which Location. Delta[2] correlation coefficients for each CAP are given (d^2).

Patterns in assemblage metrics and the abundance and biomass of prominent taxa

A significant effect of Location for both the total abundance of all individuals and species richness (Table 14) was correlated with a trend of greater values within the Exploratory sites and with both metrics decreasing across the Planned study locations, with the lowest values at Location 3 (Fig. 16). Pairwise comparisons found the total abundance of all fish within the Exploratory sites was significantly higher or approaching significance compared to all other locations, whereas Location 3 consistently had lower values, that were significant or approaching significant compared to all other locations (Table 15). Significant differences in species richness between locations were less pronounced but followed a similar pattern to total abundance (Table 15).

A significant effect of Location for both longnose trevally and lunartail pufferfish (Table 15) appeared to be driven by lower abundances of longnose trevally in the eastern Location 3 but lower abundances of lunartail pufferfish in the Exploratory sites (Fig. 16), with support for this pattern in the pairwise comparisons (Table 15). When considering commercially important species, the contrast between the Exploratory sites and Planned sites can be clearly seen in the pattern of abundance for goldband snapper (Fig. 16). However, likely due to high Site to Site variability, this pattern in the abundance of goldband snapper was not significant.

The abundance of the four next most abundant commercially important species were also examined (Fig. 17), and despite being too rare for formal statistical analysis they were found to be almost entirely constrained to the Exploratory sites.

Table 14. Results of permutational multivariate analysis of variance (PERMANOVA) of the total abundance and species richness, and the abundance and biomass of the three most abundant species and the most abundant commercially important species in response to the factors Location, and Site (Location); including data from the Exploratory sites as an extra Location. Significant results ($p < 0.05$) are shown in bold and results approaching significance are show in italics.

		Abundance				Biomass			
Taxa	Source	*df*	MS	*F*	*p*	*df*	MS	*F*	*p*
Total abundance	Location	3	7.34	9.89	**0.003**	-	-	-	-
	Site (Location)	8	0.74	1.18	0.32	-	-	-	-
Species richness	Location	3	1.37	7.85	**0.008**	-	-	-	-
	Site (Location)	8	0.17	0.86	0.55	-	-	-	-
C. chrysophrys	Location	3	9.01	6.22	**0.03**	3	2550.30	24.57	**0.003**
	Site (Location)	8	1.46	3.29	**0.005**	8	102.92	0.66	0.73
L. lunaris	Location	3	2.07	4.14	**0.04**	3	192.17	1.24	0.36
	Site (Location)	8	0.50	4.02	**0.001**	9	160.75	2.74	**0.01**
Nemipterus spp.	Location	3	2.31	1.76	0.24	3	1196.30	3.33	*0.09*
	Site (Location)	8	1.32	3.71	**0.003**	8	363.17	2.49	**0.03**
P. multidens	Location	3	2.92	1.49	0.28	3	875.92	1.27	0.35
	Site (Location)	8	1.97	8.38	**0.0001**	8	699.41	12.33	**0.0001**

Table 15. Pairwise comparisons of for factor of Location. Significant results ($p < 0.05$) are shown in bold and results approaching significance are show in italics..

		Abundance		Biomass	
Taxa	Location	*t*	*p*	*t*	*p*
Total abundance	0, 1	2.79	**0.05**	-	-
	0, 2	2.35	*0.08*	-	-
	0, 3	5.29	**0.005**	-	-
	1, 2	0.22	0.84	-	-
	1, 3	4.88	**0.007**	-	-
	2, 3	2.39	*0.08*	-	-
Species richness	0, 1	2.06	0.10	-	-
	0, 2	2.37	*0.08*	-	-
	0, 3	4.23	**0.01**	-	-
	1, 2	0.68	0.53	-	-
	1, 3	3.53	**0.02**	-	-
	2, 3	2.25	*0.09*	-	-
C. chrysophrys	0, 1	0.88	0.42	1.54	0.19
	0, 2	1.64	0.18	11.00	**0.0002**
	0, 3	3.79	**0.02**	5.76	**0.004**
	1, 2	1.95	0.12	6.20	**0.003**
	1, 3	3.72	**0.02**	5.20	**0.006**
	2, 3	1.48	0.22	0.50	0.63
L. lunaris	0, 1	1.87	0.13	-	-
	0, 2	2.58	*0.06*	-	-
	0, 3	0.87	0.43	-	-
	1, 2	1.65	0.17	-	-
	1, 3	1.78	0.14	-	-
	2, 3	2.45	*0.07*	-	-

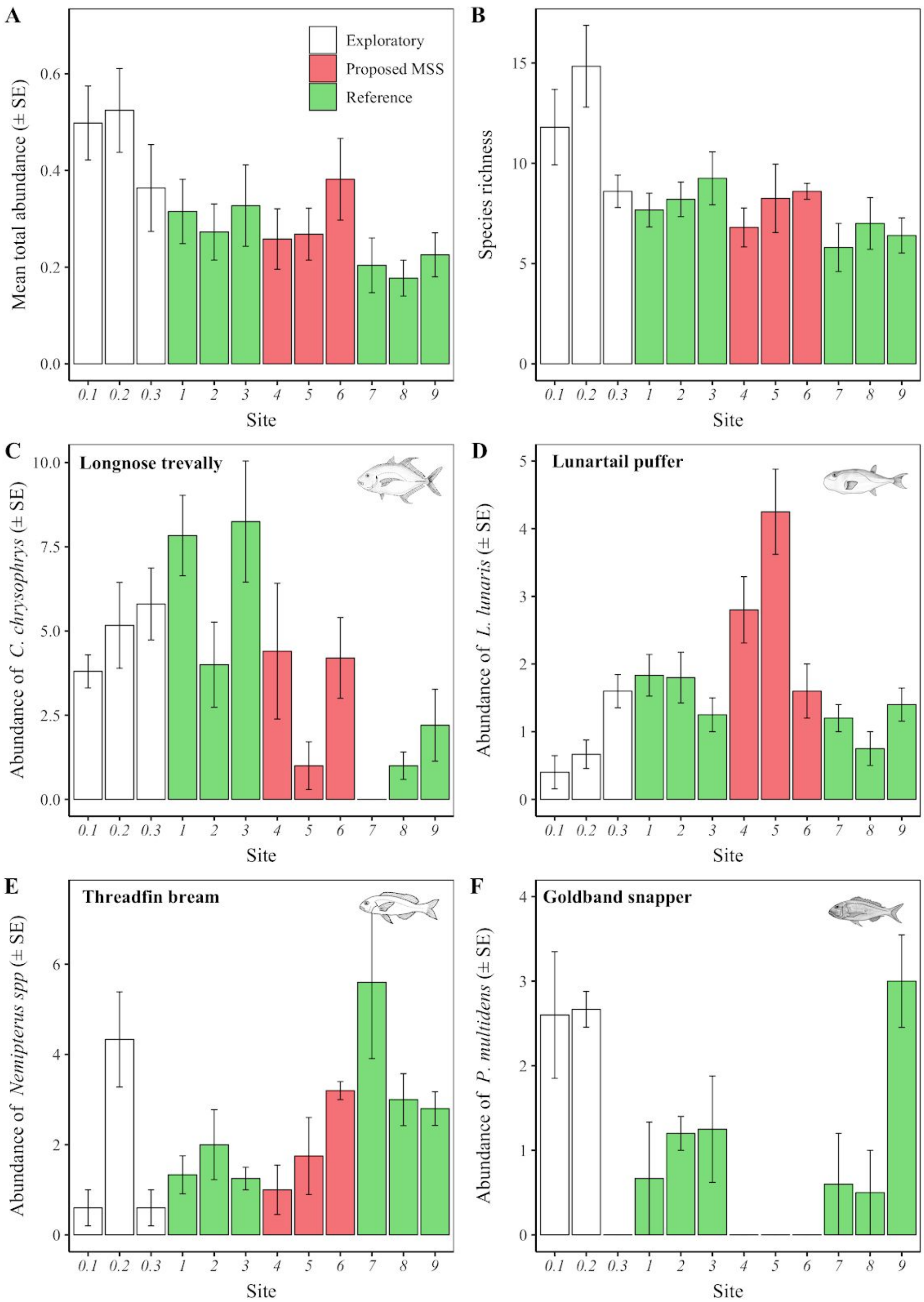

Figure 16. Mean total abundance of all individuals (A), species richness (B) and abundance of the three most abundant species (C-E) and the most abundant commercially important species (F) across Exploratory sites 0.1-0.3 and planned sites (1-9). Sites 1-3 are from Location 1, 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3.

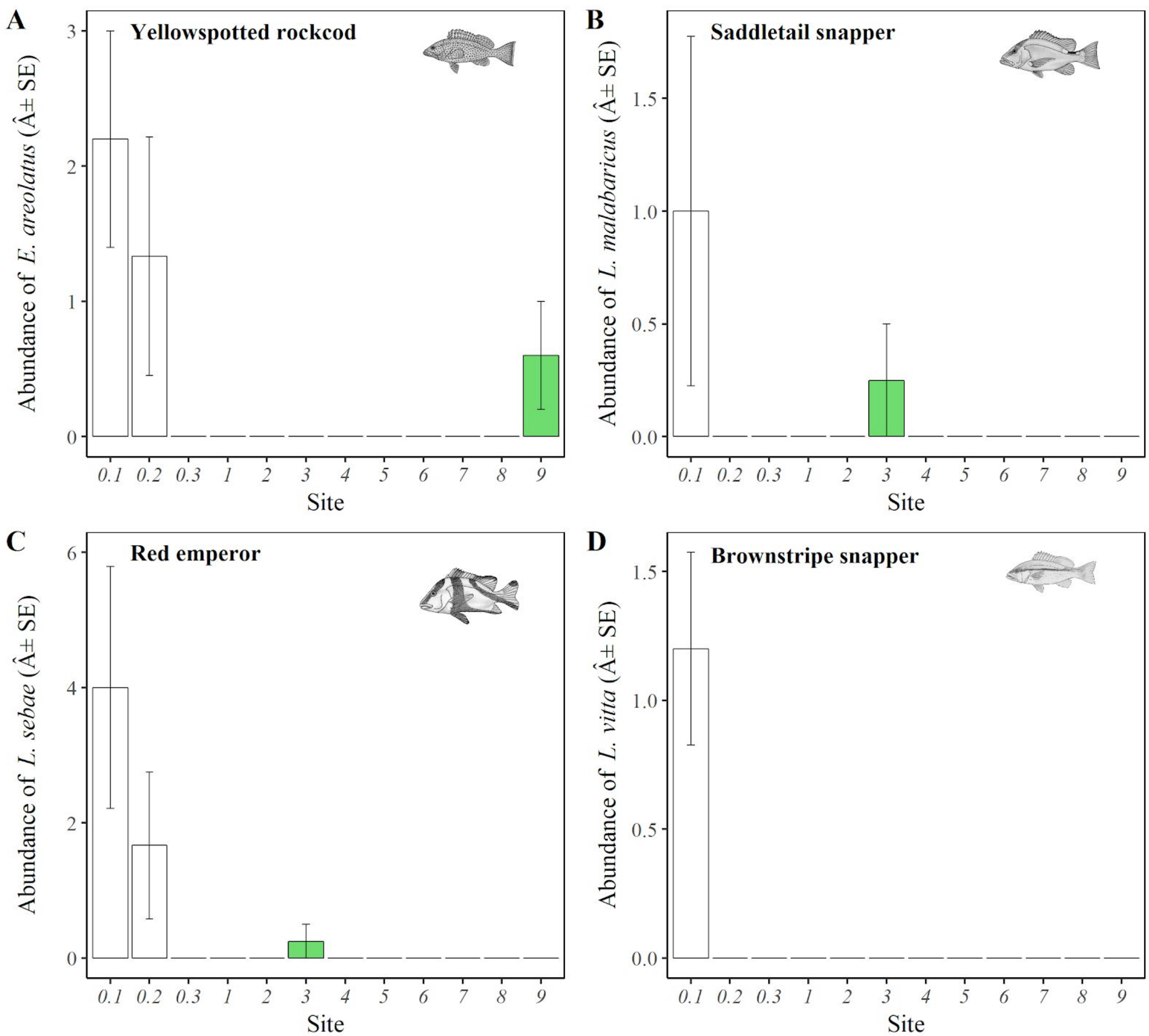

Figure 17. Comparison of the mean abundance of the four next most abundant commercially important species across Exploratory sites 0.1-0.3 and Planned sites (1-9). Sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3.

Spatial exploration of benthos and fish assemblage abundance compositional differences between Planned and Exploratory sites

Hierarchical CLUSTER analysis

Hierarchical CLUSTER analysis of the substrate composition across all sites identified three high level groupings (Table 15) which are spatially distinct (Fig. 18). Group A was typified by epibiota, Group B by fine sediments and Group C by coarse sediments, which is supported by the representative images of benthos from each Location in Supplementary Table 2 (Table 15). CLUSTER analysis of the fish assemblage identified two high level groups (Table 16) which were highly spatially distinct (Fig. 19). For the fish, Group A was typified by commercially important species known to be associated with high-relief habitats, whereas Group B was typified by non-commercial species typical of soft-sediment habitats.

Table 15. One-way simper analysis to identify the occurrence substrate components which differentiate each group from the others was obtained using hierarchical CLUSTER analysis. Substrate types which were unique to a group are identified with an asterix (*).

Group A	Group B	Group C
Octocoral coral*	Relief*	Sand
Bioturbated bedforms*	Mud*	Gravel*
Sand		

Table 16. One-way simper analysis to identify species that differentiate the two groupings were obtained using hierarchical CLUSTER analysis. Species which were unique to a group are identified with an asterix (*).

Group A	Group B
*Lutjanus sebae**	*Lagocephalus lunaris**
*Epinephelus areolatus**	*Nemipterus spp**
*Argyrops spinifer**	*Netuma thalassina*
*Pristipomoides multidens**	*Saurida undosquamis*
*Gymnocranius grandoculis**	
*Abalistes stellatus**	
*Lutjanus vitta**	
Netuma thalassina	

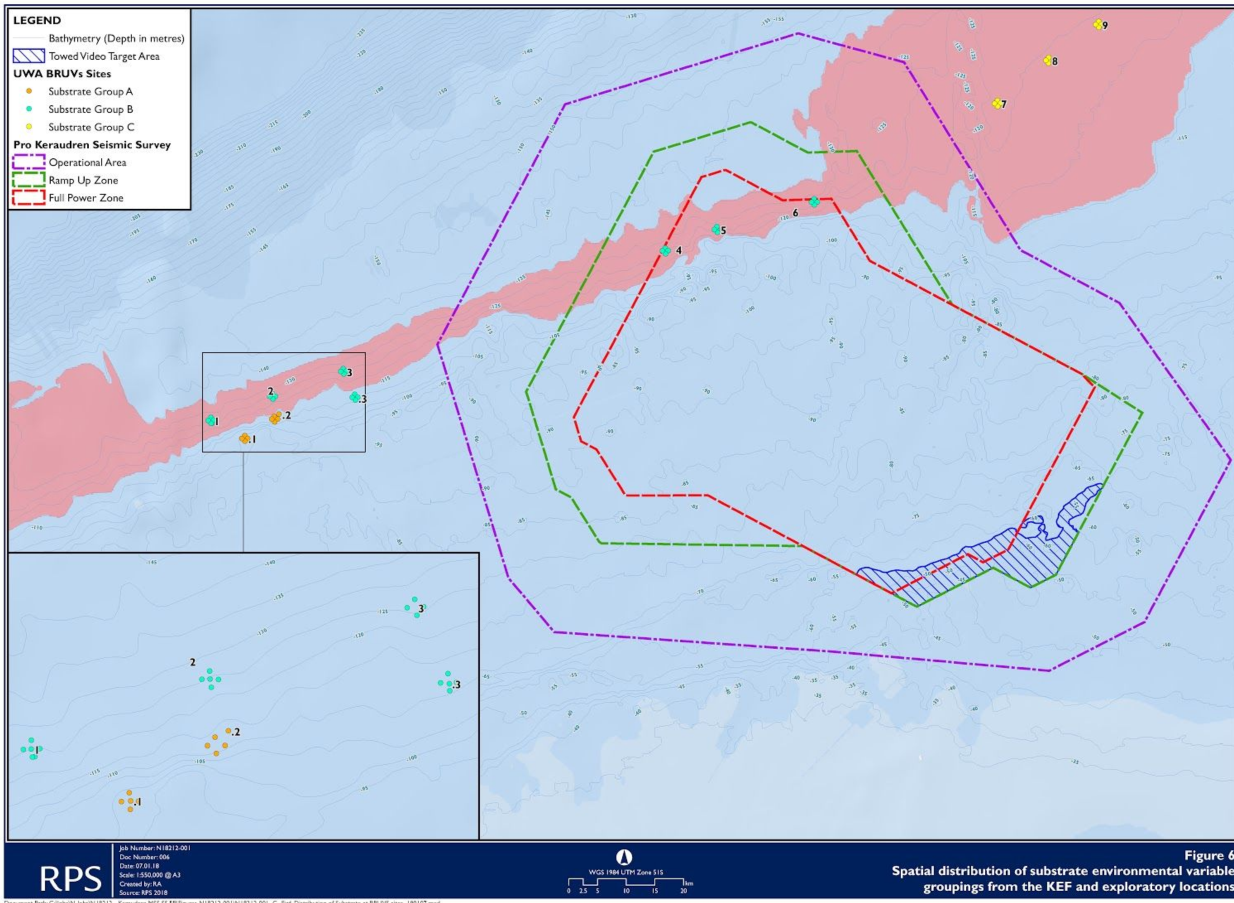

Figure 18. Spatial representation of CLUSTER factor groupings of sites by substrate composition overlaid over bathymetry. Sites 0.1-0.3 are from the Exploratory sites, sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3. Figure produced by RPS.

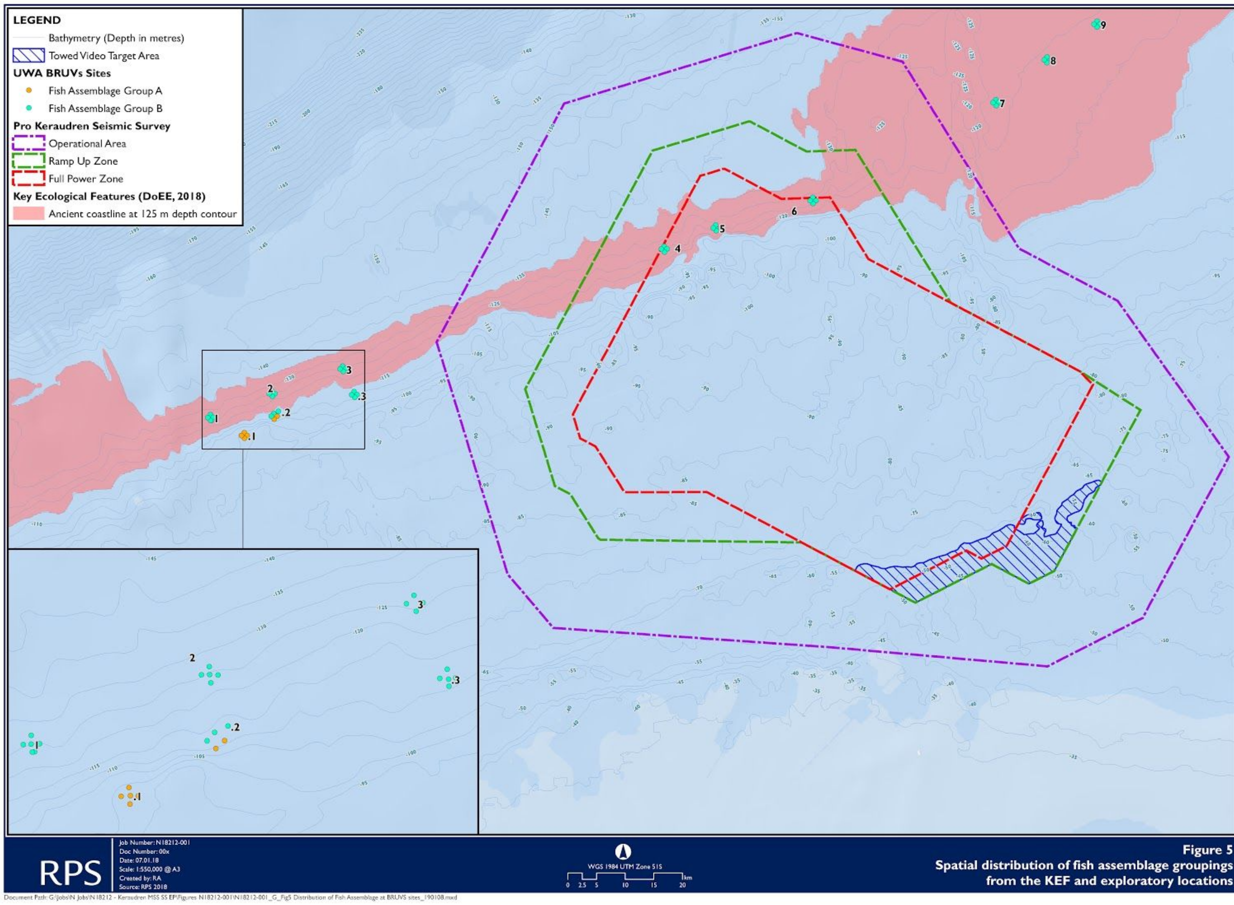

Figure 19. Spatial representation of CLUSTER factor groupings of sites by fish abundance composition overlaid over bathymetry. Sites 0.1-0.3 are from the Exploratory sites, sites 1-3 are from Location 1, sites 4-6 are from the Proposed MSS Location and sites 7-9 are from Location 3. Figure produced by RPS.

Discussion

This survey has characterised the benthic habitat and fish assemblage abundance and biomass composition within a proposed MSS area and two adjacent western and eastern reference locations, based on a sampling design intended to characterise the fish assemblage associated with the ancient submerged coastline key ecological feature (KEF) at a depth of 125 metres off the North West Shelf (NWS) of Australia. In addition, emergent hard substrate reefs at Exploratory sites adjacent to Location one have been documented at a water depth of 95-115 m.

The Planned survey sites were found to be broadly comparable in terms of measured environmental variables, for example percent cover of octocoral ranged from 0-7.5% across all Planned sites and locations. A longitudinal gradient was observed in the derived environmental variable mean turbidity, a long-term mean monthly metric derived from remote sensing imagery, and broadly matched the trend in variation in the fish assemblage from the westernmost to easternmost sites. In the NWS, surface mixing has been suggested to be an indicator of deepwater nutrient exchange occurring along the shelf edge (Brewer et al. 2007), and a subsequent driver of benthic productivity. Despite all sites being distributed along the 125 m depth contour, our westernmost study sites were close to the ~100m shelf edge and in closer proximity to greater variation in bathymetric depth and slope (Fig. 18 and 20), whereas the eastern sites were located further away from this geomorphic feature and were surrounded by a large expanse of more uniform depth and slope (Fig. 18 and 20). Potentially bathymetric driven upwelling at these sites may decrease from west to east, thus correlating with the longitudinal patterns found in the sampled fish assemblage. Equally though, this broad scale gradient in the assemblages could be driven by west-east gradients in other variables that have not been measured or derived in this study. Of the more abundant species, only the longnose trevally, *C. chrysophrys,* was significantly different between locations with a greater number of individuals recorded at Location 1, suggesting the multivariate differences in assemblage patterns observed were likely driven by a proportion of the large number of rare species observed across these sites.

The only commercially important species found in any numbers within the Planned survey sites was the goldband snapper, *Pristipomoides multidens.* Despite being completely absent from the proposed MSS operational area no significant different in abundance was detected between locations, likely due to the high level of Site to Site variability and low numbers of individuals recorded. Given their life history characteristics, goldband snapper are likely to be associated with high relief habitats, however, no quantitative assessments of the spatial scale of home ranges or movement are available (Froese and Pauly 2011). Its absence within the proposed MSS suggests a lack of suitable habitat in the vicinity of the sampling sites. However, in general we found only limited variation in the overall fish assemblage between the proposed MSS operational area and reference locations.

The Exploratory sites, adjacent to Location one, were located amongst more structurally complex features, which may equate to terrace and step features resulting from changes in sea level over the past 100,000 years, as identified by DoEE (Department of the Environment and Energy 2017), and are in the same depth range as the 'ancient coastline between 90 and 120 m depth' KEF defined in the Marine Bioregional Plan for the South-west Marine Region (DSEWPaC 2012). Within the Exploratory sites, sites 0.1 and 0.2 had higher relief emergent habitat with a significant increase in the percentage cover of octocoral (see representative images of benthos from each Site in Supplementary Table 2). However, Exploratory Site 0.3 was more similar to the Planned survey locations (in terms of environmental variables), suggesting that while more structurally complex habitats exist in adjacent shallower (95-115 m) locations, they are not consistently distributed across this depth range (e.g. see bathymetry in Fig. 19). In addition, visibility at the Exploratory sites was approximately twice that of the study sites, presumably due to lower cover of soft-sediments, which at the study sites were observed to be readily stirred up by fish activity and near-seabed water currents around the stereo-BRUV. The contrast between Planned and Exploratory sites was also clearly demonstrated in the spatial representation of CLUSTER groupings based on substrate and benthos composition (Fig. 18). A similar pattern was evident in the fish data with Exploratory sites 0.1 and 0.2 having greater occurrence and abundance of commercially important species such as the red emperor *Lutjanus sebae*, and the yellowspotted rockcod *Epinephelus areolatus,* and a greater abundance of goldband snapper, and Exploratory Site 0.3 being more similar (in terms of fish composition) to the Planned survey locations. Again, this trend was supported in the spatial representation of CLUSTER groupings based on fish composition (Fig. 19). Goldband snapper, red emperor and yellowspotted rockcod are very important target species across the Indo-Pacific (Cappo et al. 2009) and are typically closely associated with higher relief habitat (Pistorius and Taylor 2009) as also found in the current study.

Understanding the life-history characteristics of a fish species, especially those of commercial importance, is necessary for understanding how individuals may relate to the environment or respond to anthropogenic or environmental disturbance (Claudet et al. 2010). For demersal species, home range size and movement patterns can be strongly correlated with body-size (Harasti et al. 2015), but also be strongly influenced by ontogenetic variation in habitat usage changing between different life stages (Kimirei et al. 2011, Parsons et al. 2014). Telemetry studies provide the most direct approach to study and quantify home range size and habitat use in demersal fishes, and such studies have frequently provided surprising insights into hitherto unknown behavioral modality in highly studied coastal water and commercially important demersal species (e.g. the pink snapper *Pagrus auratus*; Willis et al. 2001, Parsons et al. 2003, Egli and Babcock 2004). Both Parsons *et al.* (2003) and Willis et al. (2001) found that pink snapper had relatively restricted home ranges (< 1 km) and that they can exhibit long-term (> 3years; Willis et al. 2001) site fidelity, however, the sample size with these studies, as with many telemetry studies, was small so the generality of these results should be viewed with caution. Parsons *et al.* (2003) also suggested that for pink snapper, some individuals may relocate their home range over time, but again, due to a small sample size (n = 4) these results should be viewed with caution. To our knowledge there have been no telemetry studies of home range and habitat use conducted for the commercially important species more typical of mesophotic reefs and sampled in the current study, likely due to the challenges of conducting acoustic telemetry at the typical depths (50-150 m) at which these species occur.

Numerous studies have demonstrated that fish assemblage composition varies with depth and habitat (Connell and Lincoln-Smith 1999, Fitzpatrick et al. 2012, McLean et al. 2016, Wellington et al. 2018), but have generally found the greatest variation in shallow waters (Moore et al. 2009, Chatfield et al. 2010, Langlois et al. 2012)). Variability within fish assemblages across mesophotic and deeper habitats has been attributed less to variation in depth and more to variation in habitat (Monk et al. 2016, Langlois et al. 2017, Wellington et al. 2018). Within the current study there was a less than 20 m difference in the depth between the Planned study locations and Exploratory sites, however both exhibited different habitat and fish assemblage characteristics. The lack of substantial structurally complex features or mesophotic reef habitat in the Planned locations is perhaps reflective of the coarse nature of the KEF mapping. When the mapped KEF boundary is overlaid on a map of seabed slope there are linear and structurally complex features typical of an ancient submerged coastline occuring ~5 km to south of the KEF boundary and BRUVS sites (Figure 20). Although existing public-access seabed slope data are fairly coarse compared to the resolutions achievable using multibeam sonar (Monk et al. 2016), the benthos and fish assemblage characterised at the two most westernmost Exploratory sites further supports the utility of using existing public-access seabed slope data (Figure 20). Therefore, if further sampling were conducted within the proposed MSS, across the 95-115m depth range and using existing bathymetry to target high-slope regions (after Hill et al. 2014), it is likely that benthic assemblages would be found with greater structural complexity, greater cover of epibiota and with associated fish assemblages with a comparable proportion of commercially important fish species as were found within the two westernmost Exploratory sites (sites 0.1 and 0.2, Figure 20).

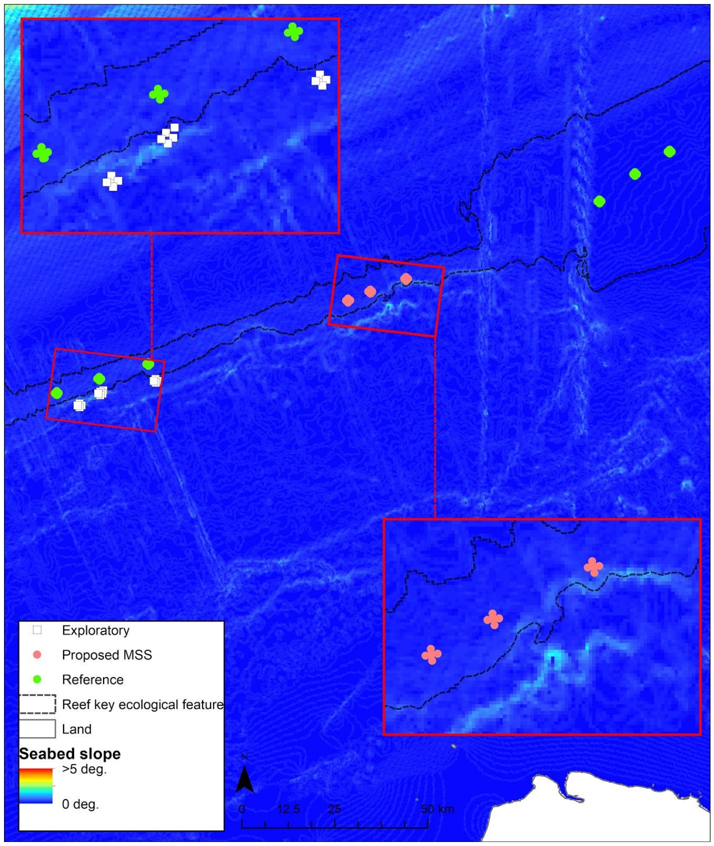

Figure 20. Location of the three study locations, proposed MSS locations and western and eastern reference locations in relation of mapped ancient submerged coastline KEF (dashed line). Background represents the seabed slope based generated by Geosciences Australia (http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_76992). The top inset shows the western reference Location within the mapped KEF with adjacent Exploratory sites to the south in shallower water with sites 0.1 and 0.2 on areas of higher slope. The bottom inset shows the proposed MSS Location within the KEF with shallower areas characterised by higher slope to the south.

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Supplementary table 1. Species and life history information. E, only found at exploratory sites.

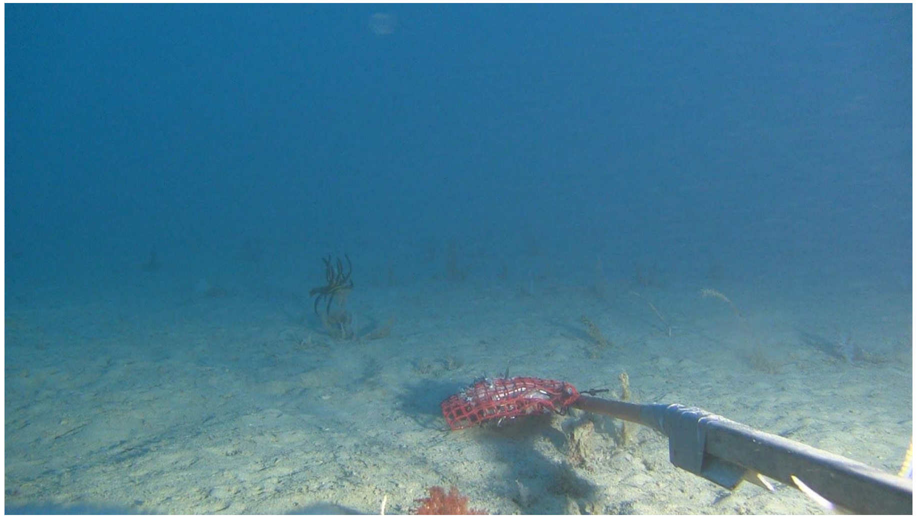
E	Family	Scientific	Common name	Feeding guild	IUCN ranking	Max length (mm)	Fishing type	Mean abundance per deployment +/- SE	Total relative abundance
	Ariidae	*Netuma thalassina*	Giant salmon catfish	invertebrate carnivore		1850		0.81 +/- 0.13	47
E	*Balistidae*	*Abalistes stellatus*	Starry triggerfish	invertebrate carnivore		600		0.12 +/- 0.06	7
	Bothidae	*Unknown spp*	Flounder	unknown				0.03 +/- 0.02	2
	Carangidae	*Carangoides caeruleopinnatus*	Blue-spined trevally	generalist carnivore	Least Concern	410		0.29 +/- 0.16	17
	Carangidae	*Carangoides chrysophrys*	Club-nosed trevally	generalist carnivore	Least Concern	720		4.1 +/- 0.45	238
	Carangidae	*Carangoides malabaricus*	Malabar trevally	generalist carnivore	Least Concern	600		0.03 +/- 0.02	2
	Carangidae	*Carangoides sp10*	Unknown juvenile trevally	unknown				0.21 +/- 0.06	12
	Carangidae	*Carangoides spp*	Trevally	unknown				0.05 +/- 0.04	3
	Carangidae	*Caranx ignobilis*	Giant trevally	piscivore	Least Concern	1700		0.71 +/- 0.08	41
	Carangidae	*Caranx tille*	Tille trevally	generalist carnivore	Least Concern	800		0.4 +/- 0.3	23
	Carangidae	*Decapterus spp*	Mackerel scad	invertebrate carnivore				1.02 +/- 0.45	59
	Carangidae	*Seriola dumerili*	Greater amberjack	generalist carnivore	Least Concern	1900		0.02 +/- 0.02	1
	Carangidae	*Seriola hippos*	Samsonfish	generalist carnivore	Least Concern	1500	Commercial	0.03 +/- 0.02	2
E	*Carcharhinidae*	*Carcharhinus albimarginatus*	Silvertip shark	piscivore	Vulnerable	3000	Commercial	0.03 +/- 0.02	2
	Carcharhinidae	*Carcharhinus coatesi*	Whitecheek shark	generalist carnivore		870		0.14 +/- 0.05	8
	Carcharhinidae	*Carcharhinus plumbeus*	Sandbar shark	generalist carnivore	Vulnerable	1800	Commercial	0.12 +/- 0.04	7
	Carcharhinidae	*Carcharhinus sorrah*	School shark	generalist carnivore	Near Threatened	1600	Commercial	0.43 +/- 0.07	25

	Carcharhinidae	*Carcharhinus spp*	Unknown shark	unknown				0.02 +/- 0.02	1
	Carcharhinidae	*Galeocerdo cuvier*	Tiger shark	generalist carnivore	Near Threatened	7500		0.02 +/- 0.02	1
	Carcharhinidae	*Loxodon macrorhinus*	Sliteye shark	generalist carnivore	Least Concern	980	Commercial	0.33 +/- 0.06	19
	Echeneidae	*Echeneis naucrates*	Sharksucker	generalist carnivore	Least Concern	1100		0.22 +/- 0.06	13
	Fistulariidae	*Fistularia commersonii*	Smooth flutemouth	generalist carnivore	Least Concern	1600		0.02 +/- 0.02	1
E	*Labridae*	*Bodianus solatus*	Sunburnt pigfish	invertebrate carnivore	Data Deficient	350		0.05 +/- 0.04	3
E	*Lethrinidae*	*Gymnocranius grandoculis*	Robinson's seabream	generalist carnivore	Least Concern	800	Commercial	0.17 +/- 0.07	10
E	*Lethrinidae*	*Lethrinus lentjan*	Pink ear emperor	generalist carnivore	Least Concern	520	Commercial	0.02 +/- 0.02	1
	Lutjanidae	*Lutjanus malabaricus*	Saddletail snapper	piscivore		1000	Commercial	0.1 +/- 0.07	6
E	*Lutjanidae*	*Lutjanus russellii*	Moses' snapper	generalist carnivore	Least Concern	500	Commercial	0.09 +/- 0.06	5
	Lutjanidae	*Lutjanus sebae*	Red emperor	generalist carnivore	Least Concern	1160	Commercial	0.53 +/- 0.23	31
E	*Lutjanidae*	*Lutjanus vitta*	Brownstripe snapper	generalist carnivore	Least Concern	400	Commercial	0.1 +/- 0.05	6
	Lutjanidae	*Pristipomoides multidens*	Goldband snapper	generalist carnivore	Least Concern	900	Commercial	1.05 +/- 0.19	61
E	*Lutjanidae*	*Pristipomoides sieboldii*	Lavender snapper	generalist carnivore	Least Concern	790		0.03 +/- 0.03	2
E	*Mullidae*	*Upeneus moluccensis*	Goldband goatfish	invertebrate carnivore	Least Concern	220		0.02 +/- 0.02	1
	Nemipteridae	*Nemipterus spp*	Threadfin bream	generalist carnivore				2.26 +/- 0.28	131
	Platycephalidae	*Unknown spp*	Flathead	unknown				0.02 +/- 0.02	1
	Priacanthidae	*Priacanthus hamrur*	Lunartail bigeye	generalist carnivore	Least Concern	450		0.02 +/- 0.02	1
E	*Rachycentridae*	*Rachycentron canadum*	Cobia	generalist carnivore	Least Concern	2000		0.02 +/- 0.02	1

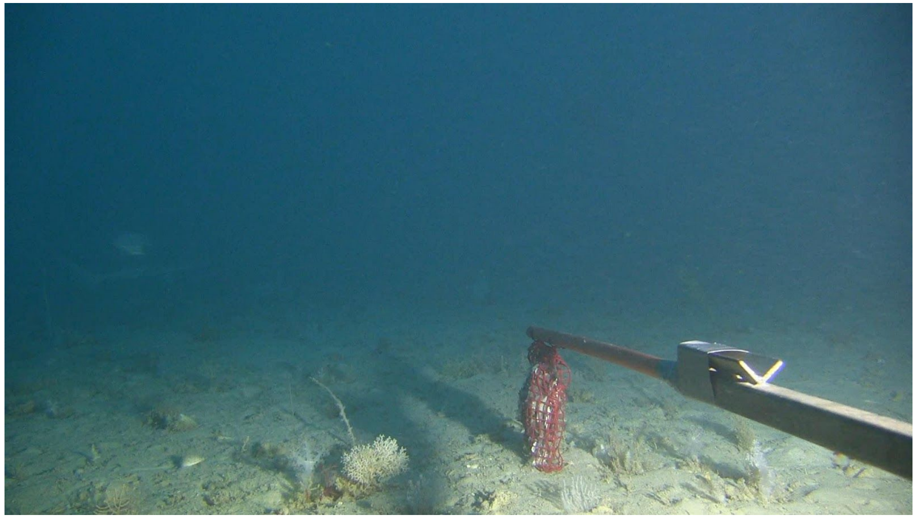
E	*Rhinidae*	*Rhynchobatus australiae*	Giant guitarfish	macroinvertebrate carnivore	Vulnerable	3000		0.03 +/- 0.02	2
E	*Scombridae*	*Scomberomorus spp*	Mackeral	unknown				0.02 +/- 0.02	1
E	*Epinephelidae*	*Epinephelus amblycephalus*	Banded grouper	invertebrate carnivore	Least Concern	500	Commercial	0.03 +/- 0.02	2
	Epinephelidae	*Epinephelus areolatus*	Areolate grouper	generalist carnivore	Least Concern	470	Commercial	0.38 +/- 0.14	22
E	*Epinephelidae*	*Epinephelus malabaricus*	Blackspotted rockcod	generalist carnivore	Near Threatened	2340	Commercial	0.02 +/- 0.02	1
	Sparidae	*Argyrops spinifer*	Frypan bream	piscivore	Least Concern	700	Commercial	0.64 +/- 0.19	37
	Sphyraenidae	*Sphyraena forsteri*	Blackspot barracuda	piscivore		750		0.02 +/- 0.02	1
	Sphyraenidae	*Sphyraena qenie*	Blackfin barracuda	piscivore		1700		0.16 +/- 0.09	9
	Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead	generalist carnivore	Endangered	4300		0.09 +/- 0.04	5
	Sphyrnidae	*Sphyrna mokarran*	Great hammerhead	piscivore	Endangered	6100		0.07 +/- 0.03	4
	Synodontidae	*Saurida longimanus*	Longfin saury	generalist carnivore		250		0.02 +/- 0.02	1
	Synodontidae	*Saurida undosquamis*	Brushtooth lizardfish	generalist carnivore	Least Concern	500		0.47 +/- 0.08	27
	Synodontidae	*Synodus indicus*	Indian lizardfish	unknown		330		0.1 +/- 0.04	6
E	*Synodontidae*	*Trachinocephalus trachinus*	Painted grinner	unknown		400		0.02 +/- 0.02	1
	Terapontidae	*Terapon jarbua*	Crescent grunter	zooplanktivore	Least Concern	360		0.41 +/- 0.15	24
	Tetraodontidae	*Arothron stellatus*	Starry puffer	generalist carnivore	Least Concern	1200		0.02 +/- 0.02	1
	Tetraodontidae	*Lagocephalus lunaris*	Lunartail puffer	generalist carnivore	Least Concern	450		1.6 +/- 0.15	93
E	*Triakidae*	*Hemitriakis falcata*	Sicklefin houndshark	generalist carnivore	Least Concern	800		0.02 +/- 0.02	1

Supplementary table 2. Representative images of benthos within field of view of stereo-BRUVs across all sampled sites.

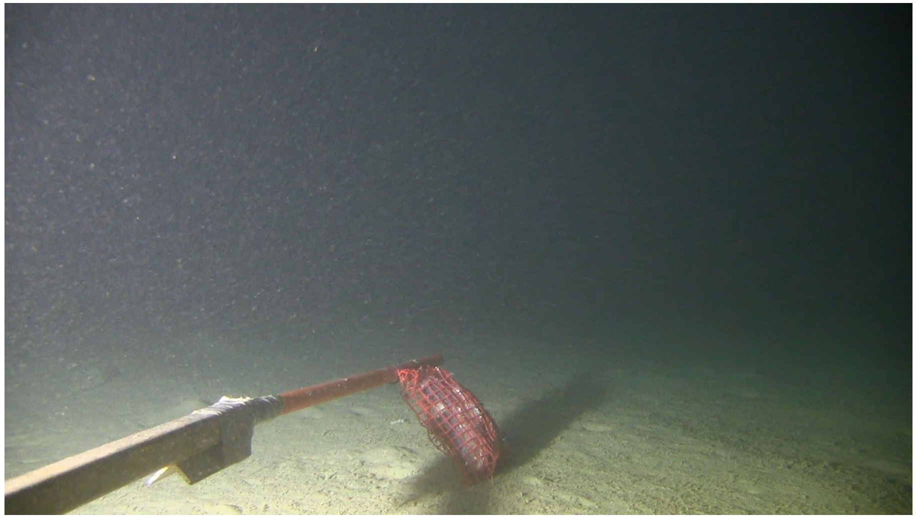
Exploratory Sites



Site 0.1 (Taken from POC11003)

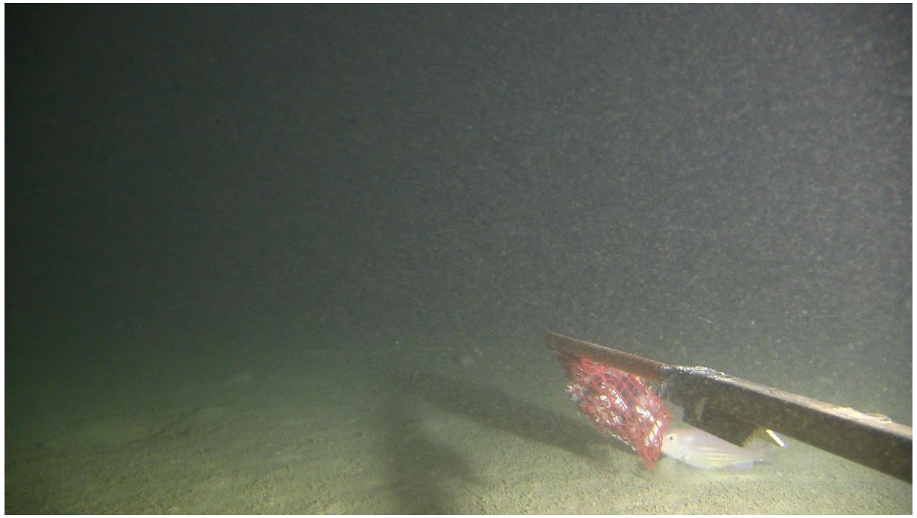


Site 0.2 (Taken from POC12005)

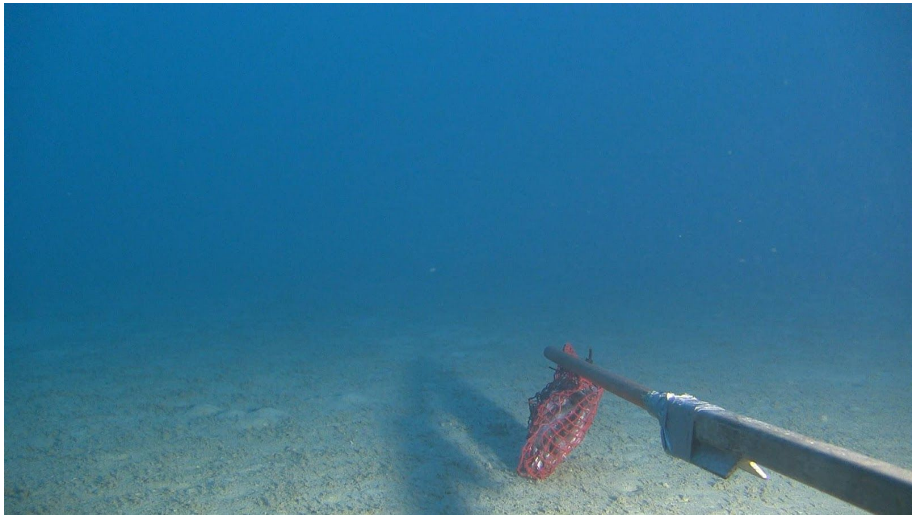


Site 0.3 (Taken from POC13005)

Planned Survey Sites

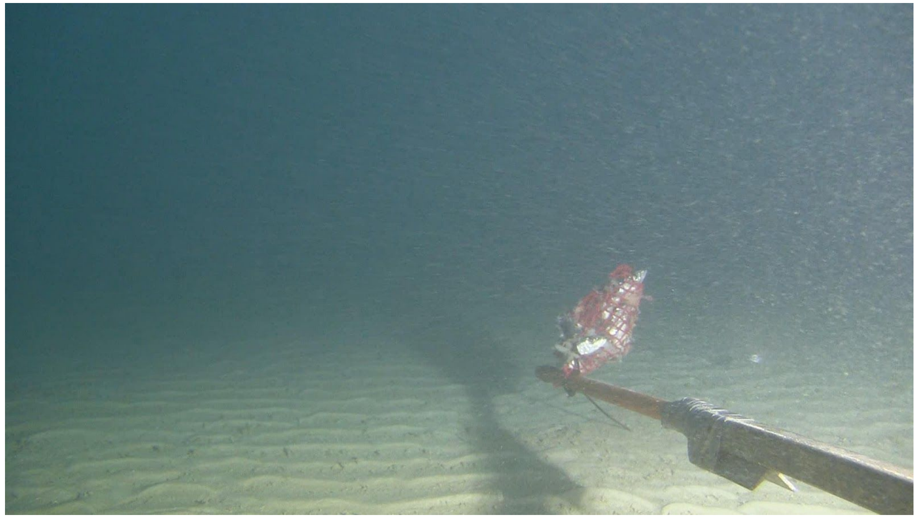


Site 1 (Taken from POC11013)

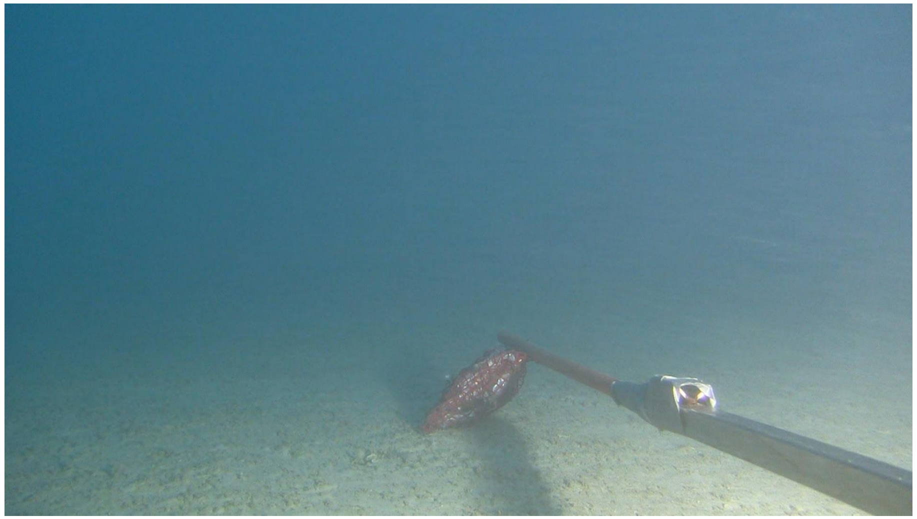


Site 2 (POC12008)

Site 3 (POC13010)

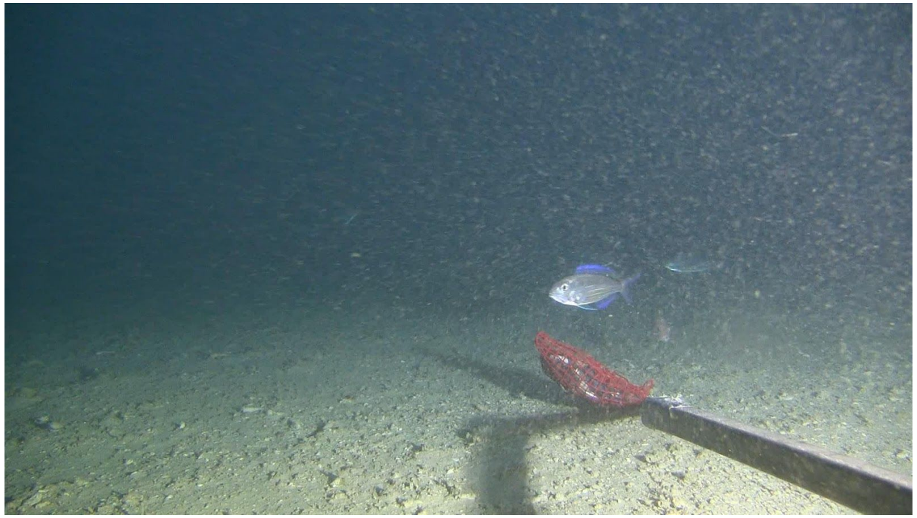


Site 4 (POC24010)



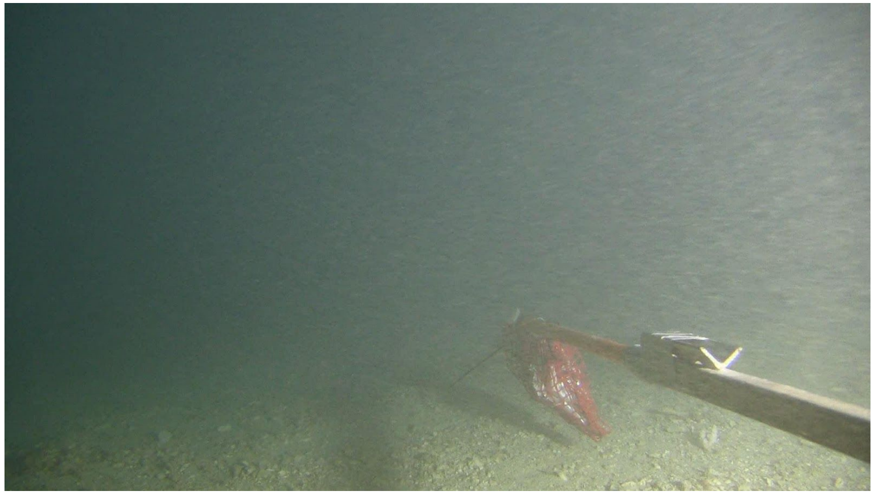
Site 5 (POC25001)

Site 6 (POC26005)



Site 7 (POC37005)

Site 8 (POC38005)



Site 9 (POC39003)

Supplementary Table 3. Description and origin of the four derived environmental variables used in analysis.

Derived variable	Description	Database
Gravel	Spatially continuous data of the seabed gravel content (sediment fraction >2000 µm) expressed as a weight percentage ranging from 0 to 100%.	Seabed Gravel Content Across the Australian Continental EEZ, 2011. Geosciences Australia
Mud	Spatially continuous data of seabed mud content (sediment fraction < 63 µm) expressed as a weight percentage ranging from 0 to 100%	Seabed Mud Content Across the Australian Continental EEZ, 2011. Geosciences Australia
Sand	Spatially continuous data of the seabed sand content (sediment fraction 63-2000 mm) expressed as a weight percentage ranging from 0 to 100%	Seabed Sand Content Across the Australian Continental EEZ, 2011. Geosciences Australia
Mean turbidity	Mean monthly parameter K490, a downwelling diffuse attenuation coefficient at 490 nm, a turbidity parameter, of Australian oceans between 2009 and 2011. K490 is a derived product from MODIS (aqua) images using NASA's SeaDAS image processing software. The spatial resolution of the datasets is 0.01 dd and the unit of the datasets is 1/m.	MODIS derived k490 datasets. Geosciences Australia

Appendix B

Technical background to the habitat classification approach

RPS

Appendix B Technical background to the habitat classification approach

Background to the habitat classification approach used in the Santos KEF fish and pearl oyster habitat survey report

Fully hierarchical habitat classification schemes work in a very similar way as taxonomic classifications. The further down the hierarchy you go, the greater the resolution achieved. Branches of the hierarchy define points at which higher classifications can be sub-divided (in a top-down system). In the case of CATAMI - which is the basis for the classifications used in the AIMS north west shoals to shore research program – a single hierarchical classification is not defined. The authors of CATAMI describe the scheme as 'hierarchical' and 'dovetailing' with EUNIS and NISB (Althaus et al. 2015). However, CATAMI does not present a single hierarchical structure but more of a 'deconstructed' hierarchical design (see Althaus et al. 2013, 2015), where physical and biological hierarchies are presented independently.

CATAMI is described as 'hierarchical' by the authors, but is based on a series of hierarchical structures which are not linked. These linkages are important from an ecological point-of-view, and hence necessary to support a more balanced and robust assessment in the Keraudren MSS EP. It is feasible to interpret a single hierarchical classification from the CATAMI scheme, but the process doesn't define that this is required, or how it may be achieved consistently. This makes linkages or relationships between environmental (substrate, relief and bedforms) and biological components of biotopes more difficult to identify, and raises the potential of inconsistency between analyses as interpretations of hierarchies may be different between assessors.

The approach used in the Santos KEF fish and pearl oyster habitat survey report aligns with the concept of defining biotopes as geographical habitat classification units (Connor et al. 2004). A biotope is an area of specific environmental conditions supporting a specific biological assemblage, operating together at a specific scale (Connor et al. 1997). In the context of the Santos study, a biotope would define the different habitat types under broad habitat descriptions defined by the Department of Fisheries (2016). This approach allows development of a single hierarchical classification system, where relationships between environmental and biological components can be identified, and the relative ecological value of a biotope in comparison to other biotopes within the same broad description (e.g. 'Garden' habitat) can be determined.

The term 'biotope' was first introduced in 1908, originally in reference to the abiotic component of an ecosystem (the biotic component being referred to as the 'biocenosis', as first postulated by Mőbius in 1877 (Olenin & Ducrotoy 2006)). The more contemporary interpretation of biotope representing both habitat and community components was first used in the UK in the early 1990s, and has since been adopted in international documents.

The process used in this study to classify habitats (biotopes) is compatible with CATAMI but also applies the same basic hierarchical approach as other studies classifying offshore benthic habitats (e.g. Hooper et al. 2011a,b). It is also compatible with other existing biotope and habitat classifications such as the National Intertidal/Subtidal Benthic (NISB) habitat classification scheme (Mount et al. 2007), EUNIS (Davies et al. 2004) or the Marine Habitat Classification for Britain and Ireland (JNCC 2015).

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Appendix E - FishCube Data

E1. Introduction

Santos has obtained catch and effort data (FishCube data) for WA commercial fisheries from WA DPIRD for the purposes of understanding the relative distribution of fishing effort in relation to the Keraudren Extension 3D MSS.

FishCube data is available for WA fisheries in 60 nm x 60 nm and for 10 nm x 10 nm Catch and Effort System (CAES) blocks. The commercial wildcatch fisheries data are provided in a spreadsheet format and includes the following characteristics for each block:

- **Weight (kg)** – a measure of fish catches per CAES block during the period of interest;
- **Vessel Count** – a measure of the number of vessels that fished in a CAES block during the period of interest; and
- **Fishing Day Count** – a measure of fishing effort, represented by the number of days when one or more vessels fished in a CAES block during the period of interest.

Due to confidentiality reasons, WA DPIRD are not permitted to release catch and effort data for CAES blocks where less than three vessels fished during the period requested. Where this applies, the Vessel Count category is marked 'Less than 3', while Weight and Fishing Day Count are marked as 'N/A'. CAES blocks provided in this way confirm that some fishing effort did occur within the block during that period, but the associated catch and effort values are not available. CAES blocks where no fishing is recorded do not return any data and are excluded. In some instances, the low number of vessels and low density of fishing effort that occurs across the region meant a significant number of blocks were fished by less than three vessels, particularly at the finer spatial and temporal scale of 10 nm x 10 nm blocks.

Commercial collector fisheries data (e.g. Specimen Shell Fishery, Hermit Crab Fishery) are presented in a different format from the commercial wildcatch fisheries, providing the following characteristics for each block:

- **Catch Unit Count** – a measure of the number of units collected during the period of interest; and
- **Licence Count** – a measure of the number of licences active within the block during the period of interest.

The catch and effort data used in this study was obtained on 07/Oct/2019 from the Department of Primary Industries and Regional Development, Western Australia. Santos acknowledges that the State of Western Australia is the owner of the copyright of this information.

E2. Scoping and Analysis of Relevant Fisheries

In the scoping phase of this Environment Plan (EP) and stakeholder identification, Santos referred to stakeholder information and FishCube data analysed for the previous Keraudren 3D MSS EP. Santos also requested additional FishCube data from DPRID for the following fisheries which overlap the Keraudren Extension 3D MSS operational area or have activities located in adjacent coastal waters:

- Mackerel Managed Fishery (Area 2)
- Pilbara Fish Trawl (Interim) Managed Fishery
- Pilbara Line Fishery (Condition)
- Pilbara Trap Managed Fishery
- Nickol Bay Prawn Managed Fishery

- Pearl Oyster Managed Fishery
- Pilbara Developing Crab Fishery
- Specimen Shell Managed Fishery
- Hermit Crab Fishery

Fished Areas (2009 – 2018)

FishCube data was obtained for the whole of these fisheries for a combined 10-year period, 2009 – 2018, the most recent ten calendar years available from DPIRD. The purpose of using the ten-year dataset was to understand the relative distribution of fishing effort, with the extended ten-year period reducing the likelihood of confidential data returns.

The data showed that fishing effort within the Nickol Bay Prawn Managed Fishery, Pilbara Developing Crab Fishery and Hermit Crab Fishery was limited to coastal waters over 40 km from the operational area and so these fisheries were not examined further.

Four fisheries were identified as having blocks with fishing effort overlapping the operational area:

- Mackerel Managed Fishery (Area 2) (**Section E3**)
- Pilbara Fish Trawl (Interim) Managed Fishery (**Section E4**)
- Pilbara Line Fishery (Condition) (**Section E5**)
- Pilbara Trap Managed Fishery (**Section E6**)
- Specimen Shell Managed Fishery (**Section E7**)

In addition, the Pearl Oyster Managed Fishery (**Section E8**) was identified as having blocks with fishing effort approximately 32 km shoreward from the operational area. As there is no spatial overlap with the fishing effort in this fishery, the fishery will not be encountered by the survey vessel during the survey. However, due to the potential presence of pearl divers in the water at these locations and interest in seismic survey activities from stakeholders in this fishery, the fishing effort data has been analysed further in their respective sections.

For each fishery, fishing effort (fishing day count) has been mapped for the entire fishery for the 10-year (2009 – 2018) dataset. The Mackerel Managed Fishery, Pilbara Fish Trawl (Interim) Managed Fishery, and Pearl Oyster Managed Fishery have been mapped at the 10 nm block scale. The Pilbara Line Fishery, Pilbara Trap Managed Fishery and Specimen Shell Managed Fishery data have been mapped at the coarser 60 nm scale as data at the 10 nm scale was not available.

The total block area of fishing effort and the area of overlap with the operational area and ramp-up zone were calculated using ArcGIS. Using these areas, the percentage of the block fishing effort which is overlapped by the operational area and survey area (with ramp-up zone) are summarised in **Table E-1**.

Maps are presented in **Section E3 to E8**.

Table E-1: Area of overlap between block areas of fishing effort and the operational area and survey area with ramp-up zone.

Fishery	Block area of fishing effort (km²)	Operational area overlap (km²)	% overlap of operational area with fishing effort	Ramp-up zone overlap (km²)	% overlap of survey area (with ramp up zone) with fishery effort
Mackerel Managed Fishery (Area 2)	51,848	2,439	5	1,417	3
Pilbara Fish Trawl Managed Fishery	23,058	6,310	27	4,655	20
Pilbara Line Fishery (Condition)	86,006	19,691	23 *	11,205	13 *
Pilbara Trap Managed Fishery	146,414	8,802	6 *	4,069	3 *
Specimen Shell Managed Fishery	43,321	14,532	34 *	9,213	21 *
Pearl Oyster Fishery	13,051	0	0	0	0
* Based on course resolution 60 nm blocks. Area of fishing effort and % overlap for these fisheries are, therefore, likely to be overestimated.					

Annual Fishing Effort (2014 – 2018)

Annual fishing effort data for the most recent five calendar years (2014, 2015, 2016, 2017 and 2018) has also been reviewed and mapped for each of these fisheries to identify which blocks in the vicinity of the operational area have been fished each year.

The exception to this is the Specimen Shell Managed Fishery for which annual data was not requested. Stakeholder consultation with WAFIC and the Specimen Shell Industry Association for the previous Keraudren 3D MSS confirmed that fishing effort in offshore waters near the operational area would have undertaken from a boat using an ROV (used by a single licence holder in the fishery) and that seismic survey activities in this waters should not impact upon routine specimen shell collecting activities. Therefore, annual data for the Shell Managed Fishery has not been requested or assessed.

Maps are presented in **Section E3 to E8**.

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E3. Mackerel Managed Fishery (Area 2)

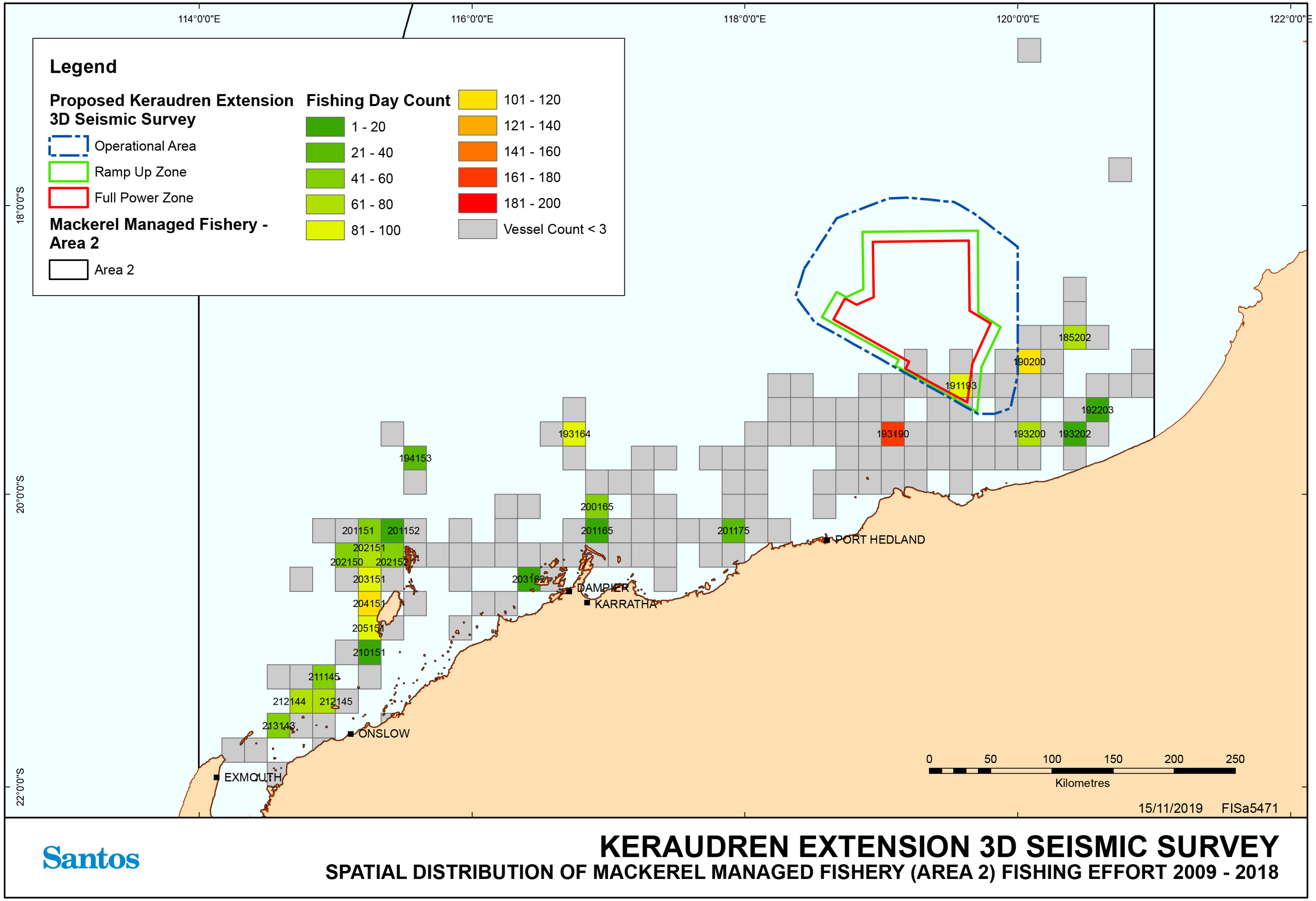

Figure E1: Mackerel Managed Fishery (Area 2) fishing effort – 10-year period (2009 – 2018)

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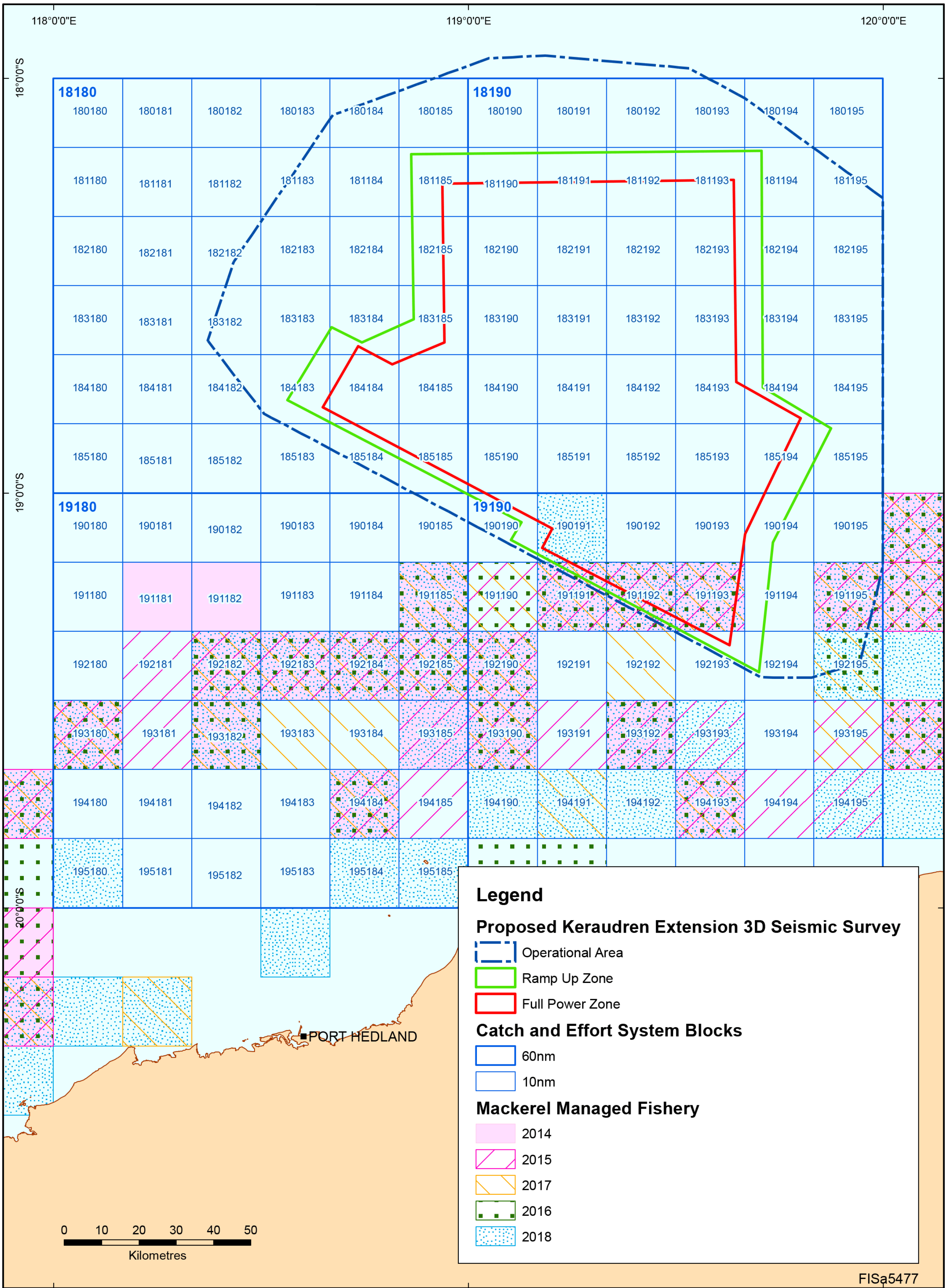

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KERAUDREN EXTENSION 3D SEISMIC SURVEY
2014-2018 MACKEREL MANAGED FISHERY

Figure E2: Mackerel Managed Fishery (Area 2) - Annual fishing effort (2014 – 2018)

E4. Pilbara Fish Trawl (Interim) Managed Fishery

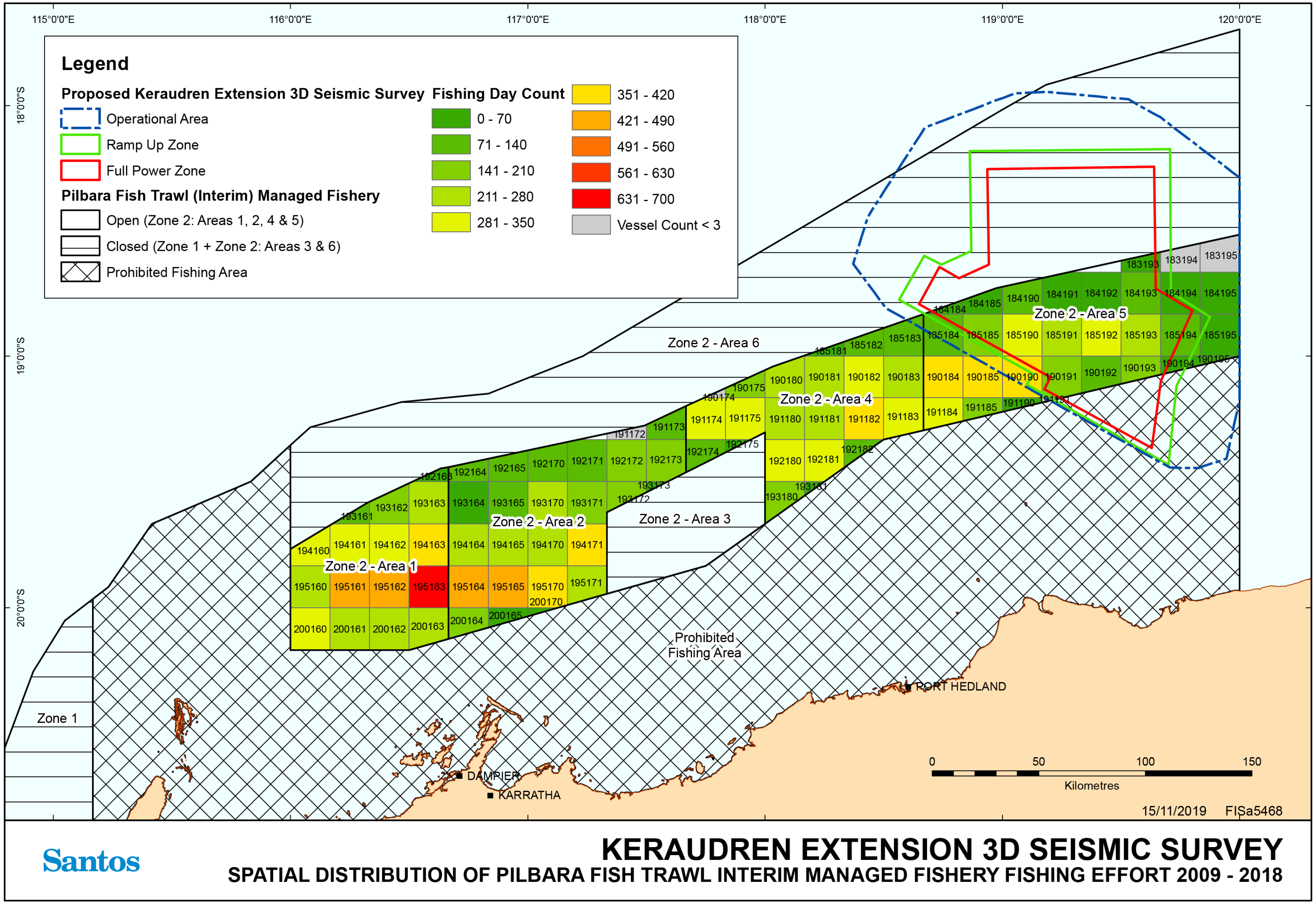

Figure E3: Pilbara Fish Trawl (Interim) Managed Fishery fishing effort – 10-year period (2009 – 2018)

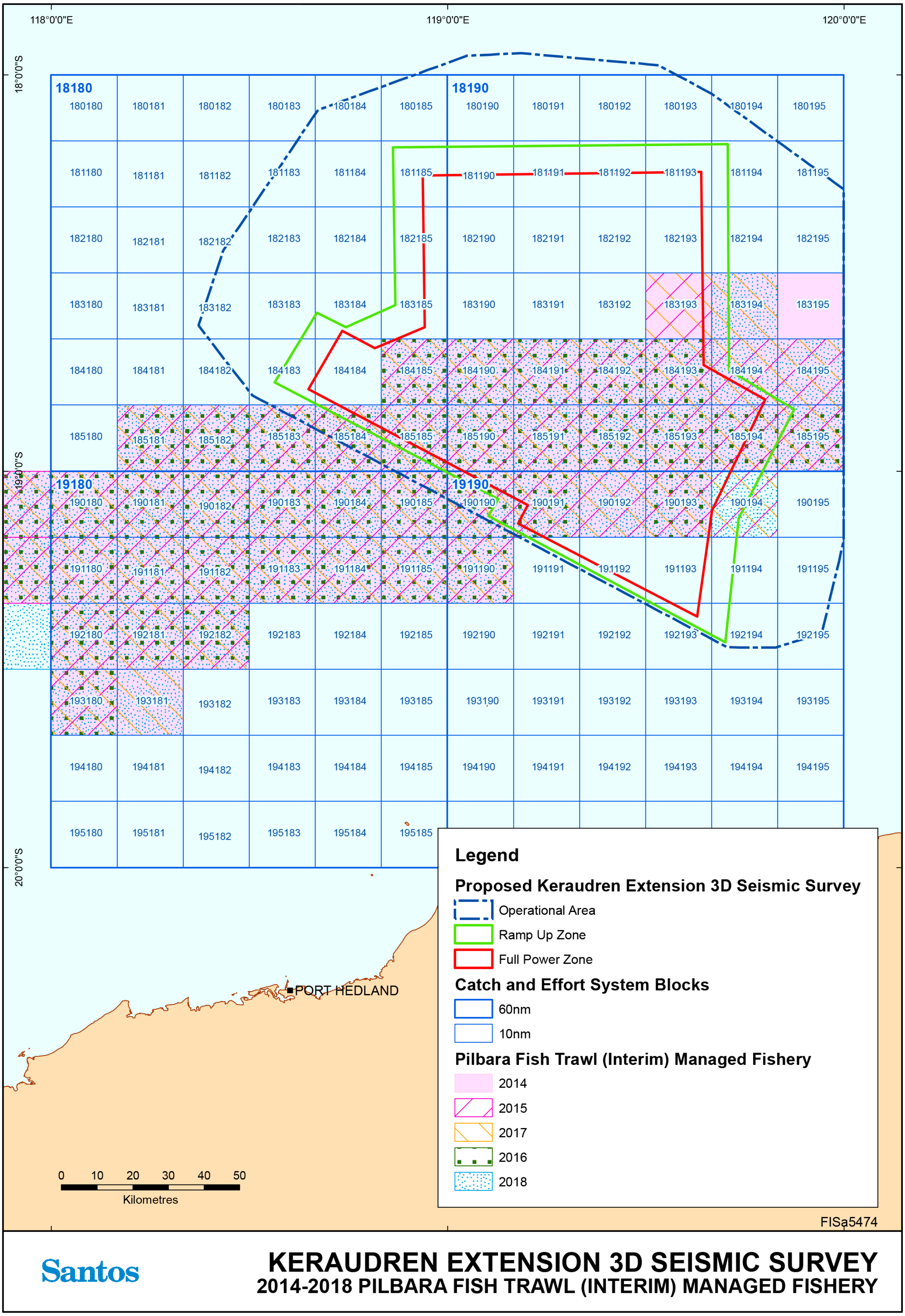

Figure E4: Pilbara Fish Trawl (Interim) Managed Fishery - Annual fishing effort (2014 – 2018)

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E5. Pilbara Line Fishery

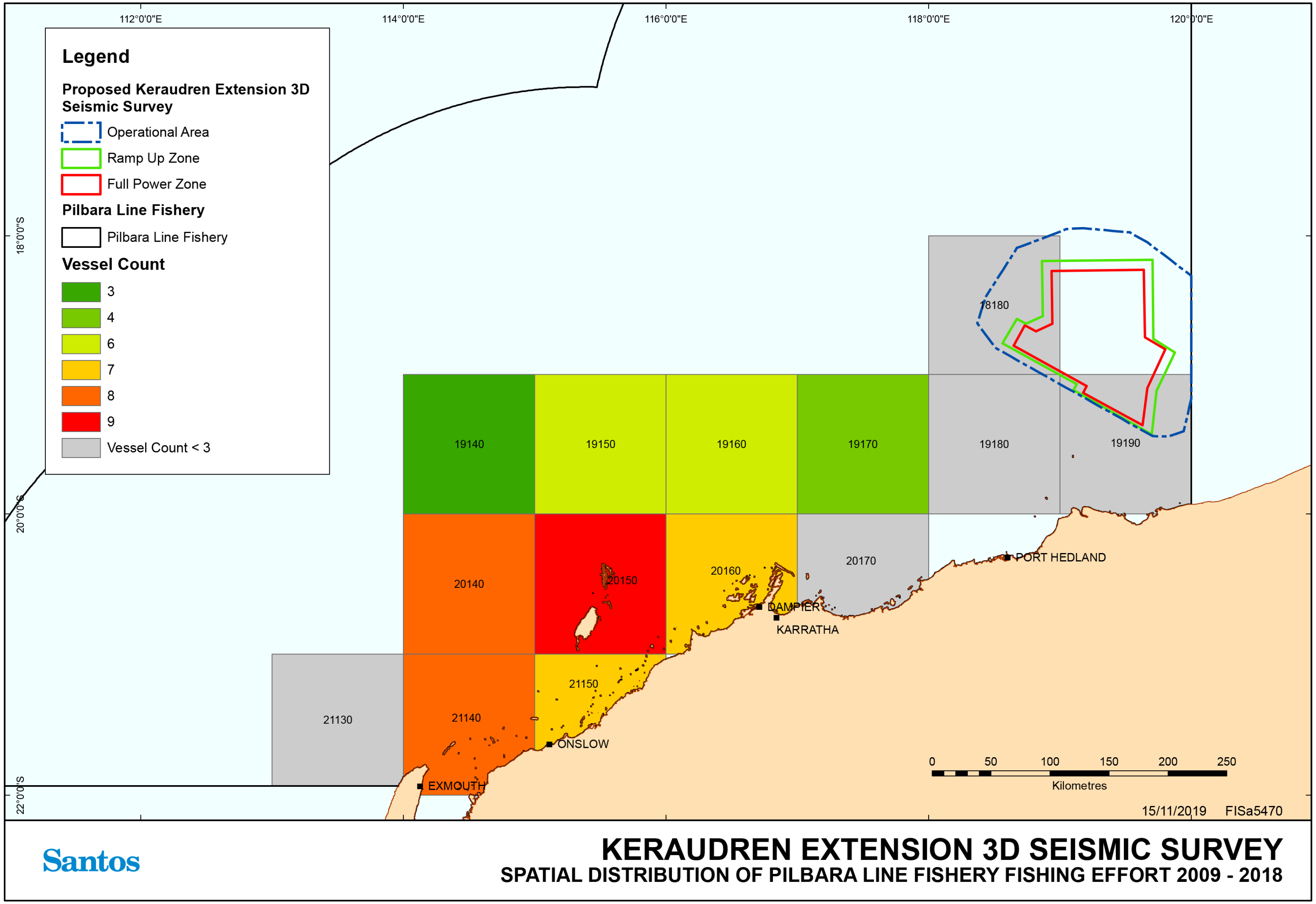


Figure E5: Pilbara Line Fishery – 10-year period (2009 – 2018)

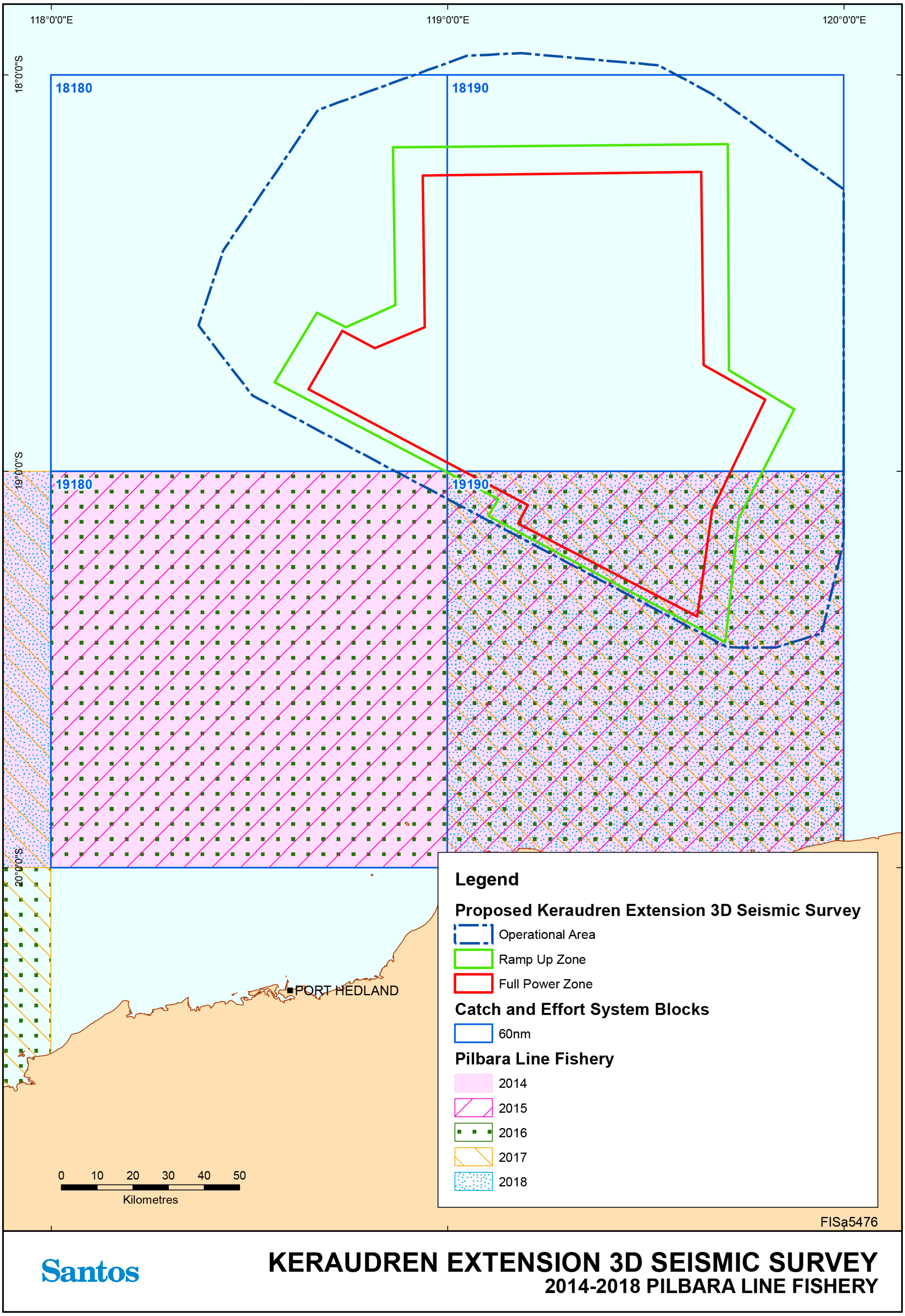


Figure E6: Pilbara Line Fishery - Annual fishing effort (2014 – 2018)

E6. Pilbara Trap Managed Fishery

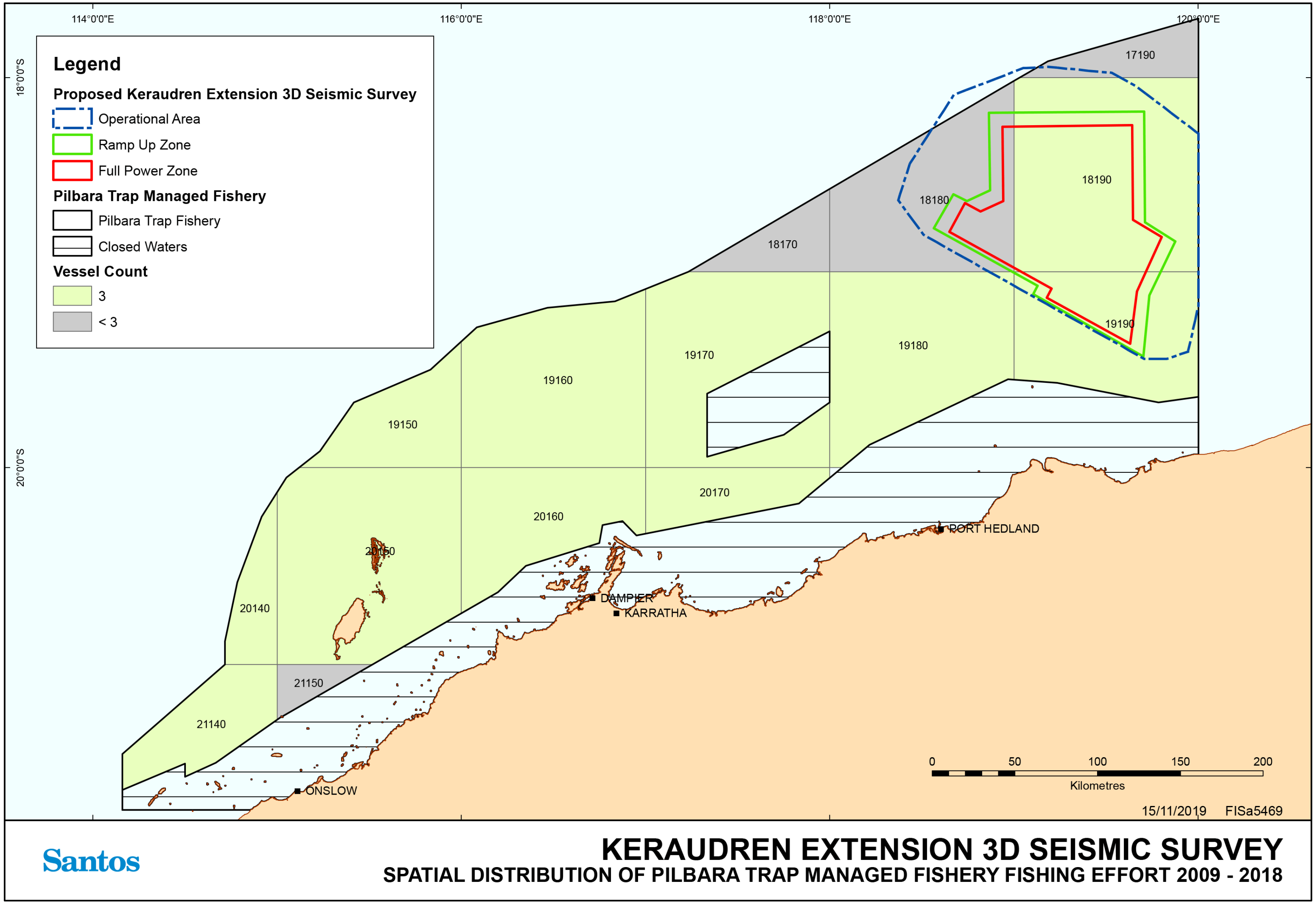


Figure E7: Pilbara Trap Managed Fishery fishing effort – 10-year period (2009 – 2018)

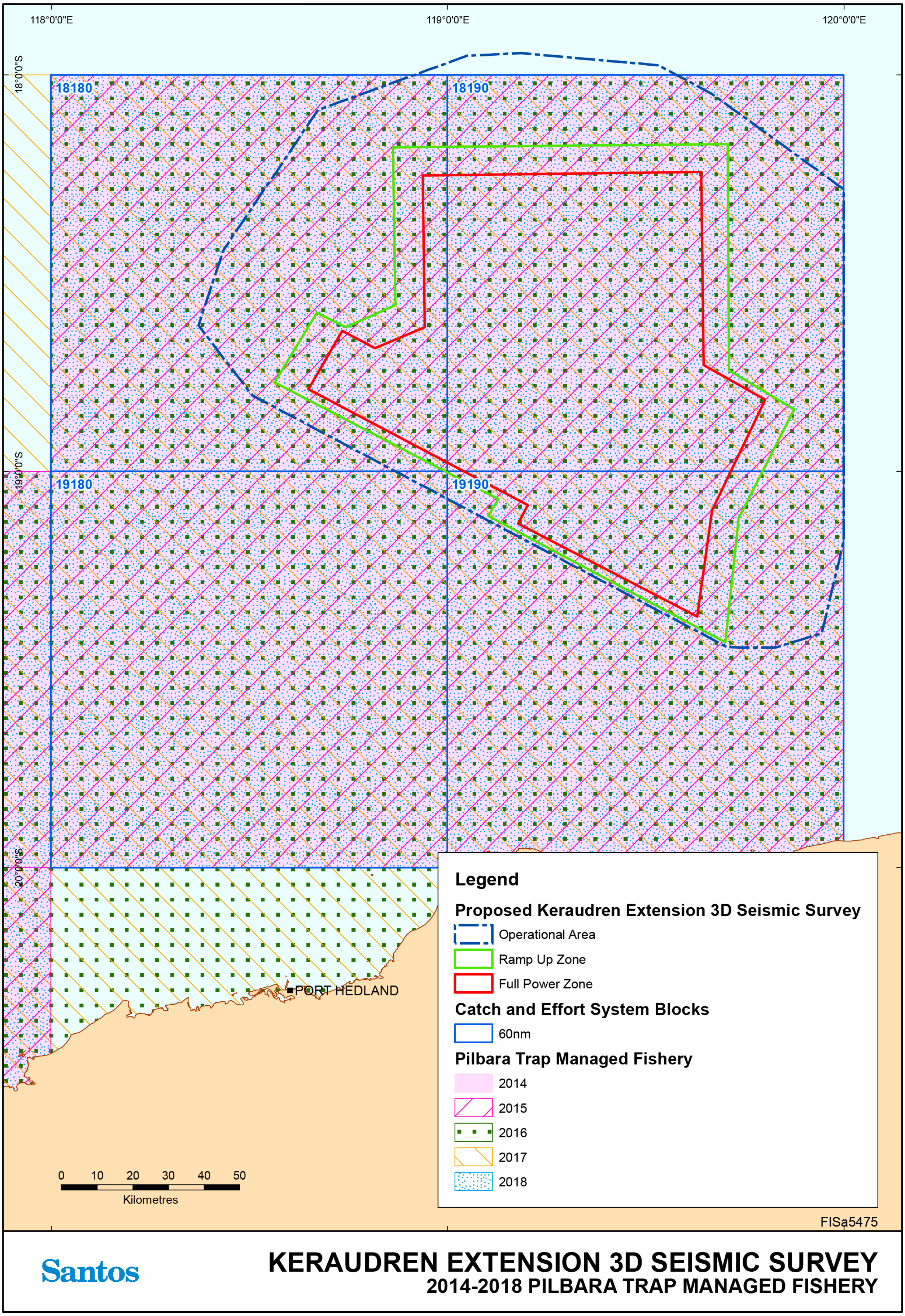


Figure E8: Pilbara Trap Managed Fishery - Annual fishing effort (2014 – 2018)

E7. Specimen Shell Managed Fishery

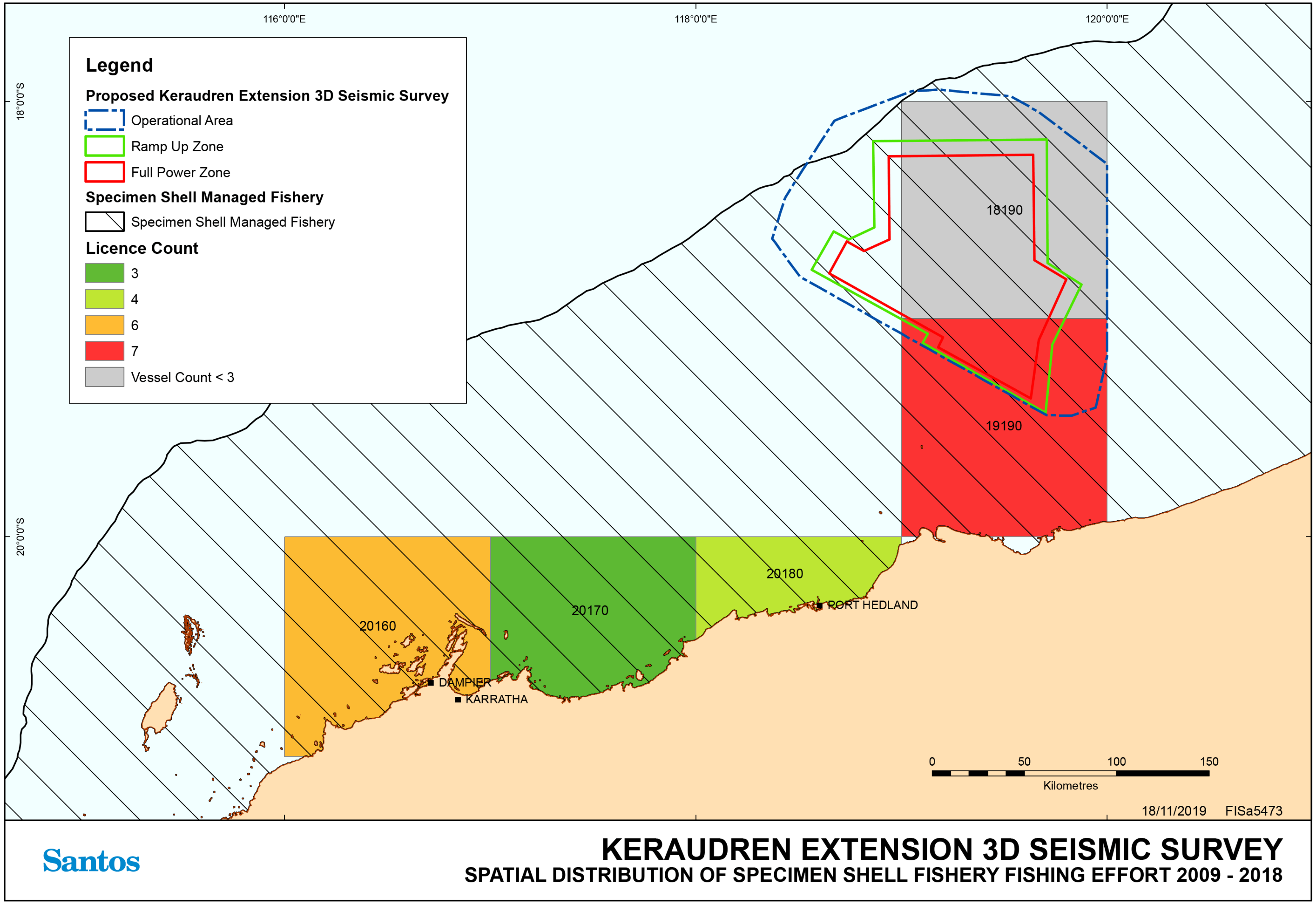


Figure E9: Specimen Shell Managed Fishery fishing effort – 10-year period (2009 – 2018)

E8. Pearl Oyster Managed Fishery (Area 2)

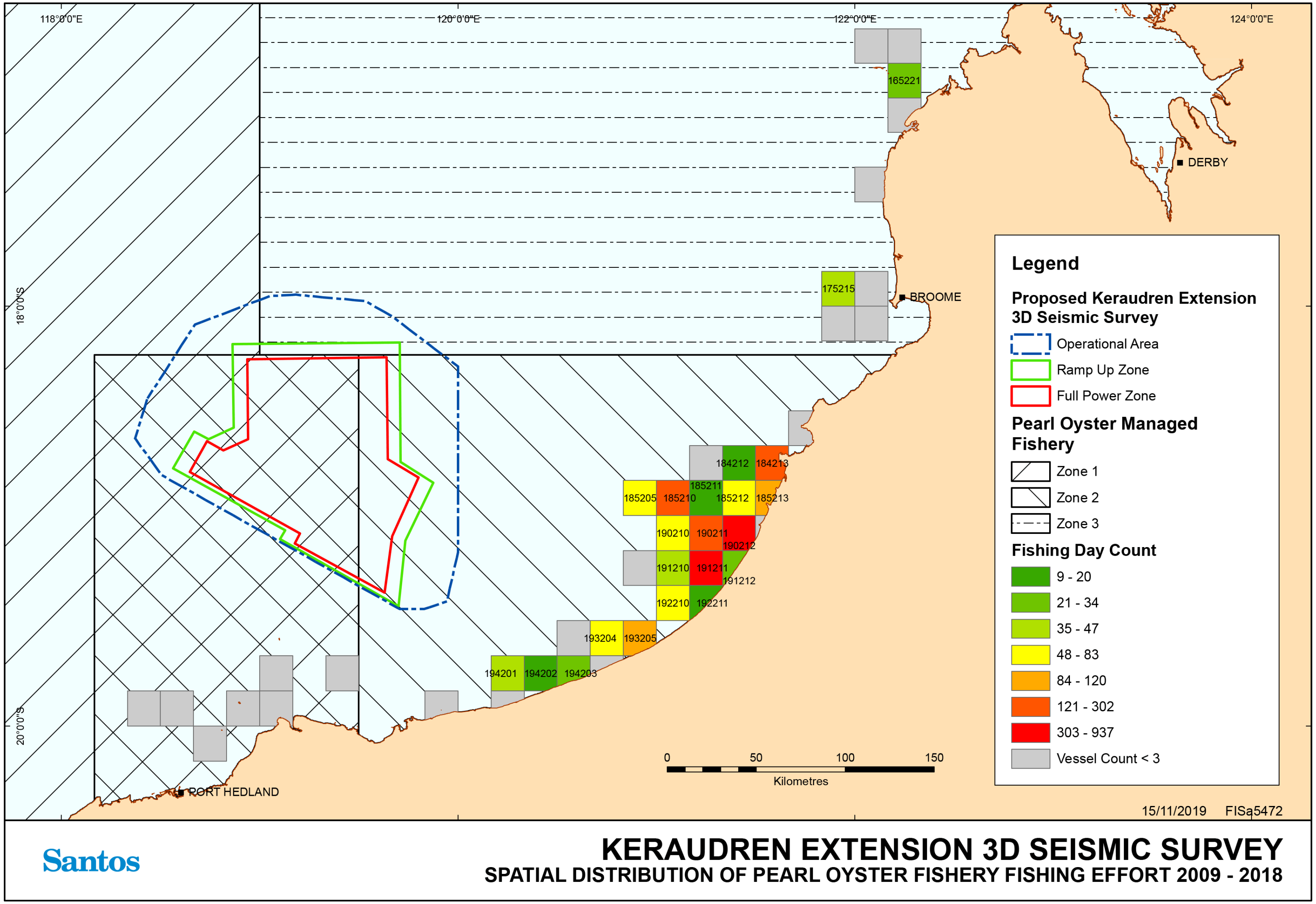
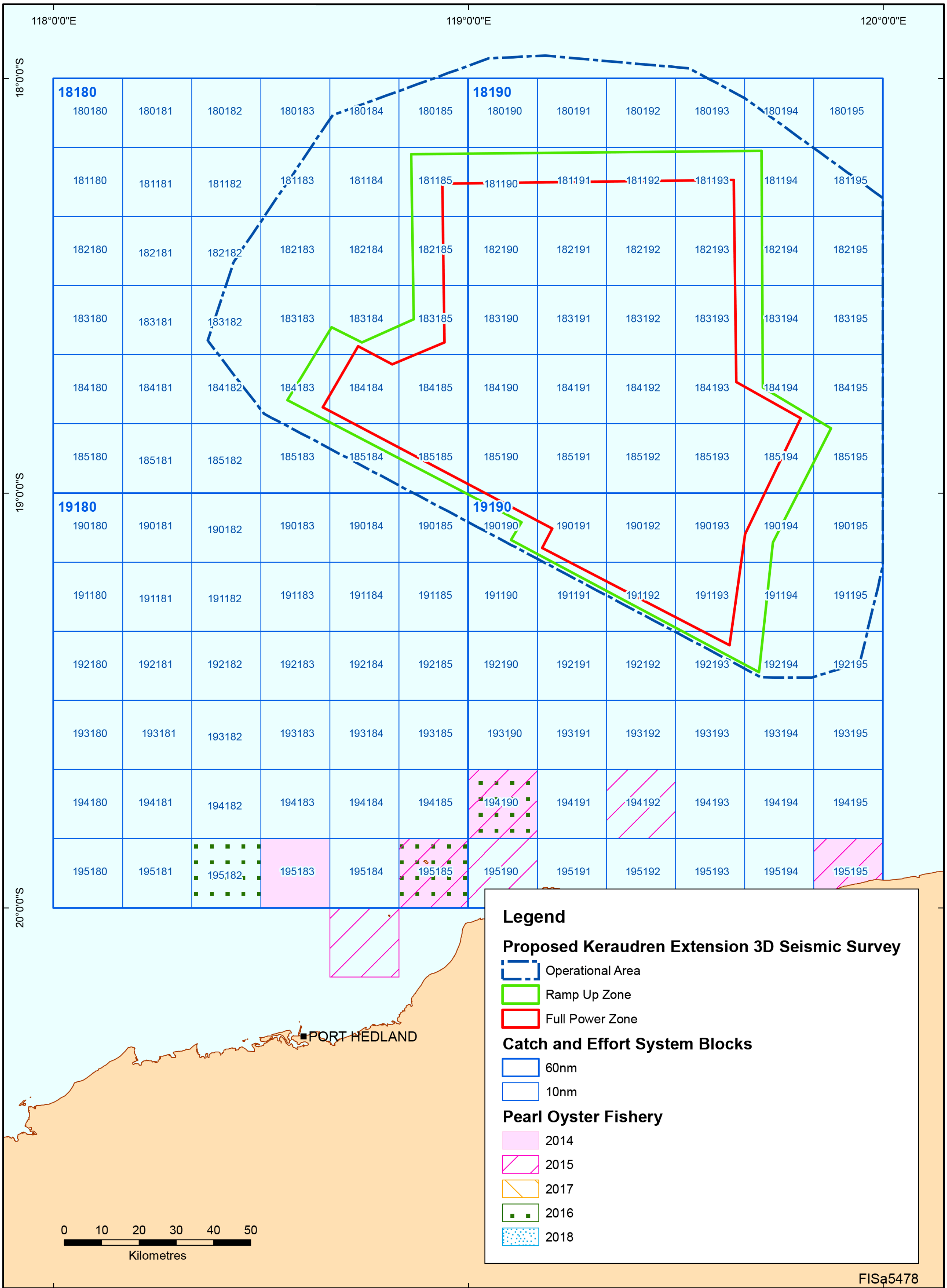


Figure E10: Pearl Oyster Managed Fishery fishing effort – 10-year period (2009 – 2018)



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KERAUDREN EXTENSION 3D SEISMIC SURVEY
2014-2018 PEARL OYSTER FISHERY

Figure E11: Pearl Oyster Managed Fishery - Annual fishing effort (2014 – 2018)

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Appendix F – Stakeholder Consultation Report

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Keraudren Extension 3D Marine Seismic Survey

Environment Plan

STAKEHOLDER CONSULTATION

STAKEHOLDER CONSULTATION

Consultation Correspondence

Consultation, [redacted]

From: Consultation, [redacted]
Sent: Thursday, 10 October 2019 10:40 AM
Subject: Santos Consultation | Keraudren Extension Seismic Survey
Attachments: Santos Consultation - Keraudren Extension Seismic Survey.pdf; SURa5443_Keraudren_Ext_onshore_localities.pdf

Good morning stakeholders,

On behalf of Santos, please find attached consultation material outlining the Keraudren Extension 3D Marine Seismic Survey. The survey is proposed for 2020 in Commonwealth waters offshore Port Hedland WA.

Santos is preparing an Environment Plan in accordance with the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cth).

Should you require additional information or have a comment to make about the proposed activity, please be in touch via the contact details below. Please be aware that your feedback will be communicated to NOPSEMA, as is required under legislation.

We look forward to hearing from you.

Kind regards

Santos

[redacted]
Santos Limited, Level 7 100 St Georges Tce, Perth WA 6000
[redacted]

https://www.santos.com/

[redacted]

From: [redacted]
Sent: Wednesday, 9 October 2019 2:05 PM
To: [redacted]
Cc: [redacted]
Subject: ![EXT]: 2019 Oct 9 - Santos - Bedout Basin - Keraudren Extension 3D Marine Seismic Survey Phase 2 - [redacted]
Attachments: Santos Consultation - Keraudren Extension Seismic Survey.pdf; SANT_3295_Brochure_[redacted].pdf

Good afternoon [redacted]

Santos is preparing an Environment Plan in accordance with the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cth) for the Keraudren Extension 3D Marine Seismic Survey.

WAFIC is sending this information out (via a blind email) on a fee-for-service basis for Santos to ensure all licence holders receive this in a timely manner via an accurate list. All feedback / input etc is to go directly to [redacted] at Santos (see below).

On behalf of Santos, please find attached consultation material outlining this proposed seismic survey incorporating three fact sheets - the first attachment is overarching generic information about all aspects of the proposed seismic survey, the other attachments are information specific to each of your licences in each fishery - [redacted]

Location: Approximately 141 km north of Port Hedland.

Water Depth: Range of approximately 50 metres to 200 metres.

Schedule: Earliest commencement February 2020 pending regulatory approvals and vessel availability, to be acquired in multiple stages between 2020 and 2022.

Survey Duration: Total survey duration across all stages with contingency time included is 161 days.

Exclusion Zone: A 3 NM exclusion zone requested around the seismic vessel and streamers.

Support Vessels: One survey vessel and one or two support vessels.

Feedback: If you have any issues or concerned with these activities, the proposed compensation process or any other issues relevant to this location and this proposed activity then please respond directly to Santos:
[redacted] or 08 6218 [redacted].

Santos has noted that you please be aware that your feedback will be communicated to NOPSEMA, as is required under legislation.

Many thanks [redacted]

[redacted]

WAFIC FISHING PEARLING AQUACULTURE

[redacted]

L1, 56 Marine Tce. Fremantle WA 6160
PO Box 1605. Fremantle WA 6959

T [redacted]
M [redacted]

wafic.org.au
wamsc.com.au

WESTERN AUSTRALIAN FISHING INDUSTRY COUNCIL INC

Santos

STAKEHOLDER CONSULTATION

Notifications

Public Comment Period

NOTIFICATIONS

NOPSEMA Public Comment Period

The following Notice appeared as follows:

- Santos Website from 20 December 2019
- The Australian Newspaper on Monday 6 January 2020
- The West Australian Newspaper on Monday 6 January 2020
- Pilbara News on Wednesday 8 January 2020.

Marine Seismic Survey Notice

Santos Limited is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey activity in Commonwealth Waters approximately 141 km north of Port Hedland in WA. The survey will be acquired in multiple stages between 2020 and 2022, with survey acquisition limited to a window between 1 February and 31 July of each year. The total survey duration (all stages) with contingency time is 161 days.

An environment plan (EP) for the activity has been prepared in accordance with the regulation administered by NOPSEMA under the Offshore Petroleum and Greenhouse Gas Storage Act 2006. A comment period is open until 19 January 2020 providing the public with an opportunity to submit a comment in relation to the EP.

To submit a comment or for further information about the activity, see NOPSEMAs website at:

https:/info.nopsema.gov.au/home/open_for_comment.

Santos

#20W4188336-6/1

From: Consultation, [redacted]
Bcc: [redacted]
Subject: Santos Consultation | Keraudren Extension 3D Marine Seismic Survey - Public Comment period
Date: Friday, 3 January 2020 9:31:00 AM
Attachments: image001.jpg
image003.jpg
image004.jpg
image005.jpg

Good morning

As per previous advice, Santos is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey activity in Commonwealth Waters approximately 141 km north of Port Hedland in WA. The survey will be acquired in multiple stages between 2020 and 2022, with survey acquisition limited to a window between 1 February and 31 July of each year. The total survey duration (all stages) with contingency time is 161 days.

An environment plan (EP) for the activity has been prepared in accordance with the regulation administered by NOPSEMA under the Offshore Petroleum and Greenhouse Gas Storage Act 2006. A comment period is open until 19 January 2020 providing the public with an opportunity to submit a comment in relation to the EP.

To submit a comment or for further information about the activity, see NOPSEMA's website at: https:/info.nopsema.gov.au/home/open_for_comment.

Kind regards

[redacted]
Santos Limited, Level 7 100 St Georges Tce, Perth WA 6000
t: +61 8 6218 [redacted] m: +61 [redacted]

https://www.santos.com/

Santos

STAKEHOLDER CONSULTATION

Consultation Packs

Santos

Bedout Basin

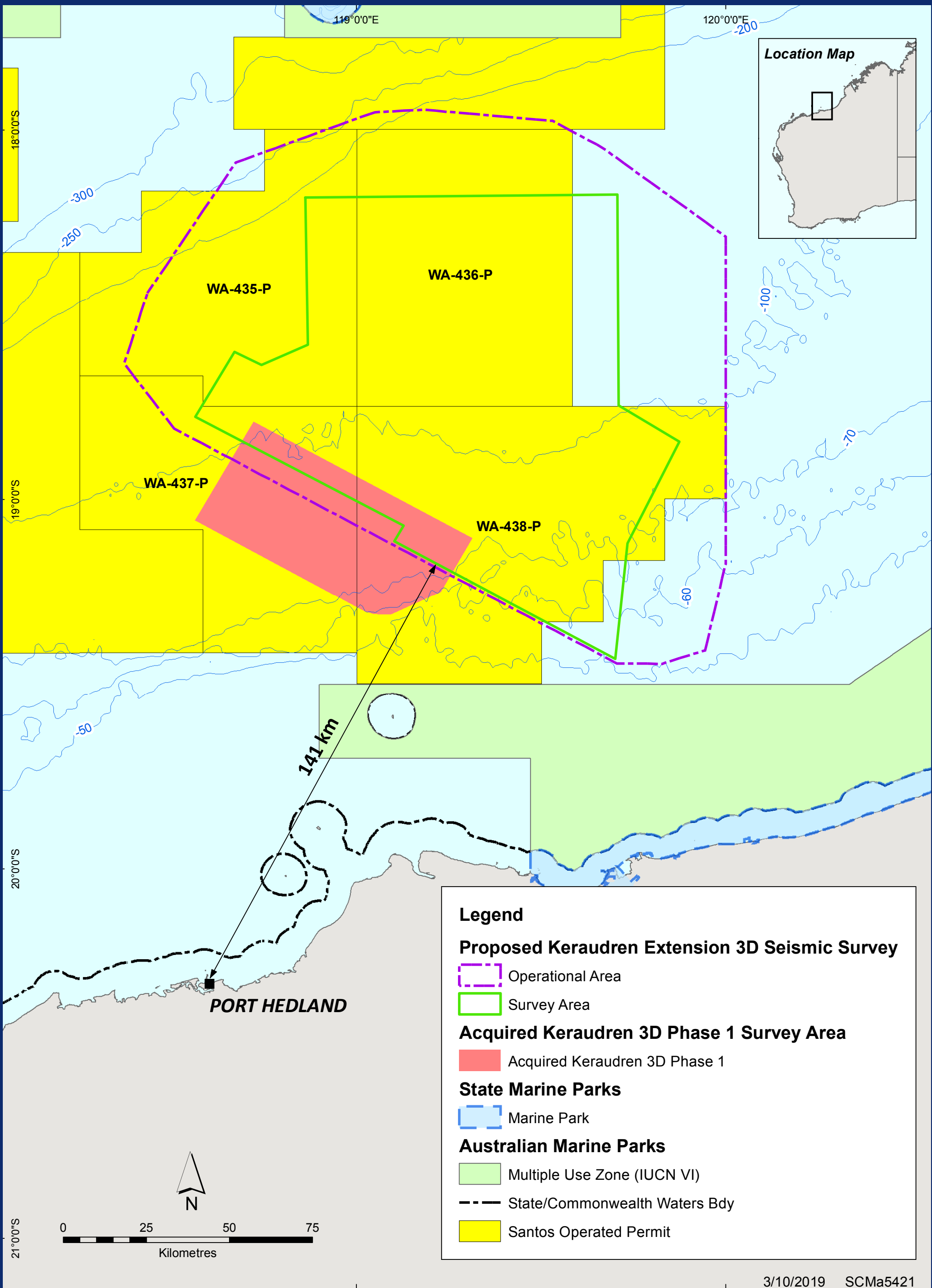
Keraudren Extension 3D Marine Seismic Survey (MSS)

Santos is seeking to acquire subsurface data via a seismic survey in Commonwealth waters approximately 141 km north of Port Hedland. This proposed seismic survey, called Keraudren Extension (Phase 2) - the "Survey", is adjacent to the Keraudren Seismic Survey (Phase 1) completed by Santos in July 2019 and is required to complete exploration and appraisal of the hydrocarbon resources within petroleum permits WA-435-P, WA-436-P, WA-437-P and WA-438-P in the Bedout Sub-basin.

Recent exploration drilling undertaken by Santos in these permits has identified hydrocarbons within several new reservoirs. These results have highlighted the potential to extend prospectivity to a larger area than previously recognised. In order to evaluate this potential and provide adequate coverage and data quality, Santos require additional subsurface data via seismic survey.

KERAUDREN EXTENSION 3D MSS INFORMATION		
Earliest commencement date	February 2020 pending regulatory and business approvals, and vessel availability.	
Estimated duration	Santos will be seeking approval to allow the survey to be acquired in multiple stages between 2020 and 2022. Santos' preference is to complete the survey in two stages, with the first stage in 2020 and second stage in 2021. If this is not achieved, then a further survey (third stage) may be required in 2022. Survey stages will only be acquired in a window between 1 February and 31 July each year. Total survey duration (all stages) with contingency time is 161 days. 24 hour operations.	
Estimated completion	Pending approval, the Environment Plan (EP) will be valid until 31 July 2022.	
Water depth	The water depths of the survey area are in the range of ~50 m to ~200 m.	
Anticipated worst case spill scenario	Vessel collision, considered highly unlikely.	
Response tier required	In the event of a hydrocarbon spill caused by a vessel collision, a Level 2 response would be implemented as per activity-specific Oil Pollution Emergency Plan (OPEP) arrangements described in the EP.	
Survey vessels	One survey vessel, with one to two support vessels. Vessel details are unknown at this point in time.	
Aircraft	Aircraft maybe used for crew changes, critical equipment supply and emergency response uses. Aircraft includes helicopters and drones.	
Exclusion zone details	3 nm requested around survey vessel and streamers.	
Nearest proximity to key regional features	Regional Feature	Distance to survey area
	Port Hedland	141 km
	Eighty Mile Beach State Marine Park	52 km
	Multiple Use Zone Australian Marine Park	7.3 km
	Nearest pearling lease	86 km
	Nearest mainland point	58 km
	Bedout Island	65 km
	Rowley Shoals Marine Park	52 km
	Mermaid Reef	106 km
	Argo-Rowley Terrace Marine Park	47 km

Keraudren Extension location map



SURVEY AREA	
Latitude	**Longitude**
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OPERATIONAL AREA	
Latitude	**Longitude**
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18º 05' 18.564" S	118º 40' 25.232" E
17º 57' 07.051" S	119º 03' 01.378" E
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Proposed Activity

The full fold survey covers a total area of approximately 7,070 km^2. For the purposes of this consultation pack, the "Survey Area" has been expanded to 11,205 km^2 to represent a conservative area within which underwater sound may be emitted from a seismic source (i.e. includes the seismic source array ramp-up and full power zones). An additional buffer around the survey area is allowed for vessel manoeuvring which provides for a total "Operational Area" of 20,108 km^2.

Seismic acquisition will be via methods and procedures similar to other seismic surveys conducted in Australian waters. The seismic survey vessel will travel along a series of pre-determined lines towing cables (known as streamers or acoustic receivers) which contain microphones (known as hydrophones). As the survey vessel travels along the lines, sound waves will be directed down through the water and into the geology below the seabed. The sound that reflects back is measured by the hydrophones and is later processed to provide information about the structure and composition of geological formations below the seabed.

The survey vessel will tow two or three source arrays and 12 streamers, spaced approximately 75 m to 90 m apart. The seismic source arrays will have a total volume not greater than 3,500 cubic inches and be towed approximately 7 m below sea surface. The streamer array will be approximately 9 km long and positioned nominally 20 m below the ocean surface, and always greater than 10 m above seabed.

During the proposed activities, the survey vessel will traverse the pre-determined lines separated by 450 m. The vessel will travel back and forth across the Survey Area in a "race track" pattern, at a speed of approximately 4.5 knots, sending the sound waves down through the water approximately every 8.33 m.

Support vessels will be on standby to direct any shipping traffic away from the survey vessel and towed streamers.

Timing

Survey stages will only be undertaken in the period between 1 February and 31 July.

A 1 March to 31 July period was previously accepted by NOPSEMA for the first Keraudren Survey, and Santos did not request a 1 February start date due to a vessel not being available.

The number and duration of each stage to achieve full survey objectives will depend on weather conditions, environmental factors such as whale migration and vessel availability.

Santos commits to informing stakeholders of the precise survey dates once known. Santos currently anticipates being in the field in an initial window between February and July 2020 subject to regulatory and business approvals, and vessel availability.

Santos commits to ongoing consultation with relevant stakeholders prior to activity commencement, at a frequency suited to individual stakeholders.

Stakeholder Engagement

Santos encourages open, two way communication with stakeholders throughout the planning and implementation of the survey. Receiving this consultation package is the first stage of stakeholder engagement.

If you wish to discuss this consultation material further please provide comment within six weeks.

Consultation for this activity will be ongoing post regulatory acceptance, until the activity is completed.

Environmental Approval

Petroleum activities, which includes seismic surveys, in Commonwealth waters are regulated by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA), a Commonwealth statutory authority. Before Santos can undertake a seismic survey, our plan for managing the environment (the Environment Plan or EP) must be accepted by NOPSEMA in accordance with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations (2009).

The EP will describe the environment in which the survey will take place, an assessment of the impacts and risks arising from the survey, and the identification of control measures to manage the potential impacts and risks to levels that are acceptable and as low as reasonably practicable (ALARP).

Effective 25 April 2019, seismic survey environment plans submitted to NOPSEMA must be published on their website for a 30-day public comment period. Santos anticipates that the survey environment plan will be available for public comment between December 2019 and January 2020. Santos will provide relevant stakeholders with a notification following commencement of the public comment period. Additional information on the public comment period can be found at https://info.nopsema.gov.au/home/open_for_comment.

This process does not remove the need for Santos to consult with relevant persons during preparation of an environment plan. As such, all stakeholders are encouraged to review this material and to make contact with Santos.

While the seismic vessel has yet to be determined, this picture is representative of the type of vessel that will be used.

General Commitments

In the development of the survey Environment Plan, Santos will incorporate similar control measures to those made in the *Keraudren Seismic Survey Environment Plan* (Phase 1) accepted by NOPSEMA on March 25, 2019. Any additional control measures identified during stakeholder engagement and the public comment period will be considered for inclusion in the Environment Plan. A summary of key control measures proposed for the survey are summarised below.

POTENTIAL AREA OF INTEREST	SANTOS COMMITMENTS
Maritime Notices - Notices to Mariners (NTM) and AUSCOAST warnings	A notification will be provided prior to survey vessel arrival in the Operational Area to AMSA's RCC (minimum two days prior), AHO (minimum three weeks prior) and Pilbara Port Authority (minimum one week prior), and following vessel departure (within one week), so the maritime industry is aware of seismic survey activities.
Stakeholder consultation	Relevant persons identified during stakeholder consultation and listed in the Environment Plan will be provided a commencement notification at least two weeks prior to the survey commencing. Santos Consultation Coordinator will remain available before, during and after the survey to ensure stakeholder feedback is recorded, evaluated and responded to.
Exclusion zone established to reduce potential for collision or interference with other marine user activities	An exclusion zone of 3 nautical miles around the survey vessel and streamers will be requested from all vessels in the vicinity of the survey during seismic operations.
Support vessel in place during activity to reduce potential for collision or interference with other marine users	At least one support vessel will be on standby at all times to monitor the survey vessel exclusion zone to identify approaching third-party vessels and communicate with the vessels.
Maritime navigational concerns	A visual and radar watch will be maintained on the bridge at all times. The survey vessel will display appropriate day shapes and lights to indicate it is towing it is therefore restricted in its ability to manoeuvre, and the streamers will tow surface tail buoys fitted with radar reflectors.
Concurrent operational planning with relevant marine users including commercial fishers	Marine user requests to develop communication protocols and provide operational survey plans, commencement and cessation notifications, and daily operational reports will be met. Santos will not restrict commercial fishing access to the Operational Area and is committed to concurrent operational planning with commercial fishers. There will be open radio communications between the survey vessel and commercial fishing vessels, radio details to be provided prior to survey commencement.
Commercial fishery payment ('make good') claims	Santos has made an overarching commitment that commercial fishing licence holders will be no worse off as a result of the seismic survey. All evidence-based payment claims made by commercial fishing licence holders relating to temporary loss of fish catch, displacement costs, or equipment damage or loss due to entanglement with seismic equipment or vessel will be assessed for merit by Santos. Specific details of these arrangements will be distributed to relevant commercial fishers.
No acquisition during peak humpback whale migration	Seismic source arrays will not be operated beyond 31 July each year to avoid the peak humpback whale migration period. Seismic acquisition will be suspended for 24 hours if there are 3 humpback whale sightings within the shutdown/power-down zones within a 24 hour period. If the survey is required to shutdown/ power-down 3 times within 24 hours for 3 consecutive days as a result of sighting humpback whales, this is taken as peak migration and the survey will end.
Identification of presence of divers, concurrent operations with divers.	Santos will notify local diving operators and pearl farm operators of the proposed seismic survey who may undertake diving activities within 60 km of seismic source.
No recreational fishing from any seismic survey or support vessels within the Operational Area	Seismic and support vessels will be prohibited from recreational fishing within the Operational Area.

Feedback

Your feedback concerning potential or perceived impacts of the planned seismic survey is important to us.

If you have any queries or concerns regarding this survey, or any of Santos' current or proposed activities, please contact us as soon as possible by phone or email.

Contact

[redacted]

Telephone: 08 6218 [redacted]

Email: Offshore.Consultation@Santos.com

STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2)
Additional Information for Commercial Fishers

Mackerel Managed Fishery (Area 2)

Santos is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey (Phase 2) - the 'Survey' in Commonwealth waters approximately 141 km north of Port Hedland.

This survey is an extension to the Keraudren Survey (Phase 1) completed in July 2019. Please note, there is very little overlap between Phase 1 and 2. The overlap between the two surveys is required in order to tie-in the acquired data. The approximate overlap would be less than 1 km (~two sail lines).

This supplementary information has been prepared for commercial fishers operating in Commonwealth and State-managed fisheries that intersect the proposed Operational Area. The identified fisheries are:

- **Mackerel Managed Fishery Area 2**
- Nickol Bay Prawn Managed Fishery
- Pearl Oyster Managed Fishery
- Pilbara Crab Managed Fishery
- Pilbara Fish Trawl (Interim) Managed Fishery
- Pilbara Line Fishery
- Pilbara Trap Managed Fishery
- North West Slope Trawl (Commonwealth Managed)
- Western Tuna and Billfish (Commonwealth Managed)

The purpose of this document is to provide additional information for commercial fishers and outline how we can work together with the intent that each can proceed with their business in a safe and efficient manner, and without loss or conflict, by:

- Minimising the extent of interruption by the seismic survey activities on commercial fishing operators' activities to the lowest practicable level;
- Where this is unavoidable, to mitigate the effects of the interruptions, and
- Where commercial fishers may potentially incur additional cost and/or loss, Santos and relevant parties to then proceed to an equitable 'make good' process.

Feedback

Your feedback concerning potential or perceived impacts of the planned seismic survey is important to us.

If you have any queries or concerns regarding the proposed survey and management commitments, please contact us as soon as possible by phone or email.

Equally, if you do not wish to receive further information from Santos on this survey, please advise either directly or through your representative body.

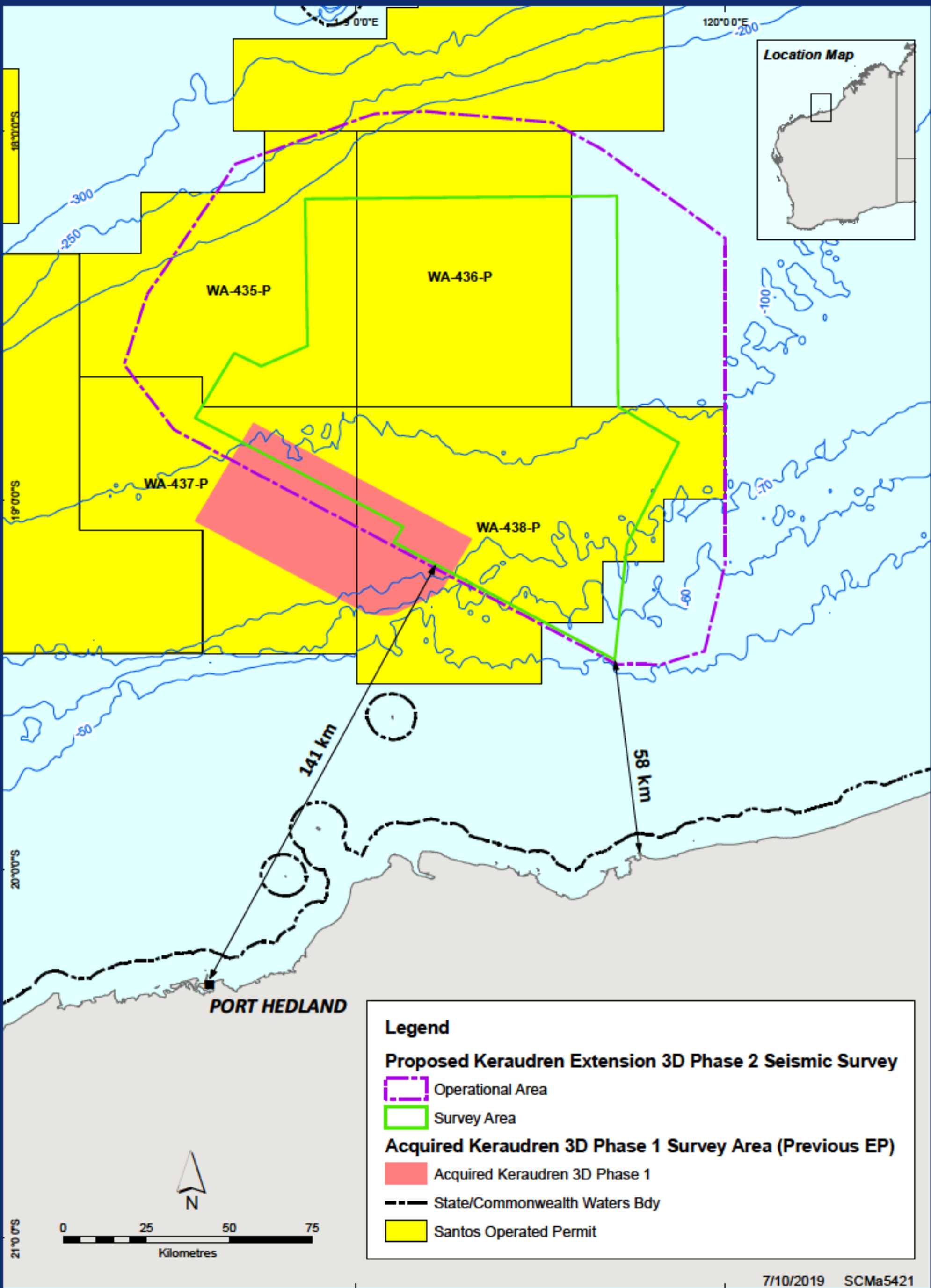
Contact

[redacted]

Telephone: 08 6218 [redacted]

Email: Offshore.Consultation@Santos.com

Keraudren Extension 3D Seismic Survey Location



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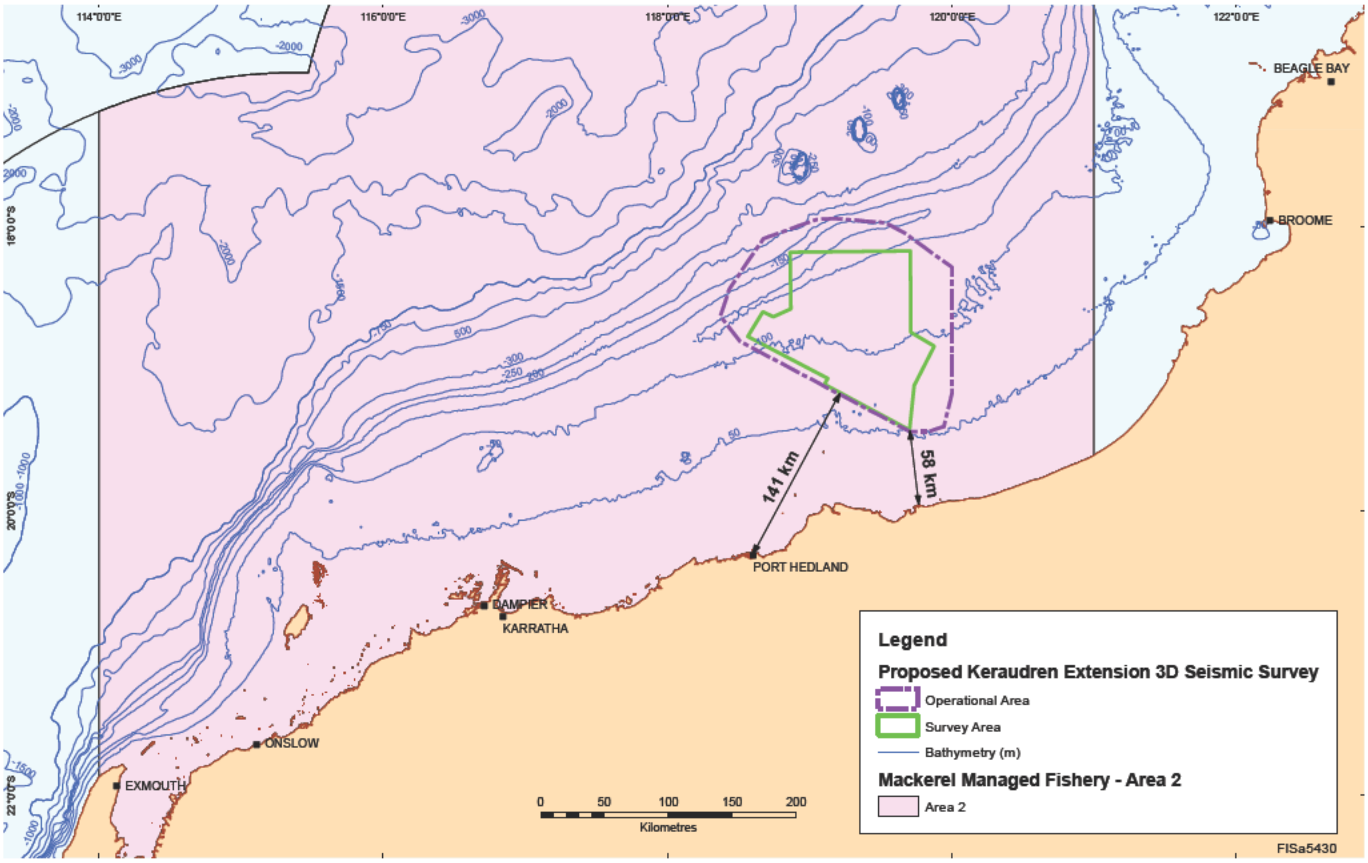
- Closest distance to the coast is 58 km, closest point to Port Hedland is 141 km.
- Water depths of the Survey Area range from approximately 50 m up to 200 m.

Mackerel Managed Fishery (Area 2)



MACKEREL MANAGED FISHERY (AREA 2)	
State managed fisheries	Mackerel Managed Fishery (Area 2)
Does the operational area overlap the fishery?	Yes
Has there been historical fishing effort in the operational area?	Yes
No. of fishery licence holders	22 licence holders (Area 2) 1 or 2 vessels throughout 2013 - 2017
Target species	Spanish Mackerel, Grey Mackerel
Fishing season[1]	All year – peak May to August Roughly 3 days per trip
Operational area overlap	Based on a review of Fish Cube[2] data, there has been historical mackerel fishing effort in the southern end of the Survey Area, surrounding the 60 m water depth contour. Fish Cube data shows that 37,219 km² of the Mackerel Managed Fishery (Area 2) has been fished between 2013 to 2017. The Survey Area overlaps with 701 km² or 1.88% of this area of recorded fishing effort. This overlap percentage is based on the area of historical fishing effort and not the entire fishery area, which is 50,507 km².

1. Fishing season information is based on historical stakeholder consultation with fishers.
2. Based on 2013-2017 Fish Cube data. Santos is currently sourcing 2018 data from DPIRD and will include this information in the environment plan.

Timing and duration

Key timing and duration considerations:

- Santos plans to split the survey over multiple stages between 2020 and 2022.
- Targeting stage one in 2020 and stage two in 2021.
- If data acquisition in stage one or two remains incomplete (i.e. due to weather delays, vessel issues, approval delays, etc.), then a stage three in 2022 may be required.
- Surveys will only be acquired in a window between 1 February and 31 July each year.
- There will be no survey activity between 1 August and 31 January each year.
- Total survey duration (all stages) with extra time added for any contingencies is 161 days (over 2020, 2021 and possibly 2022).
- Each survey stage would be acquired over a nominal 70 to 80 day period.
- 24-hour operations.

NOPSEMA previously accepted a 1 March to 31 July period for the Keraudren Survey (Phase 1) under the Environment Plan (EP) accepted in April and survey completed in July 2019. Under this EP Santos did not request a 1 February start date due to a vessel not being available.

The proposed survey window attempts to minimise overlap with spawning periods of commercial key indicator fish species and migrating whales – see below 'Operating Window Environmental Sensitives Chart'.

The actual timing of the survey stages will be subject to the receipt of the necessary regulatory and business approvals and availability of suitable seismic vessels.

Commercial fishers are encouraged to contact Santos to discuss the survey timing and duration, as well as known fish spawning periods. Santos has acquired some helpful information via DPIRD's Fish Cube process but would welcome your input regarding:

- your peak fishing months; and
- where during these months your fishing activity occurs.

This will assist Santos to manage interface with commercial fishers in the Operational Area.

Survey acquisition

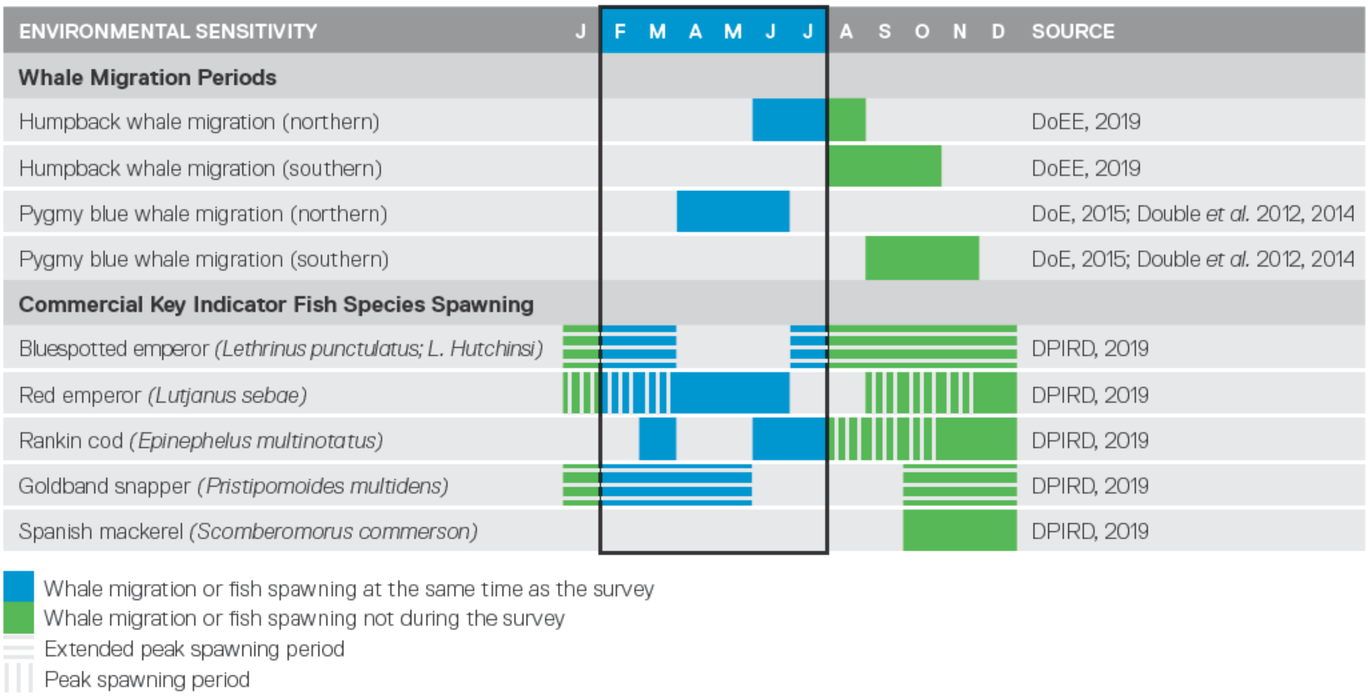
Survey acquisition will be via methods and procedures similar to other seismic surveys conducted in Australia:

- 'Racetrack' pattern.
- First stage most likely in the southern part of the Survey Area.
- Survey azimuths have not been finalised.
- Each survey stage could be acquired in different directions.

Commercial fishers are encouraged to contact Santos to discuss the proposed survey acquisition sequence and ways to minimise interference with fishing operations and vessel movements.

Operating Window: Environmental Sensitives Chart

Santos is proposing to conduct the survey in the February to July window to reduce risks to spawning commercial key indicator fish species and migrating whales.



Operational Area access and concurrent operations

Key considerations:

- Fishers will be able to access the Operational Area during the survey.
- Santos will operate concurrently with fishers.
- Safety requirements during concurrent operations - all commercial fishers to observe a 3 nautical mile (nm) exclusion zone around the survey vessel and streamers (standard survey practice).

Santos' control measures (commitments) identified within the draft Environment Plan, will outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed. The management objectives are consistent with those adopted in Keraudren Survey (Phase 1):

- No unplanned interactions with commercial fishers.
- Commercial fishing licence holders to be no worse off as a result of the seismic survey.

No unplanned interactions

The table below contains an outline of the proposed control measures to ensure no unplanned interactions, and the expected way of evidencing compliance to these measures. Commercial fishers are encouraged to contact Santos for a copy of the draft communications protocol referred to in the below table.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
Santos will not restrict commercial fishing access to the Operational Area and is committed to concurrent operational planning with commercial fishers.	Documented correspondence with commercial fishing licence holders.
Santos will develop communication protocols including direct radio contact for both parties at sea and provide operational survey plans, commencement and cessation notifications, and daily operational reports if requested.	Documented correspondence with commercial fishing licence holders.
At a minimum the daily operational reports will include: • Current seismic survey vessel position. • Look ahead seismic survey activities and vessel positions. • Support vessel activities and positions. • Vessel contact details. • Santos WA management contact details.	Completed daily reports.
Support vessels outside of the range of the active seismic survey will avoid commercial vessels that are actively fishing, and avoid schooling fish in the vicinity of active commercial fishing.	Completed daily reports.

Commercial fishery payment ('make good') claims

The survey will potentially impact commercial fishers whose fishing operations overlap with the seismic survey.

Santos has made an overarching commitment that commercial fishing licence holders will be no worse off as a result of the seismic survey and propose measures that enable commercial fishers to lodge a claim ('make good' payment) if applicable.

Make good payments to commercial fishing licence holders will be assessed for loss of catch and relocation expenses should concurrent fishing and seismic vessel operations not be practicable.

Santos will also assess requests for administrative support to help fishers collate historical fishing data required for make good payment claims.

Santos has based the commercial fishery payment model (described below) on what it understands to be Oil and Gas best practice for an evidence-based make good model, leveraging the CSIRO peer reviewed model that Santos implemented for the NOPSEMA–accepted Santos Bethany 3D Seismic Survey and Keraudren 3D Seismic Survey (Phase 1). CSIRO (2017) confirmed the approach proposed by Santos was consistent with international best practice.

Santos believes that the principles of the model presented below are sufficiently clear and will assess any payment claims in good faith. Commercial fishers are encouraged to contact Santos to discuss the proposed fishery payment claim model.

The control measures (commitments) identified within the draft Environment Plan, to outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed, are consistent with those adopted in Keraudren Survey (Phase 1). The management objective is to ensure Commercial fishing licence holders are no worse off as a result of the seismic survey.

While the seismic vessel has yet to be determined, this picture is representative of the type of vessel that will be used.

Commercial fishery payment ('make good') claims

The table below contains an outline of the proposed control measures and the expected way of evidencing compliance to these measures.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
All evidence-based payment claims made by commercial fishing licence holders relating to temporary loss of fish catch from within the Operational Area or displacement costs from the Operational Area as caused by each survey stage are assessed for merit by Santos.	Santos' merit assessment of commercial fishing licence holder claim. Documented correspondence with commercial fishing licence holders.
Payment to a commercial fishing licence holder for each month there is a loss of catch by the commercial fishing licence holder based on an assessment of what the commercial fishing licence holder would have caught in that month from within the Operational Area "but for" the survey stage.	Records of payment to commercial fishing licence holders.
A loss of catch will be concluded if there is a reduction in the catch per unit of effort for each species calculated over a month, compared to the average historical catch per unit of effort for the same species and corresponding month. Santos' preference is for 10 years of data to determine the average historical catch per unit of effort. However, this will be assessed on a case-by-case basis.	Documented loss of catch assessment and supporting fishing data.
If a loss of catch is substantiated, payments will be calculated based on the reduced kilograms per species caught, multiplied by market price per kilogram at the time the catch would have been sold.	Documented payment calculations and supporting fishing and market data.
Loss of catch payments will be assessed for the months of each survey stage and for up to 6 months from the completion date of each survey stage. The 6 months is considered a reasonable time to claim for a temporary loss of catch and to minimise overlap between survey stages.	Records of payment to commercial fishing licence holders, if there are claims.
Where a commercial fishing licence holder wants to receive a loss of catch payment, they will need to provide Santos with monthly catch disposal records and multiple years of historical data to allow average monthly catch rates per species to be determined. Santos' preference is for 10 years of historical data. However, this will be assessed on a case-by-case basis.	Commercial fishing licence holder payment claim and multiple years of fish catch disposal records.
Where a commercial fishing licence holder is displaced from the operational area such that it is required to relocate their operations to another area during a survey stage, Santos will make a one off payment to reimburse operational expenses which are in addition to those the commercial fishing licence holder would have borne "but for" the seismic survey stage.	Records of payment to commercial fishing licence holders.
Where a commercial fishing licence holder intends to make an operational expense claim for relocation, they will need to notify Santos as soon as practicable and prior to relocating, and state why the seismic survey has caused them to relocate. The notification can be via radio between the fishing and survey vessel.	Relocation notification from commercial fishing licence holder and Santos acknowledgement.
Where a commercial fishing licence holder wants to be reimbursed for any relocation operational expenses, they will need to provide Santos with evidence of the operating costs of bait, fuel, wages and any other costs that are additional to the costs that would have been incurred to catch the fish "but for" the relocation.	Commercial fishing licence holder historical operating cost records and relocation cost records.
Where a commercial fishing licence holder wants to receive any payment for loss of catch or relocation, they will need to lodge a claim with Santos within 8 months of the survey stage completion. The 8 months is intended to give fishers reasonable time to prepare a claim and to minimise overlap between subsequent survey stages. Noting Santos' preparedness to provide administrative support to collate fishing data for fishers.	Commercial fishing licence holder claim and supporting evidence.
Santos will not accept a claim under this Environment Plan for loss of catch and/or relocation if the claim covers the same time, area and fishing activity made in another claim for a different seismic survey.	Correspondence records.
If there are any issues with the required evidence, loss of catch determination or payment amount, Santos will, in consultation with the commercial fishing licence holder, engage an independent relevant expert to determine the issue.	Consultation with commercial fishing licence holders about appointment of independent expert (if required). Independent relevant expert assessment record (if required).
The loss of catch and relocation payment control measures will apply unless Santos enters into an agreement with a commercial fishing operator in relation to the potential impact of the survey on them. In the event of an agreement, the agreement will replace the loss of catch and/or relocation payment as the control measure.	Agreement with commercial fishing licence holder. Evidence of Santos adherence to terms of the agreement

In the event that a commercial fisher has observed a reduced catch during or immediately following the completed 2019 Keraudren Seismic Survey or is considering making a claim for the completed survey, please contact Santos as soon as possible to discuss the matter.

STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2)
Additional Information for Commercial Fishers

Nickol Bay Prawn and Pilbara Crab Managed Fisheries

Santos is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey (Phase 2) - the 'Survey' in Commonwealth waters approximately 141 km north of Port Hedland.

This survey is an extension to the Keraudren Survey (Phase 1) completed in July 2019. Please note, there is very little overlap between Phase 1 and 2. The overlap between the two surveys is required in order to tie-in the acquired data. The approximate overlap would be less than 1 km (~two sail lines).

This supplementary information has been prepared for commercial fishers operating in Commonwealth and State-managed fisheries that intersect the proposed Operational Area. The identified fisheries are:

- Mackerel Managed Fishery Area 2
- **Nickol Bay Prawn Managed Fishery**
- Pearl Oyster Managed Fishery
- **Pilbara Crab Managed Fishery**
- Pilbara Fish Trawl (Interim) Managed Fishery
- Pilbara Line Fishery
- Pilbara Trap Managed Fishery
- North West Slope Trawl (Commonwealth Managed)
- Western Tuna and Billfish (Commonwealth Managed)

The purpose of this document is to provide additional information for commercial fishers and outline how we can work together with the intent that each can proceed with their business in a safe and efficient manner, and without loss or conflict, by:

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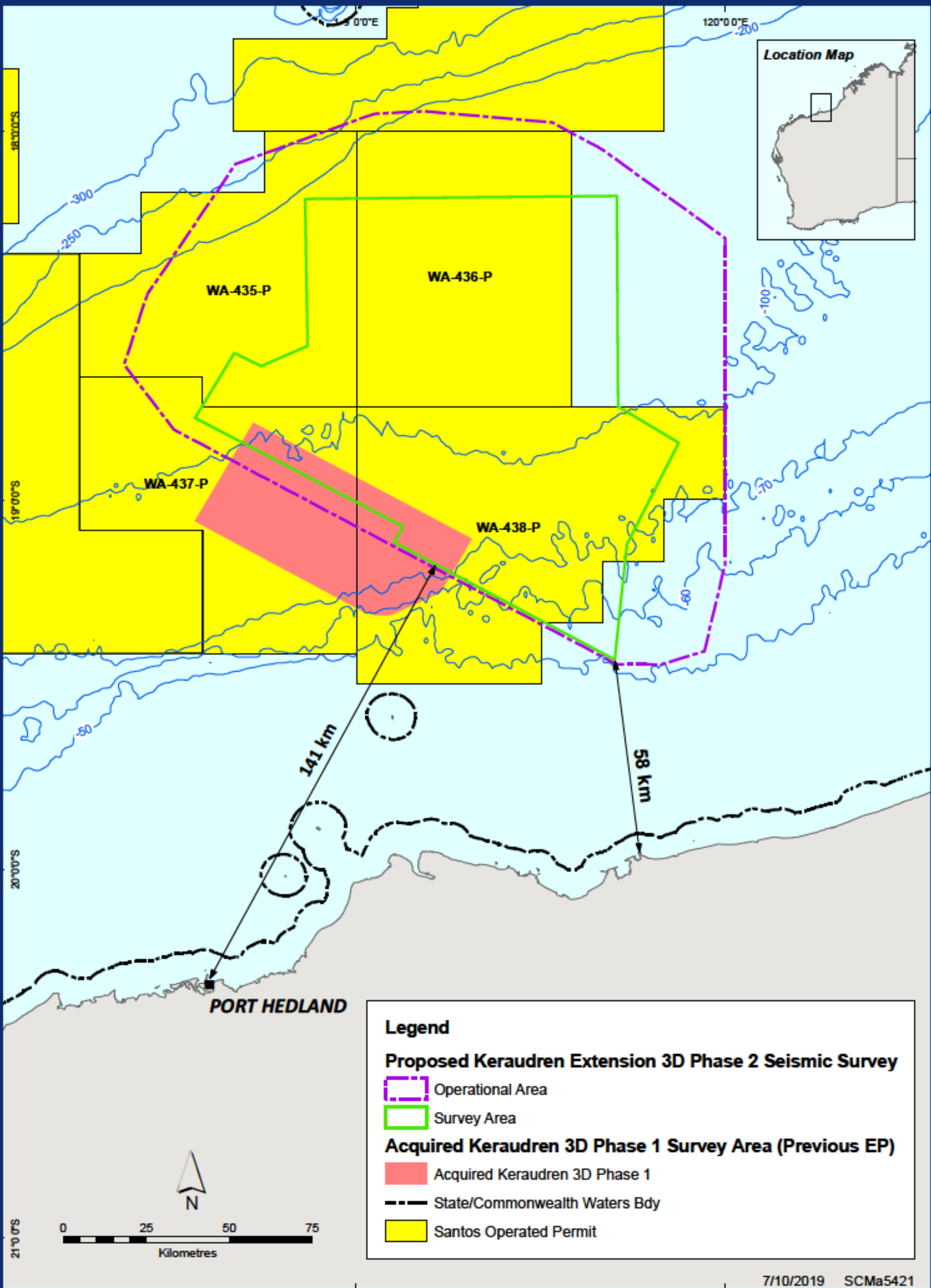
Contact

[redacted]

Telephone: 08 6218 [redacted]

Email: Offshore.Consultation@Santos.com

Keraudren Extension 3D Seismic Survey Location



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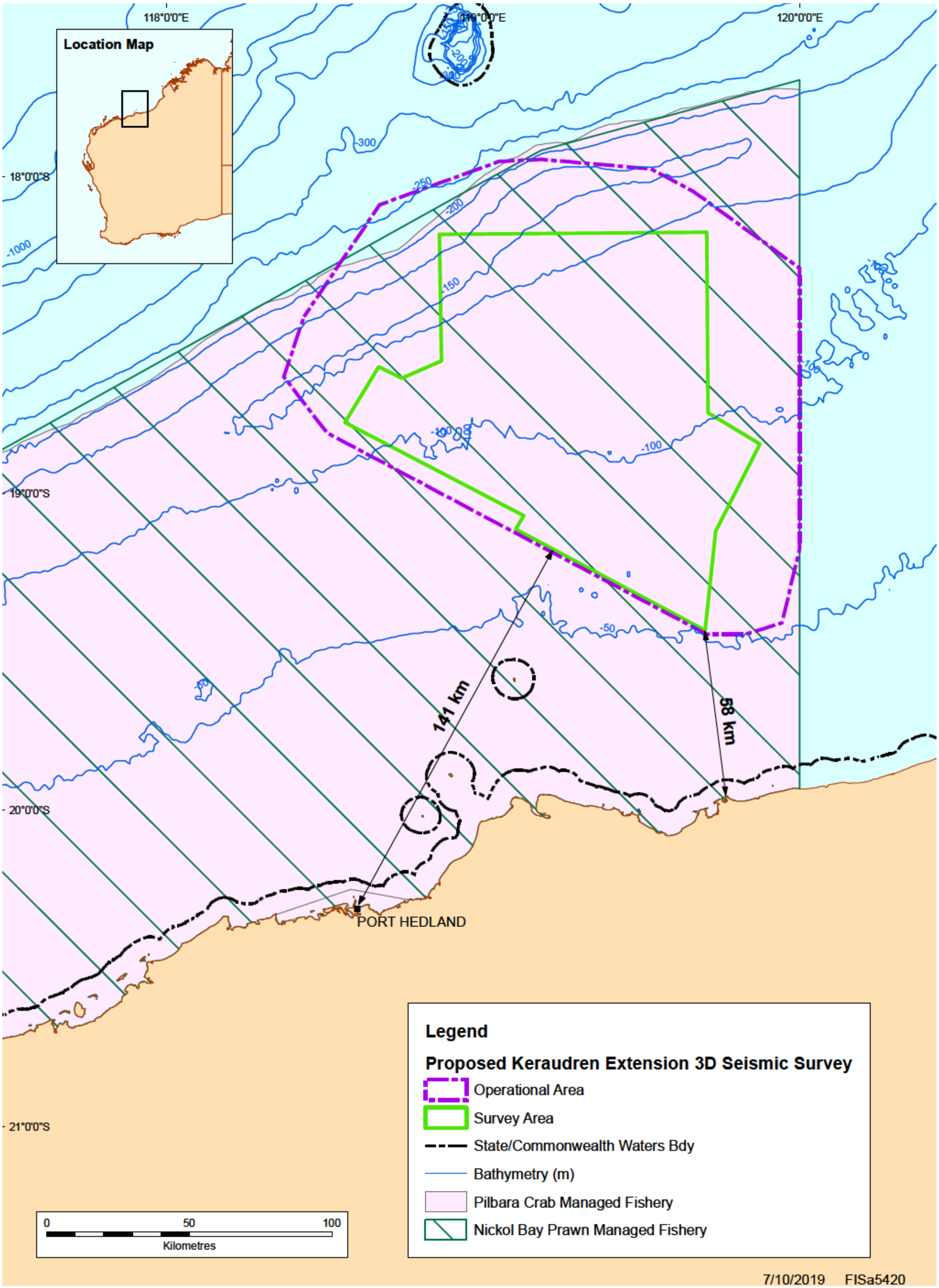
- Closest distance to the coast is 58 km, closest point to Port Hedland is 141 km.
- Water depths of the Survey Area range from approximately 50 m up to 200 m.

Nickol Bay Prawn and Pilbara Crab Managed Fisheries



Timing and duration

Key timing and duration considerations:

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The proposed survey window attempts to minimise overlap with spawning periods of commercial key indicator fish species and migrating whales – see below 'Operating Window Environmental Sensitives Chart'.

The actual timing of the survey stages will be subject to the receipt of the necessary regulatory and business approvals and availability of suitable seismic vessels.

Commercial fishers are encouraged to contact Santos to discuss the survey timing and duration, as well as known fish spawning periods. Santos has acquired some helpful information via DPIRD's Fish Cube process but would welcome your input regarding:

- your peak fishing months; and
- where during these months your fishing activity occurs.

This will assist Santos to manage interface with commercial fishers in the Operational Area.

Survey acquisition

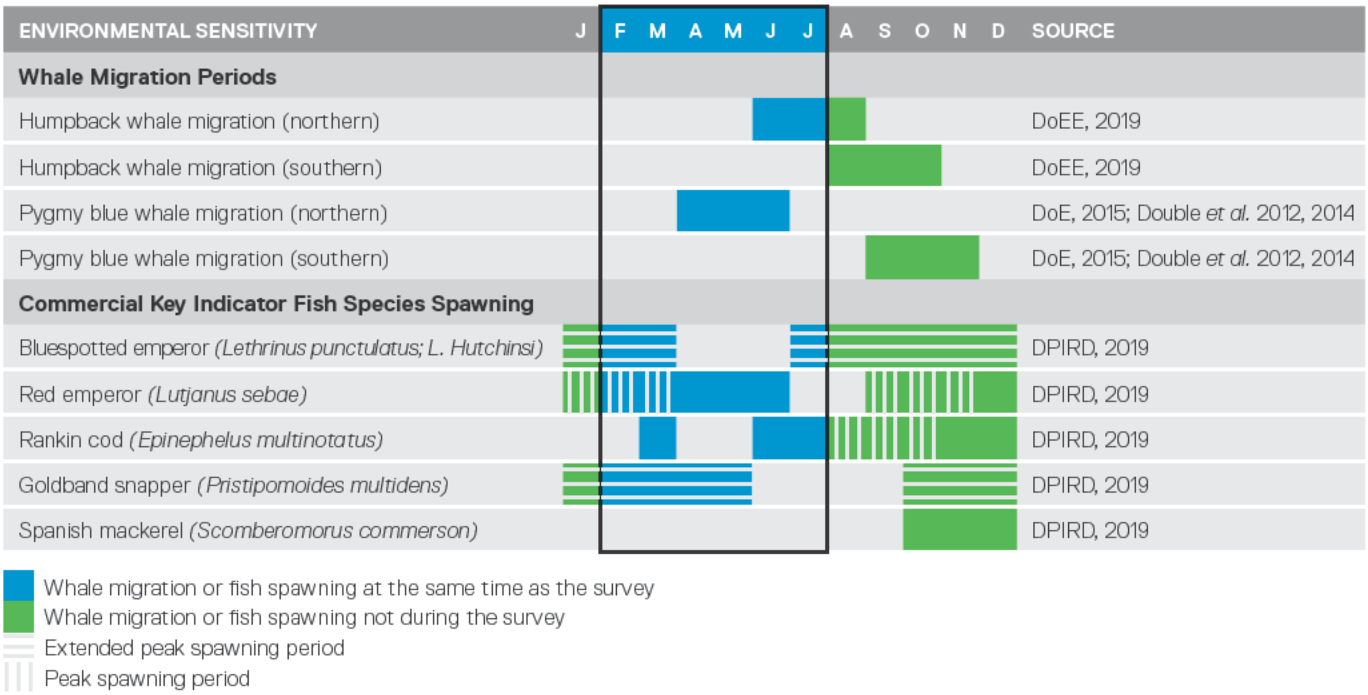
Survey acquisition will be via methods and procedures similar to other seismic surveys conducted in Australia:

- 'Racetrack' pattern.
- First stage most likely in the southern part of the Survey Area.
- Survey azimuths have not been finalised.
- Each survey stage could be acquired in different directions.

Commercial fishers are encouraged to contact Santos to discuss the proposed survey acquisition sequence and ways to minimise interference with fishing operations and vessel movements.

Operating Window: Environmental Sensitives Chart

Santos is proposing to conduct the survey in the February to July window to reduce risks to spawning commercial key indicator fish species and migrating whales.



Operational Area access and concurrent operations

Key considerations:

- Fishers will be able to access the Operational Area during the survey.
- Santos will operate concurrently with fishers.
- Safety requirements during concurrent operations - all commercial fishers to observe a 3 nautical mile (nm) exclusion zone around the survey vessel and streamers (standard survey practice).

Santos' control measures (commitments) identified within the draft Environment Plan, will outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed. The management objectives are consistent with those adopted in Keraudren Survey (Phase 1):

- No unplanned interactions with commercial fishers.
- Commercial fishing licence holders to be no worse off as a result of the seismic survey.

No unplanned interactions

The table below contains an outline of the proposed control measures to ensure no unplanned interactions, and the expected way of evidencing compliance to these measures. Commercial fishers are encouraged to contact Santos for a copy of the draft communications protocol referred to in the below table.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
Santos will not restrict commercial fishing access to the Operational Area and is committed to concurrent operational planning with commercial fishers.	Documented correspondence with commercial fishing licence holders.
Santos will develop communication protocols including direct radio contact for both parties at sea and provide operational survey plans, commencement and cessation notifications, and daily operational reports if requested.	Documented correspondence with commercial fishing licence holders.
At a minimum the daily operational reports will include: • Current seismic survey vessel position. • Look ahead seismic survey activities and vessel positions. • Support vessel activities and positions. • Vessel contact details. • Santos WA management contact details.	Completed daily reports.
Support vessels outside of the range of the active seismic survey will avoid commercial vessels that are actively fishing, and avoid schooling fish in the vicinity of active commercial fishing.	Completed daily reports.

Commercial fishery payment ('make good') claims

The survey will potentially impact commercial fishers whose fishing operations overlap with the seismic survey.

Santos has made an overarching commitment that commercial fishing licence holders will be no worse off as a result of the seismic survey and propose measures that enable commercial fishers to lodge a claim ('make good' payment) if applicable.

Make good payments to commercial fishing licence holders will be assessed for loss of catch and relocation expenses should concurrent fishing and seismic vessel operations not be practicable.

Santos will also assess requests for administrative support to help fishers collate historical fishing data required for make good payment claims.

Santos has based the commercial fishery payment model (described below) on what it understands to be Oil and Gas best practice for an evidence-based make good model, leveraging the CSIRO peer reviewed model that Santos implemented for the NOPSEMA–accepted Santos Bethany 3D Seismic Survey and Keraudren 3D Seismic Survey (Phase 1). CSIRO (2017) confirmed the approach proposed by Santos was consistent with international best practice.

Santos believes that the principles of the model presented below are sufficiently clear and will assess any payment claims in good faith. Commercial fishers are encouraged to contact Santos to discuss the proposed fishery payment claim model.

The control measures (commitments) identified within the draft Environment Plan, to outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed, are consistent with those adopted in Keraudren Survey (Phase 1). The management objective is to ensure Commercial fishing licence holders are no worse off as a result of the seismic survey.

While the seismic vessel has yet to be determined, this picture is representative of the type of vessel that will be used.

Commercial fishery payment ('make good') claims

The table below contains an outline of the proposed control measures and the expected way of evidencing compliance to these measures.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
All evidence-based payment claims made by commercial fishing licence holders relating to temporary loss of fish catch from within the Operational Area or displacement costs from the Operational Area as caused by each survey stage are assessed for merit by Santos.	Santos' merit assessment of commercial fishing licence holder claim. Documented correspondence with commercial fishing licence holders.
Payment to a commercial fishing licence holder for each month there is a loss of catch by the commercial fishing licence holder based on an assessment of what the commercial fishing licence holder would have caught in that month from within the Operational Area "but for" the survey stage.	Records of payment to commercial fishing licence holders.
A loss of catch will be concluded if there is a reduction in the catch per unit of effort for each species calculated over a month, compared to the average historical catch per unit of effort for the same species and corresponding month. Santos' preference is for 10 years of data to determine the average historical catch per unit of effort. However, this will be assessed on a case-by-case basis.	Documented loss of catch assessment and supporting fishing data.
If a loss of catch is substantiated, payments will be calculated based on the reduced kilograms per species caught, multiplied by market price per kilogram at the time the catch would have been sold.	Documented payment calculations and supporting fishing and market data.
Loss of catch payments will be assessed for the months of each survey stage and for up to 6 months from the completion date of each survey stage. The 6 months is considered a reasonable time to claim for a temporary loss of catch and to minimise overlap between survey stages.	Records of payment to commercial fishing licence holders, if there are claims.
Where a commercial fishing licence holder wants to receive a loss of catch payment, they will need to provide Santos with monthly catch disposal records and multiple years of historical data to allow average monthly catch rates per species to be determined. Santos' preference is for 10 years of historical data. However, this will be assessed on a case-by-case basis.	Commercial fishing licence holder payment claim and multiple years of fish catch disposal records.
Where a commercial fishing licence holder is displaced from the operational area such that it is required to relocate their operations to another area during a survey stage, Santos will make a one off payment to reimburse operational expenses which are in addition to those the commercial fishing licence holder would have borne "but for" the seismic survey stage.	Records of payment to commercial fishing licence holders.
Where a commercial fishing licence holder intends to make an operational expense claim for relocation, they will need to notify Santos as soon as practicable and prior to relocating, and state why the seismic survey has caused them to relocate. The notification can be via radio between the fishing and survey vessel.	Relocation notification from commercial fishing licence holder and Santos acknowledgement.
Where a commercial fishing licence holder wants to be reimbursed for any relocation operational expenses, they will need to provide Santos with evidence of the operating costs of bait, fuel, wages and any other costs that are additional to the costs that would have been incurred to catch the fish "but for" the relocation.	Commercial fishing licence holder historical operating cost records and relocation cost records.
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In the event that a commercial fisher has observed a reduced catch during or immediately following the completed 2019 Keraudren Seismic Survey or is considering making a claim for the completed survey, please contact Santos as soon as possible to discuss the matter.

STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2) Additional Information for Commercial Fishers

North West Slope Trawl and Western Tuna and Billfish Fisheries (Commonwealth Managed)

Santos is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey (Phase 2) - the 'Survey' in Commonwealth waters approximately 141 km north of Port Hedland.

This survey is an extension to the Keraudren Survey (Phase 1) completed in July 2019. Please note, there is very little overlap between Phase 1 and 2. The overlap between the two surveys is required in order to tie-in the acquired data. The approximate overlap would be less than 1 km (~two sail lines).

This supplementary information has been prepared for commercial fishers operating in Commonwealth and State-managed fisheries that intersect the proposed Operational Area. The identified fisheries are:

- Mackerel Managed Fishery Area 2
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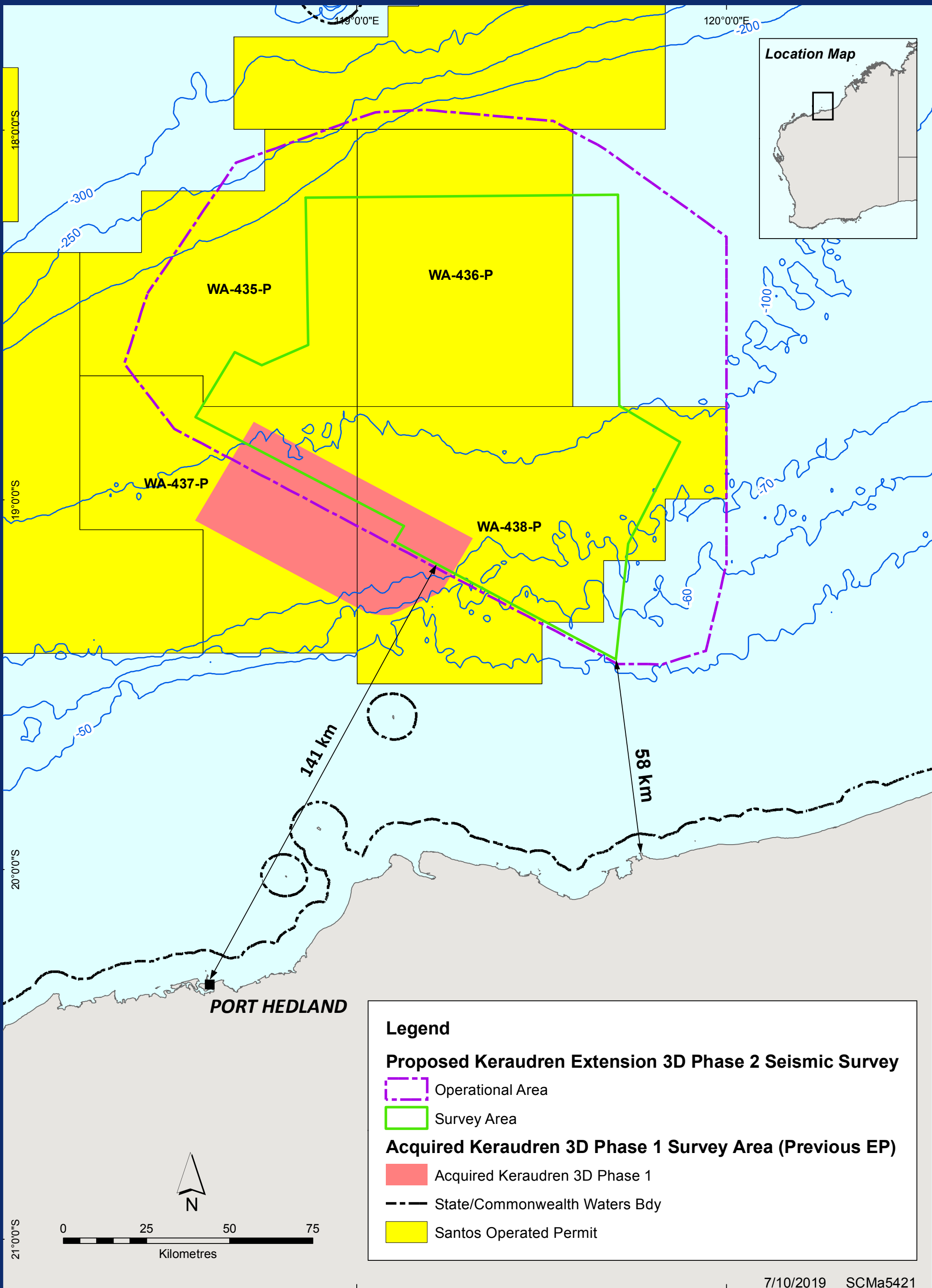

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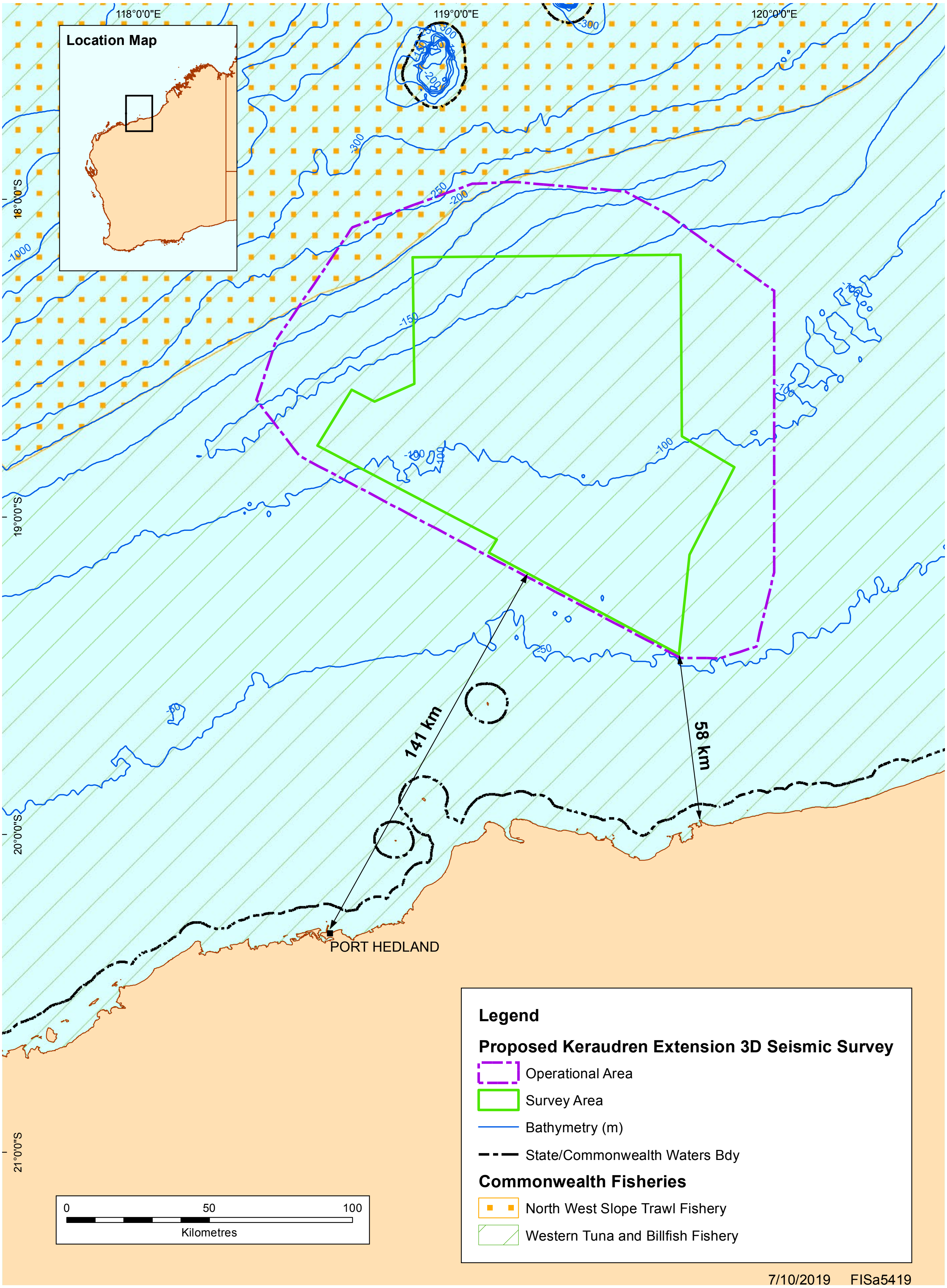

7/10/2019 FISa5419

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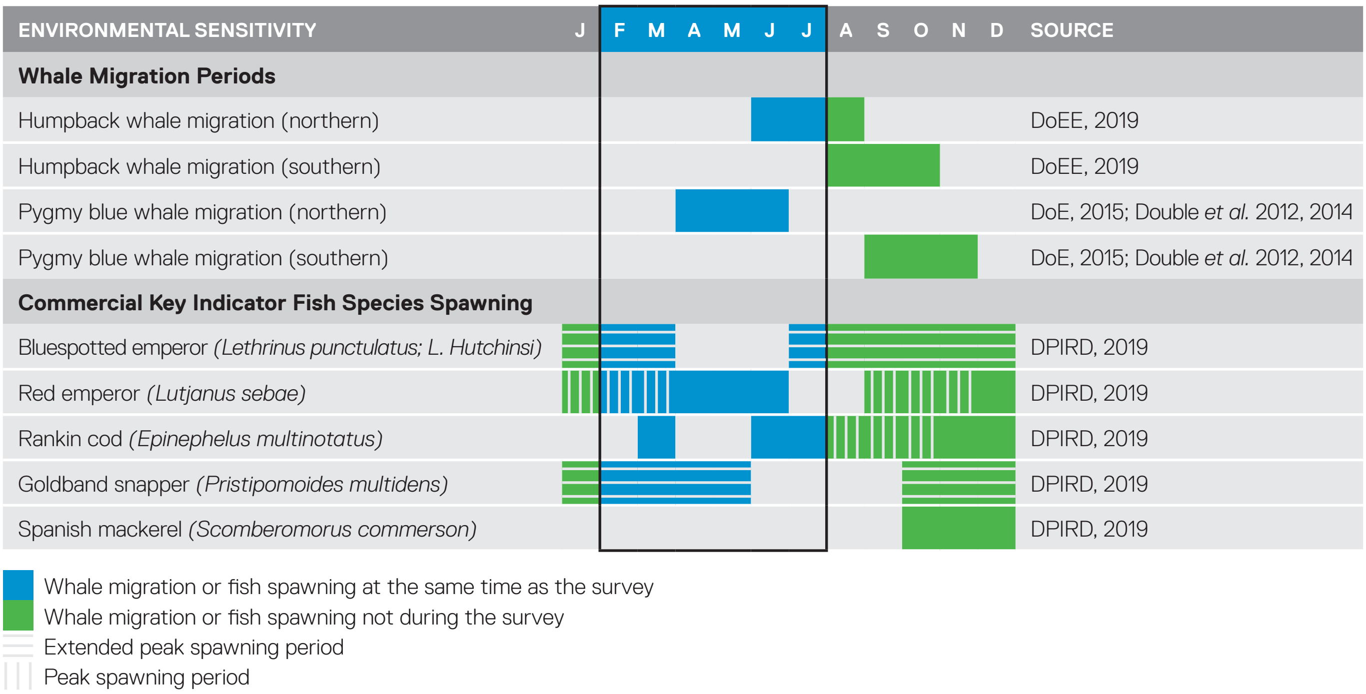

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STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2)
Additional Information for Commercial Fishers

Pearl Oyster Managed Fishery

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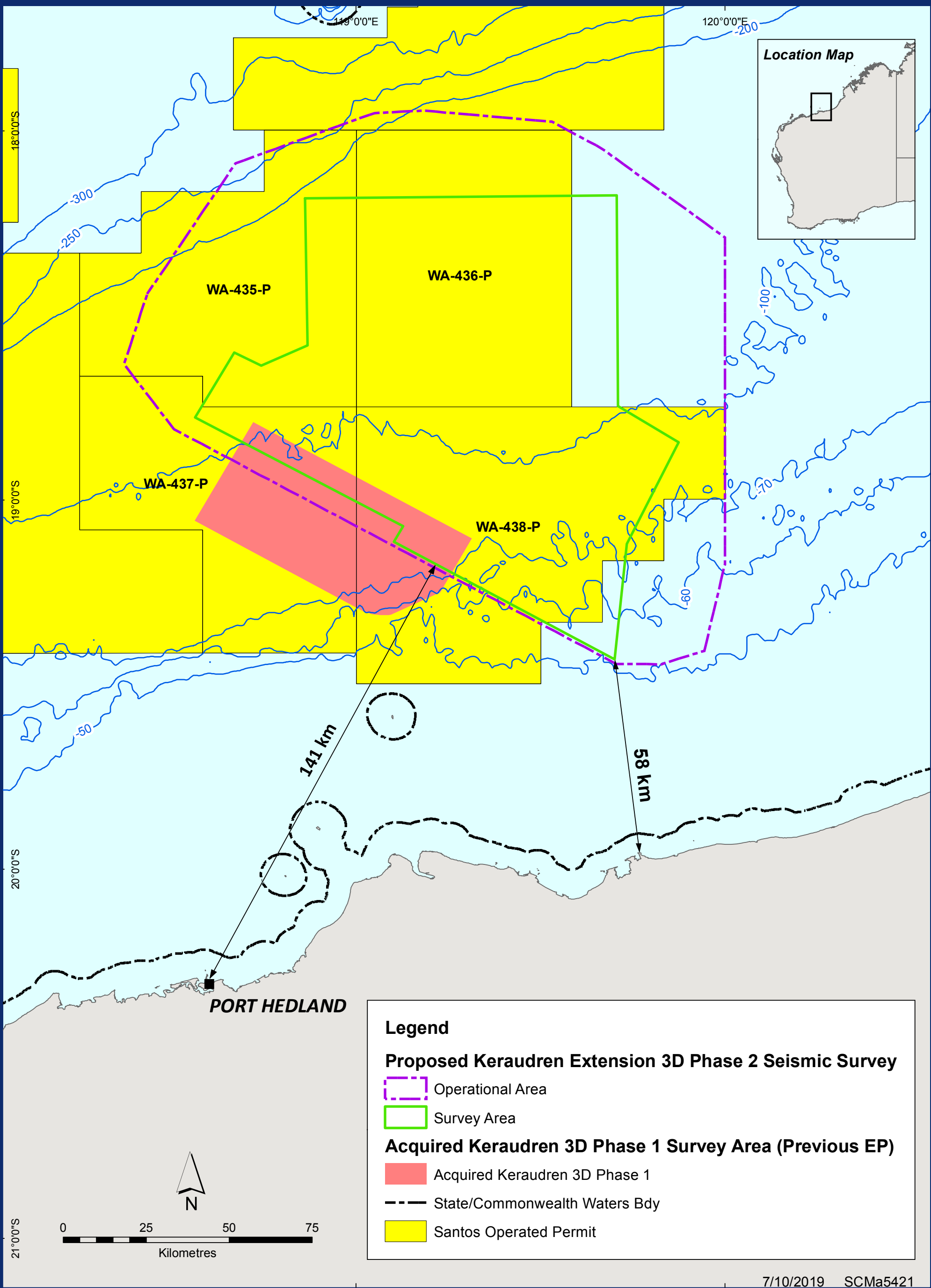
Contact

[redacted]
Telephone: 08 6218 [redacted]
Email: Offshore.Consultation@Santos.com

Keraudren Extension 3D Seismic Survey Location



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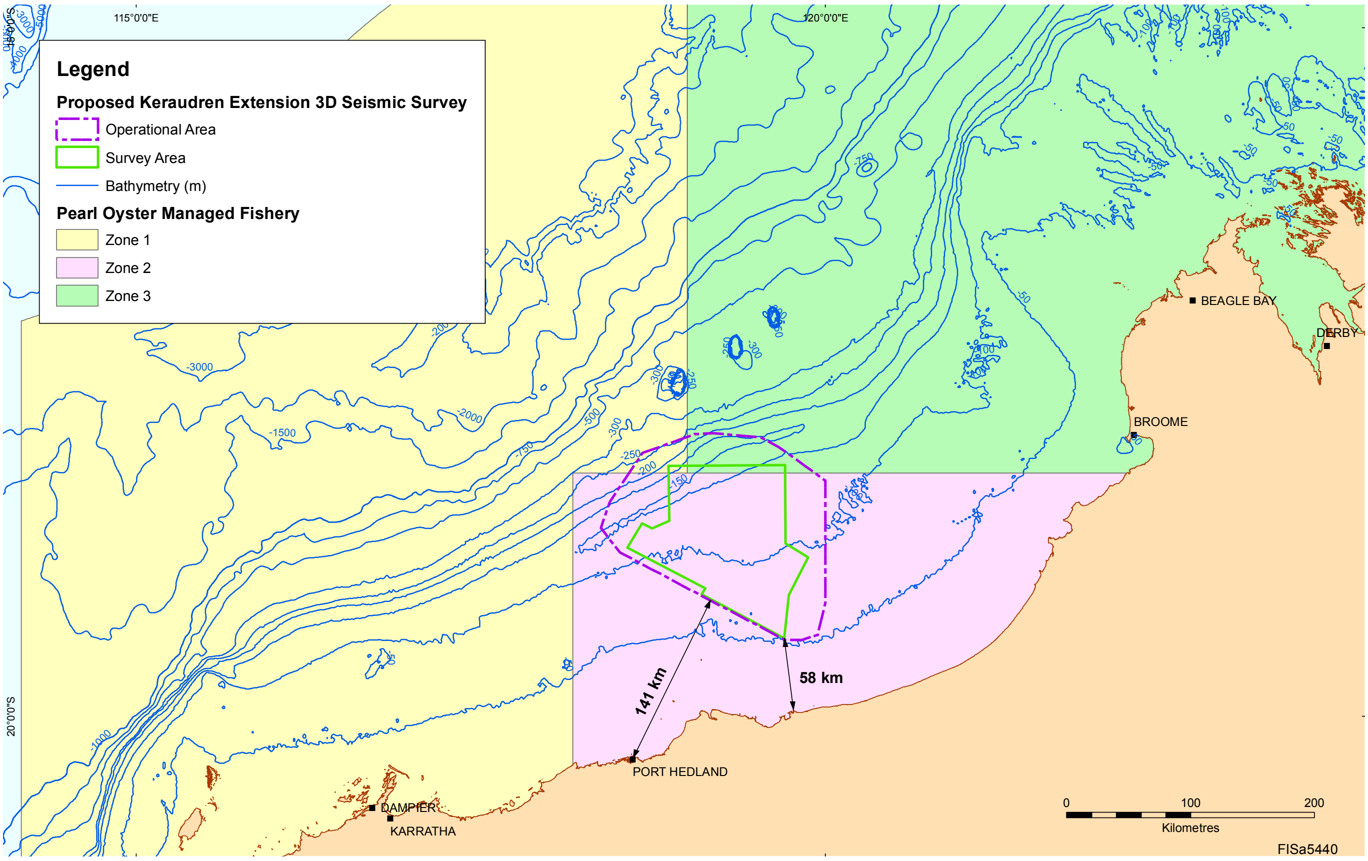
- Closest distance to the coast is 58 km, closest point to Port Hedland is 141 km.
- Water depths of the Survey Area range from approximately 50 m up to 200 m.

Pearl Oyster Managed Fishery



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The proposed survey window attempts to minimise overlap with spawning periods of commercial key indicator fish species and migrating whales – see below 'Operating Window Environmental Sensitives Chart'.

The actual timing of the survey stages will be subject to the receipt of the necessary regulatory and business approvals and availability of suitable seismic vessels.

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- your peak fishing months; and
- where during these months your fishing activity occurs.

This will assist Santos to manage interface with commercial fishers in the Operational Area.

Survey acquisition

Survey acquisition will be via methods and procedures similar to other seismic surveys conducted in Australia:

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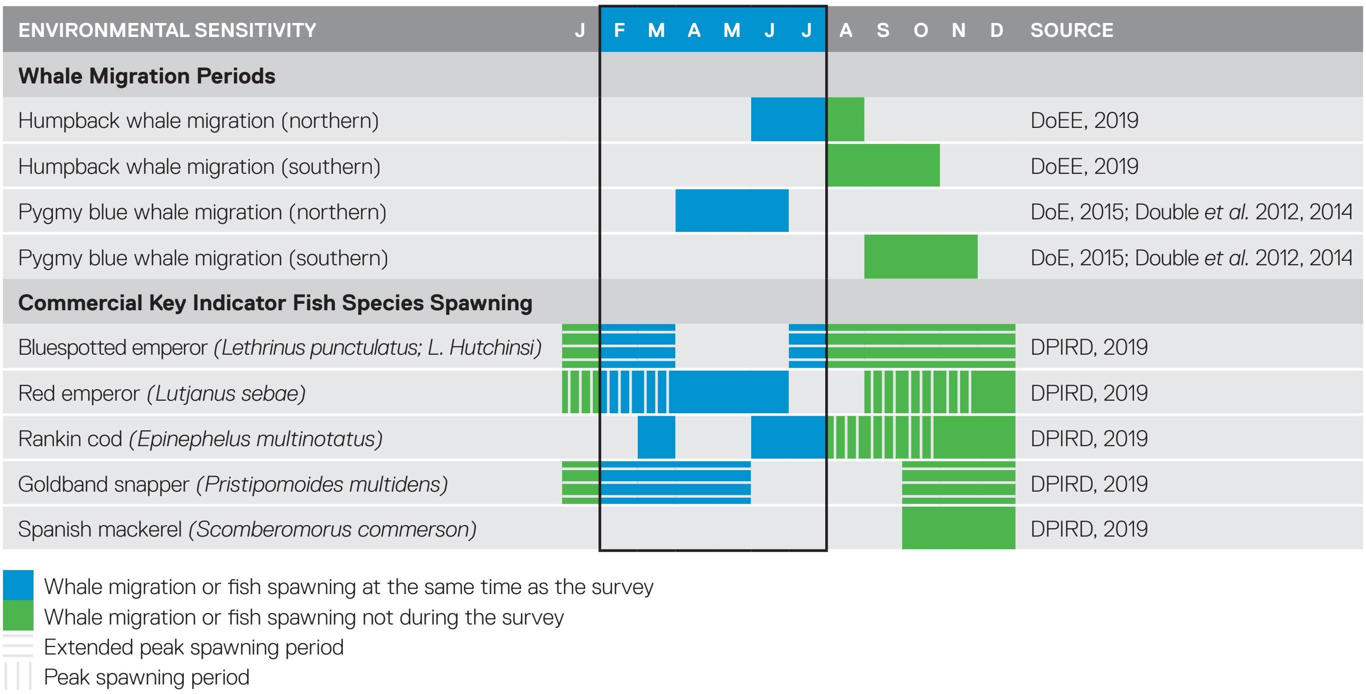
- First stage most likely in the southern part of the Survey Area.
- Survey azimuths have not been finalised.
- Each survey stage could be acquired in different directions.

Commercial fishers are encouraged to contact Santos to discuss the proposed survey acquisition sequence and ways to minimise interference with fishing operations and vessel movements.

Operating Window: Environmental Sensitives Chart

Santos is proposing to conduct the survey in the February to July window to reduce risks to spawning commercial key indicator fish species and migrating whales.



Operational Area access and concurrent operations

Key considerations:

- Fishers will be able to access the Operational Area during the survey.
- Santos will operate concurrently with fishers.
- Safety requirements during concurrent operations - all commercial fishers to observe a 3 nautical mile (nm) exclusion zone around the survey vessel and streamers (standard survey practice).

Santos' control measures (commitments) identified within the draft Environment Plan, will outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed. The management objectives are consistent with those adopted in Keraudren Survey (Phase 1):

- No unplanned interactions with commercial fishers.
- Commercial fishing licence holders to be no worse off as a result of the seismic survey.

No unplanned interactions

The table below contains an outline of the proposed control measures to ensure no unplanned interactions, and the expected way of evidencing compliance to these measures. Commercial fishers are encouraged to contact Santos for a copy of the draft communications protocol referred to in the below table.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
Santos will not restrict commercial fishing access to the Operational Area and is committed to concurrent operational planning with commercial fishers.	Documented correspondence with commercial fishing licence holders.
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At a minimum the daily operational reports will include: • Current seismic survey vessel position. • Look ahead seismic survey activities and vessel positions. • Support vessel activities and positions. • Vessel contact details. • Santos WA management contact details.	Completed daily reports.
Support vessels outside of the range of the active seismic survey will avoid commercial vessels that are actively fishing, and avoid schooling fish in the vicinity of active commercial fishing.	Completed daily reports.

Commercial fishery payment ('make good') claims

The survey will potentially impact commercial fishers whose fishing operations overlap with the seismic survey.

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Make good payments to commercial fishing licence holders will be assessed for loss of catch and relocation expenses should concurrent fishing and seismic vessel operations not be practicable.

Santos will also assess requests for administrative support to help fishers collate historical fishing data required for make good payment claims.

Santos has based the commercial fishery payment model (described below) on what it understands to be Oil and Gas best practice for an evidence-based make good model, leveraging the CSIRO peer reviewed model that Santos implemented for the NOPSEMA–accepted Santos Bethany 3D Seismic Survey and Keraudren 3D Seismic Survey (Phase 1). CSIRO (2017) confirmed the approach proposed by Santos was consistent with international best practice.

Santos believes that the principles of the model presented below are sufficiently clear and will assess any payment claims in good faith. Commercial fishers are encouraged to contact Santos to discuss the proposed fishery payment claim model.

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While the seismic vessel has yet to be determined, this picture is representative of the type of vessel that will be used.

Commercial fishery payment ('make good') claims

The table below contains an outline of the proposed control measures and the expected way of evidencing compliance to these measures.

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If a loss of catch is substantiated, payments will be calculated based on the reduced kilograms per species caught, multiplied by market price per kilogram at the time the catch would have been sold.	Documented payment calculations and supporting fishing and market data.
Loss of catch payments will be assessed for the months of each survey stage and for up to 6 months from the completion date of each survey stage. The 6 months is considered a reasonable time to claim for a temporary loss of catch and to minimise overlap between survey stages.	Records of payment to commercial fishing licence holders, if there are claims.
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In the event that a commercial fisher has observed a reduced catch during or immediately following the completed 2019 Keraudren Seismic Survey or is considering making a claim for the completed survey, please contact Santos as soon as possible to discuss the matter.

STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2)
Additional Information for Commercial Fishers

Pilbara Fish Trawl (Interim) Managed Fishery

Santos is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey (Phase 2) - the 'Survey' in Commonwealth waters approximately 141 km north of Port Hedland.

This survey is an extension to the Keraudren Survey (Phase 1) completed in July 2019. Please note, there is very little overlap between Phase 1 and 2. The overlap between the two surveys is required in order to tie-in the acquired data. The approximate overlap would be less than 1 km (~two sail lines).

This supplementary information has been prepared for commercial fishers operating in Commonwealth and State-managed fisheries that intersect the proposed Operational Area. The identified fisheries are:

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The purpose of this document is to provide additional information for commercial fishers and outline how we can work together with the intent that each can proceed with their business in a safe and efficient manner, and without loss or conflict, by:

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Feedback

Your feedback concerning potential or perceived impacts of the planned seismic survey is important to us.

If you have any queries or concerns regarding the proposed survey and management commitments, please contact us as soon as possible by phone or email.

Equally, if you do not wish to receive further information from Santos on this survey, please advise either directly or through your representative body.

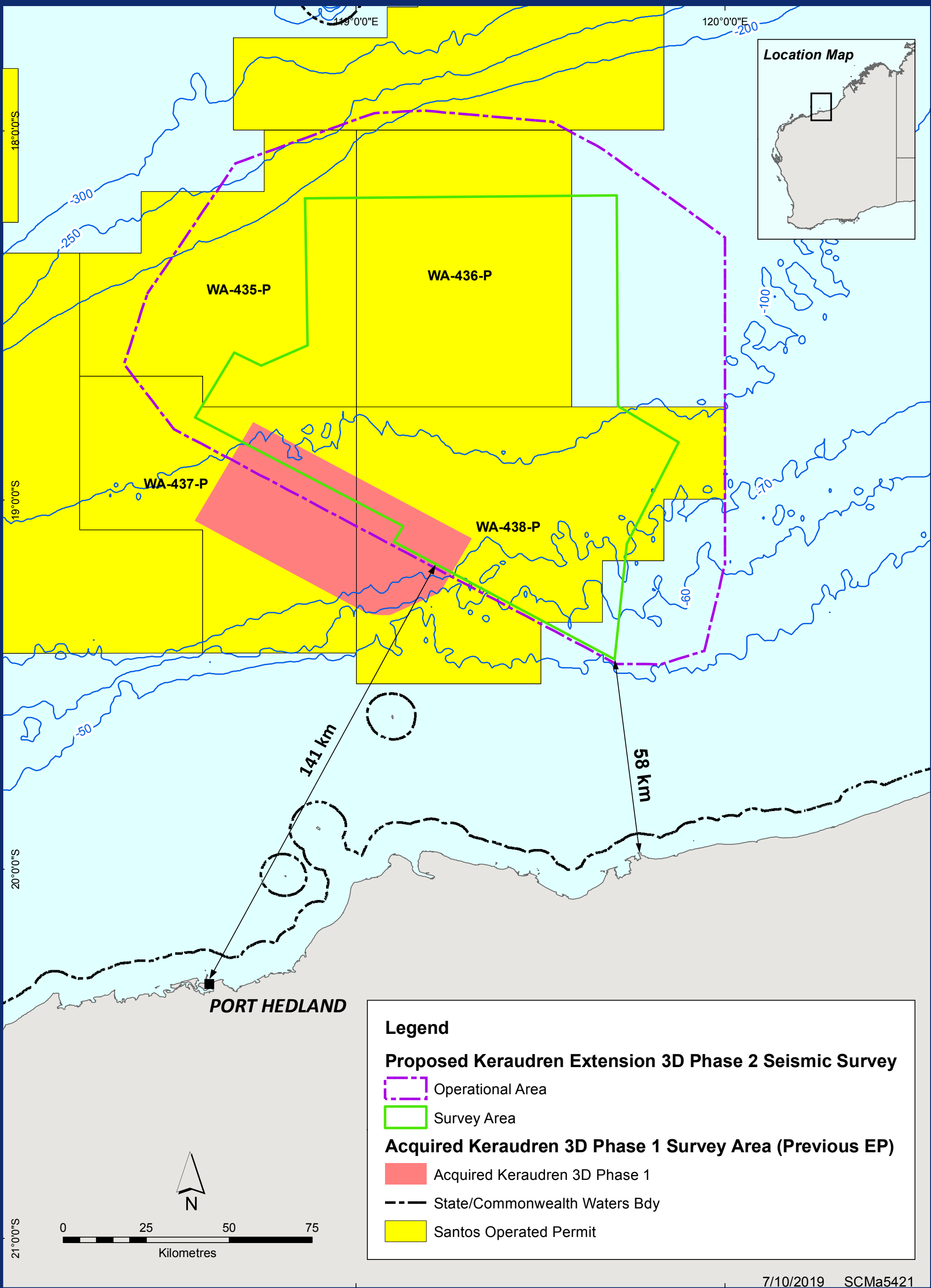
Contact

[redacted]

Telephone: 08 6218 [redacted]

Email: Offshore.Consultation@Santos.com

Keraudren Extension 3D Seismic Survey Location



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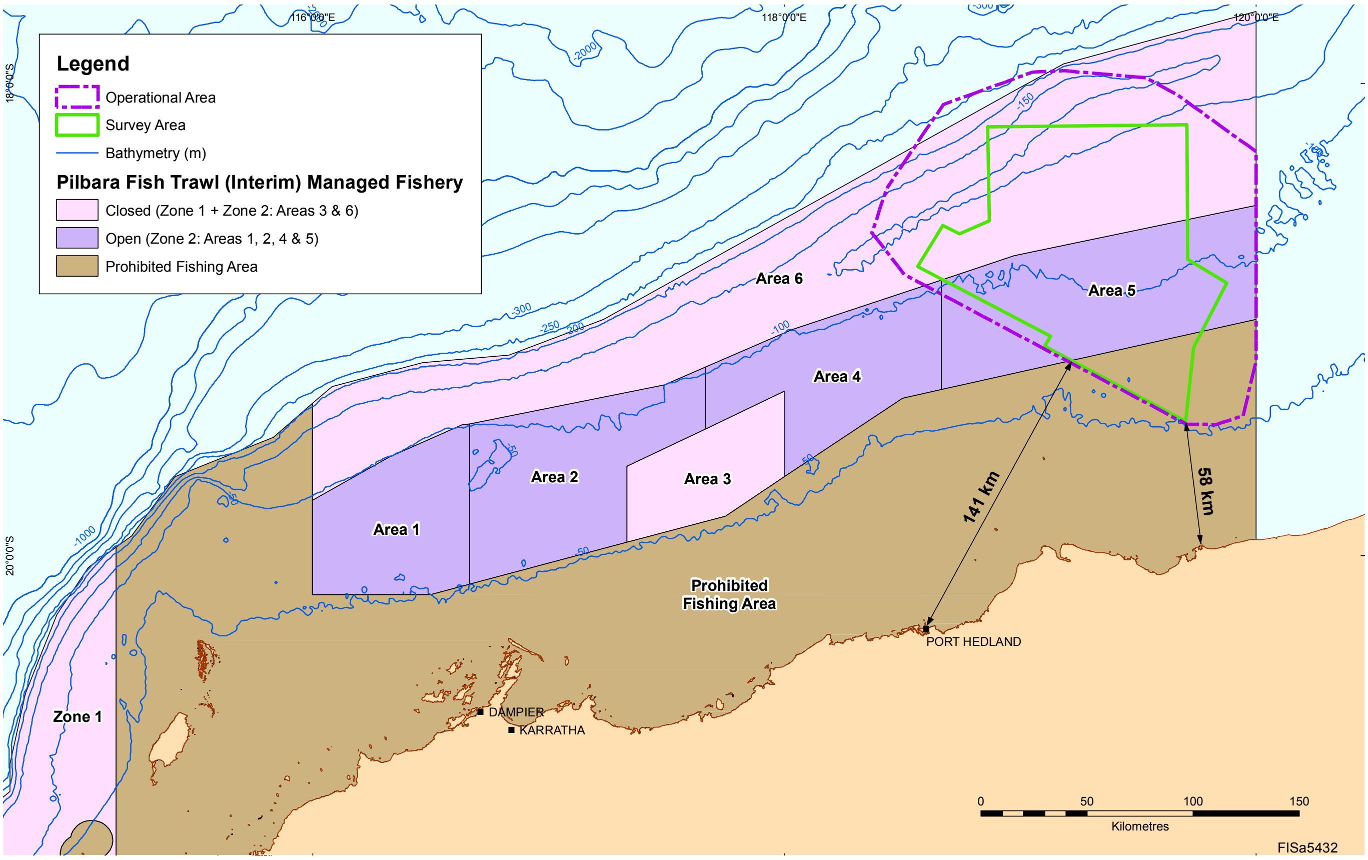

PILBARA FISH TRAWL (INTERIM) MANAGED FISHERY	
State managed fisheries	Pilbara Fish Trawl (Interim) Managed Fishery
Does the operational area overlap the fishery?	Yes
Has there been historical fishing effort in the operational area?	Yes
No. of fishery licence holders	11 individual licences 1 or 2 vessels
Target species	Blue spot emperor, red emperor, gold band snapper
Fishing season[1]	All year Average 1 trip/week 5-7 days fishing
Operational area overlap	Based on a review of Fish Cube[2] data, the PFTIMF has had one or two boats active over the operational area since 2015, and one to three vessels over the area between 2013-2014. Fish Cube data shows that 23,012 km^2 of the PFTIMF has been fished between 2013 to 2017. The Survey Area overlaps with 4,652 km^2 or 20.22% of this area of recorded fishing effort. This overlap percentage is based on the area of historical fishing effort and not the entire fishery area, which is 113,642 km^2.

1. Fishing season information is based on historical stakeholder consultation with fishers.
2. Based on 2013-2017 Fish Cube data. Santos is currently sourcing 2018 data from DPIRD and will include this information in the environment plan.

Timing and duration

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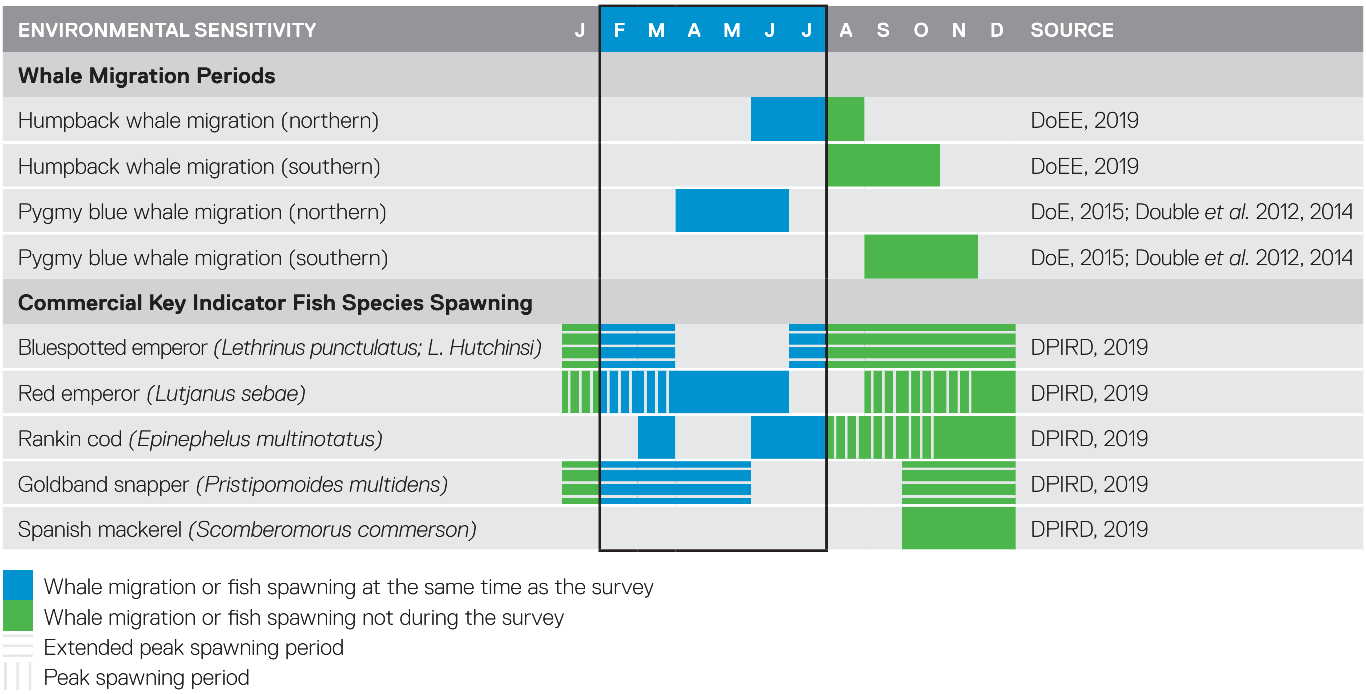

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STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2)
Additional Information for Commercial Fishers

Pilbara Line Fishery

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Feedback

Your feedback concerning potential or perceived impacts of the planned seismic survey is important to us.

If you have any queries or concerns regarding the proposed survey and management commitments, please contact us as soon as possible by phone or email.

Equally, if you do not wish to receive further information from Santos on this survey, please advise either directly or through your representative body.

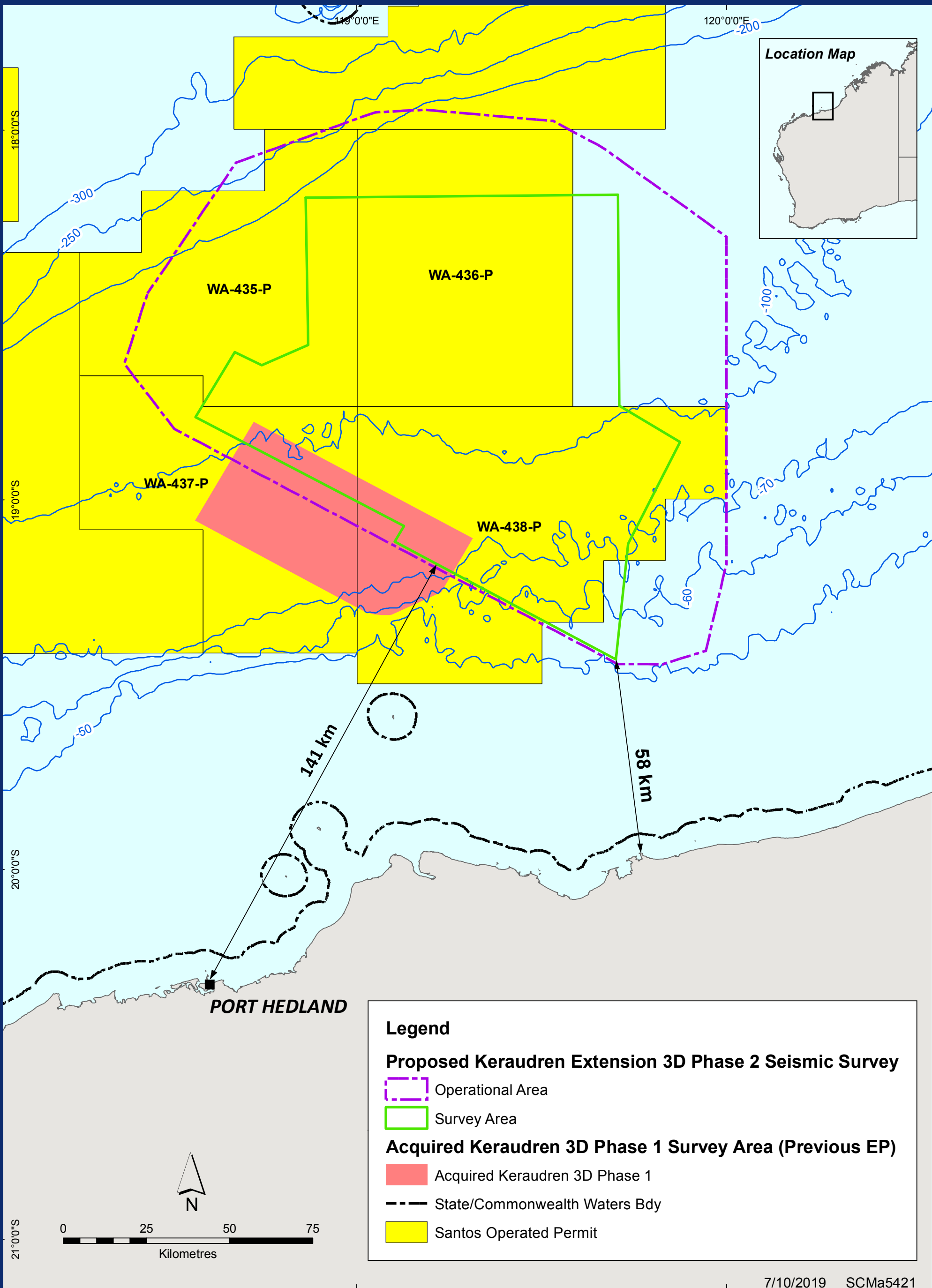
Contact

[redacted]

Telephone: 08 6218 [redacted]

Email: Offshore.Consultation@Santos.com

Keraudren Extension 3D Seismic Survey Location



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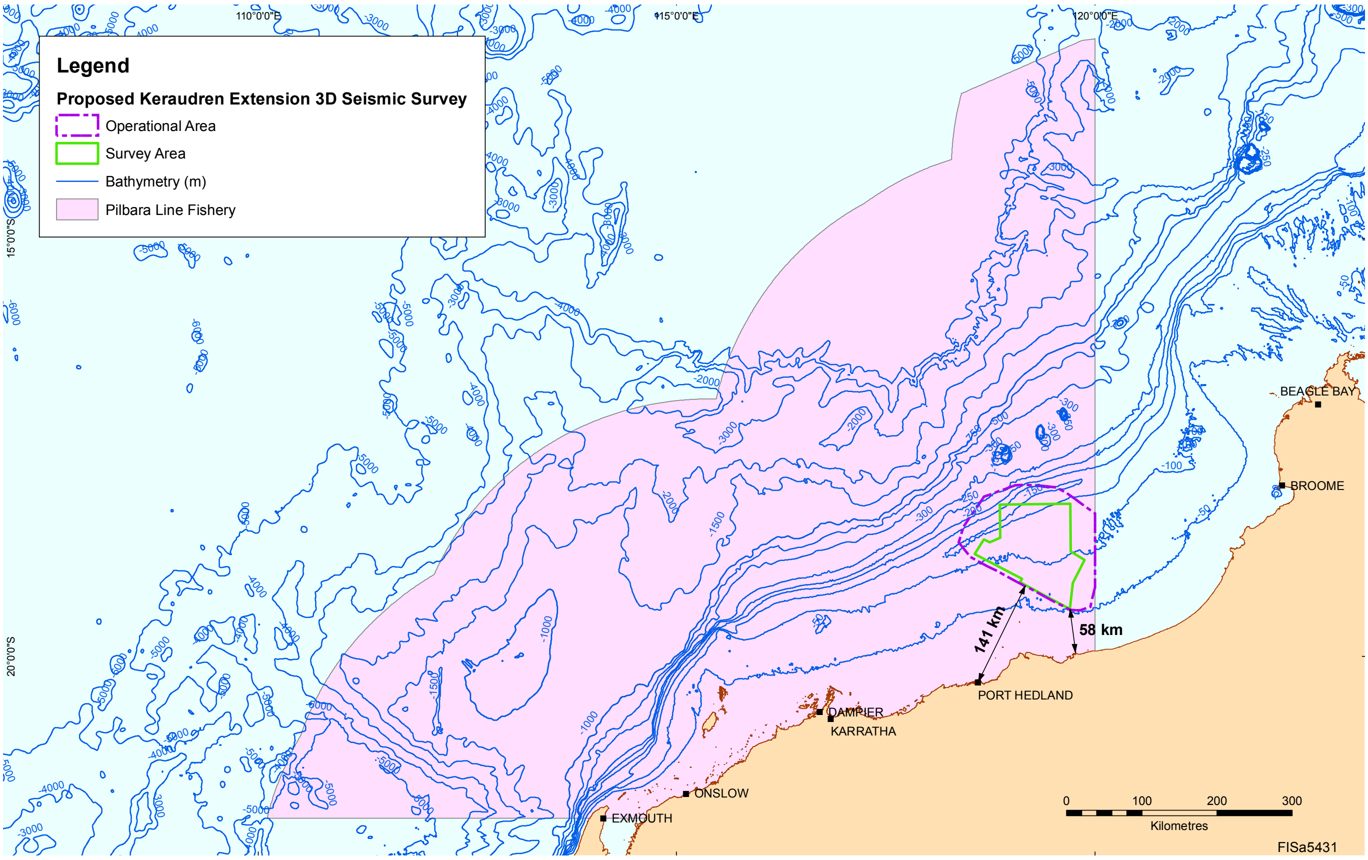
- Closest distance to the coast is 58 km, closest point to Port Hedland is 141 km.
- Water depths of the Survey Area range from approximately 50 m up to 200 m.

Pilbara Line Fishery



PILBARA LINE FISHERY	
State managed fisheries	Pilbara Line Fishery
Does the operational area overlap the fishery?	Yes
Has there been historical fishing effort in the operational area?	Yes
No. of fishery licence holders	9 individual licences (held by 7 individuals)
Target species	Goldband snapper, bluespotted emperor, red emperor
Fishing season[1]	All year
Operational area overlap	Based on a review of Fish Cube[2] data, the Pilbara Line Fishery has had activity in the southern half of the Survey Area. Fish Cube data shows that 134,318 km^2 of the Pilbara Line Fishery has been fished between 2013 to 2017. The Survey Area overlaps with 2,078 km^2 or 1.55% of this area of recorded fishing effort. This overlap percentage is based on the area of historical fishing effort and not the entire fishery area, which is 550,256 km^2.

1. Fishing season information is based on historical stakeholder consultation with fishers.
2. Based on 2013-2017 Fish Cube data. Santos is currently sourcing 2018 data from DPIRD and will include this information in the environment plan.

Timing and duration

Key timing and duration considerations:

- Santos plans to split the survey over multiple stages between 2020 and 2022.
- Targeting stage one in 2020 and stage two in 2021.
- If data acquisition in stage one or two remains incomplete (i.e. due to weather delays, vessel issues, approval delays, etc.), then a stage three in 2022 may be required.
- Surveys will only be acquired in a window between 1 February and 31 July each year.
- There will be no survey activity between 1 August and 31 January each year.
- Total survey duration (all stages) with extra time added for any contingencies is 161 days (over 2020, 2021 and possibly 2022).
- Each survey stage would be acquired over a nominal 70 to 80 day period.
- 24-hour operations.

NOPSEMA previously accepted a 1 March to 31 July period for the Keraudren Survey (Phase 1) under the Environment Plan (EP) accepted in April and survey completed in July 2019. Under this EP Santos did not request a 1 February start date due to a vessel not being available.

The proposed survey window attempts to minimise overlap with spawning periods of commercial key indicator fish species and migrating whales – see below 'Operating Window Environmental Sensitives Chart'.

The actual timing of the survey stages will be subject to the receipt of the necessary regulatory and business approvals and availability of suitable seismic vessels.

Commercial fishers are encouraged to contact Santos to discuss the survey timing and duration, as well as known fish spawning periods. Santos has acquired some helpful information via DPIRD's Fish Cube process but would welcome your input regarding:

- your peak fishing months; and
- where during these months your fishing activity occurs.

This will assist Santos to manage interface with commercial fishers in the Operational Area.

Survey acquisition

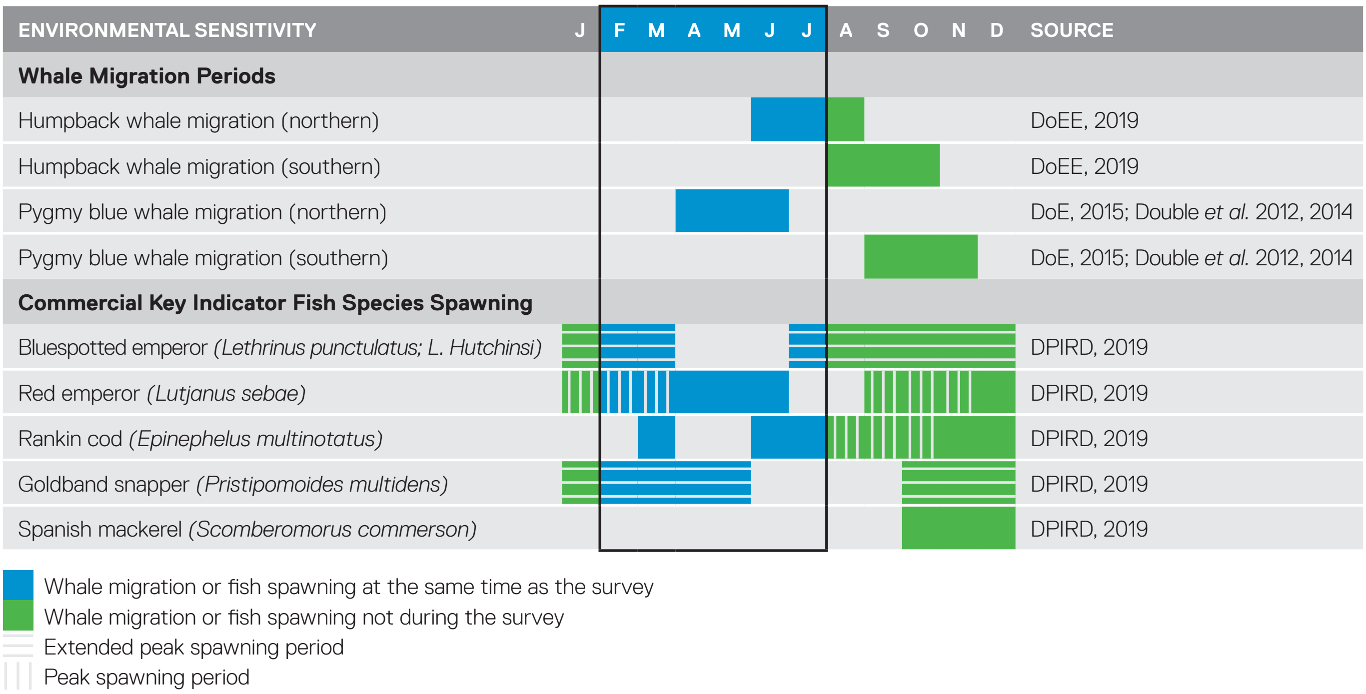
Survey acquisition will be via methods and procedures similar to other seismic surveys conducted in Australia:

- 'Racetrack' pattern.
- First stage most likely in the southern part of the Survey Area.
- Survey azimuths have not been finalised.
- Each survey stage could be acquired in different directions.

Commercial fishers are encouraged to contact Santos to discuss the proposed survey acquisition sequence and ways to minimise interference with fishing operations and vessel movements.

Operating Window: Environmental Sensitives Chart

Santos is proposing to conduct the survey in the February to July window to reduce risks to spawning commercial key indicator fish species and migrating whales.



Operational Area access and concurrent operations

Key considerations:

- Fishers will be able to access the Operational Area during the survey.
- Santos will operate concurrently with fishers.
- Safety requirements during concurrent operations - all commercial fishers to observe a 3 nautical mile (nm) exclusion zone around the survey vessel and streamers (standard survey practice).

Santos' control measures (commitments) identified within the draft Environment Plan, will outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed. The management objectives are consistent with those adopted in Keraudren Survey (Phase 1):

- No unplanned interactions with commercial fishers.
- Commercial fishing licence holders to be no worse off as a result of the seismic survey.

No unplanned interactions

The table below contains an outline of the proposed control measures to ensure no unplanned interactions, and the expected way of evidencing compliance to these measures. Commercial fishers are encouraged to contact Santos for a copy of the draft communications protocol referred to in the below table.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
Santos will not restrict commercial fishing access to the Operational Area and is committed to concurrent operational planning with commercial fishers.	Documented correspondence with commercial fishing licence holders.
Santos will develop communication protocols including direct radio contact for both parties at sea and provide operational survey plans, commencement and cessation notifications, and daily operational reports if requested.	Documented correspondence with commercial fishing licence holders.
At a minimum the daily operational reports will include: • Current seismic survey vessel position. • Look ahead seismic survey activities and vessel positions. • Support vessel activities and positions. • Vessel contact details. • Santos WA management contact details.	Completed daily reports.
Support vessels outside of the range of the active seismic survey will avoid commercial vessels that are actively fishing, and avoid schooling fish in the vicinity of active commercial fishing.	Completed daily reports.

Commercial fishery payment ('make good') claims

The survey will potentially impact commercial fishers whose fishing operations overlap with the seismic survey.

Santos has made an overarching commitment that commercial fishing licence holders will be no worse off as a result of the seismic survey and propose measures that enable commercial fishers to lodge a claim ('make good' payment) if applicable.

Make good payments to commercial fishing licence holders will be assessed for loss of catch and relocation expenses should concurrent fishing and seismic vessel operations not be practicable.

Santos will also assess requests for administrative support to help fishers collate historical fishing data required for make good payment claims.

Santos has based the commercial fishery payment model (described below) on what it understands to be Oil and Gas best practice for an evidence-based make good model, leveraging the CSIRO peer reviewed model that Santos implemented for the NOPSEMA–accepted Santos Bethany 3D Seismic Survey and Keraudren 3D Seismic Survey (Phase 1). CSIRO (2017) confirmed the approach proposed by Santos was consistent with international best practice.

Santos believes that the principles of the model presented below are sufficiently clear and will assess any payment claims in good faith. Commercial fishers are encouraged to contact Santos to discuss the proposed fishery payment claim model.

The control measures (commitments) identified within the draft Environment Plan, to outline how the potentially competing demands of commercial fishing operators and Santos' seismic survey may be managed, are consistent with those adopted in Keraudren Survey (Phase 1). The management objective is to ensure Commercial fishing licence holders are no worse off as a result of the seismic survey.

While the seismic vessel has yet to be determined, this picture is representative of the type of vessel that will be used.

Commercial fishery payment ('make good') claims

The table below contains an outline of the proposed control measures and the expected way of evidencing compliance to these measures.

PROPOSED CONTROL MEASURES	COMPLIANCE EVIDENCE
All evidence-based payment claims made by commercial fishing licence holders relating to temporary loss of fish catch from within the Operational Area or displacement costs from the Operational Area as caused by each survey stage are assessed for merit by Santos.	Santos' merit assessment of commercial fishing licence holder claim. Documented correspondence with commercial fishing licence holders.
Payment to a commercial fishing licence holder for each month there is a loss of catch by the commercial fishing licence holder based on an assessment of what the commercial fishing licence holder would have caught in that month from within the Operational Area "but for" the survey stage.	Records of payment to commercial fishing licence holders.
A loss of catch will be concluded if there is a reduction in the catch per unit of effort for each species calculated over a month, compared to the average historical catch per unit of effort for the same species and corresponding month. Santos' preference is for 10 years of data to determine the average historical catch per unit of effort. However, this will be assessed on a case-by-case basis.	Documented loss of catch assessment and supporting fishing data.
If a loss of catch is substantiated, payments will be calculated based on the reduced kilograms per species caught, multiplied by market price per kilogram at the time the catch would have been sold.	Documented payment calculations and supporting fishing and market data.
Loss of catch payments will be assessed for the months of each survey stage and for up to 6 months from the completion date of each survey stage. The 6 months is considered a reasonable time to claim for a temporary loss of catch and to minimise overlap between survey stages.	Records of payment to commercial fishing licence holders, if there are claims.
Where a commercial fishing licence holder wants to receive a loss of catch payment, they will need to provide Santos with monthly catch disposal records and multiple years of historical data to allow average monthly catch rates per species to be determined. Santos' preference is for 10 years of historical data. However, this will be assessed on a case-by-case basis.	Commercial fishing licence holder payment claim and multiple years of fish catch disposal records.
Where a commercial fishing licence holder is displaced from the operational area such that it is required to relocate their operations to another area during a survey stage, Santos will make a one off payment to reimburse operational expenses which are in addition to those the commercial fishing licence holder would have borne "but for" the seismic survey stage.	Records of payment to commercial fishing licence holders.
Where a commercial fishing licence holder intends to make an operational expense claim for relocation, they will need to notify Santos as soon as practicable and prior to relocating, and state why the seismic survey has caused them to relocate. The notification can be via radio between the fishing and survey vessel.	Relocation notification from commercial fishing licence holder and Santos acknowledgement.
Where a commercial fishing licence holder wants to be reimbursed for any relocation operational expenses, they will need to provide Santos with evidence of the operating costs of bait, fuel, wages and any other costs that are additional to the costs that would have been incurred to catch the fish "but for" the relocation.	Commercial fishing licence holder historical operating cost records and relocation cost records.
Where a commercial fishing licence holder wants to receive any payment for loss of catch or relocation, they will need to lodge a claim with Santos within 8 months of the survey stage completion. The 8 months is intended to give fishers reasonable time to prepare a claim and to minimise overlap between subsequent survey stages. Noting Santos' preparedness to provide administrative support to collate fishing data for fishers.	Commercial fishing licence holder claim and supporting evidence.
Santos will not accept a claim under this Environment Plan for loss of catch and/or relocation if the claim covers the same time, area and fishing activity made in another claim for a different seismic survey.	Correspondence records.
If there are any issues with the required evidence, loss of catch determination or payment amount, Santos will, in consultation with the commercial fishing licence holder, engage an independent relevant expert to determine the issue.	Consultation with commercial fishing licence holders about appointment of independent expert (if required). Independent relevant expert assessment record (if required).
The loss of catch and relocation payment control measures will apply unless Santos enters into an agreement with a commercial fishing operator in relation to the potential impact of the survey on them. In the event of an agreement, the agreement will replace the loss of catch and/or relocation payment as the control measure.	Agreement with commercial fishing licence holder. Evidence of Santos adherence to terms of the agreement

In the event that a commercial fisher has observed a reduced catch during or immediately following the completed 2019 Keraudren Seismic Survey or is considering making a claim for the completed survey, please contact Santos as soon as possible to discuss the matter.

STAKEHOLDER CONSULTATION

Santos

Bedout Basin

Keraudren Extension 3D Marine Seismic Survey (Phase 2)
Additional Information for Commercial Fishers

Pilbara Trap Managed Fishery

Santos is proposing to conduct the Keraudren Extension 3D Marine Seismic Survey (Phase 2) - the 'Survey' in Commonwealth waters approximately 141 km north of Port Hedland.

This survey is an extension to the Keraudren Survey (Phase 1) completed in July 2019. Please note, there is very little overlap between Phase 1 and 2. The overlap between the two surveys is required in order to tie-in the acquired data. The approximate overlap would be less than 1 km (~two sail lines).

This supplementary information has been prepared for commercial fishers operating in Commonwealth and State-managed fisheries that intersect the proposed Operational Area. The identified fisheries are:

- Mackerel Managed Fishery Area 2
- Nickol Bay Prawn Managed Fishery
- Pearl Oyster Managed Fishery
- Pilbara Crab Managed Fishery
- Pilbara Fish Trawl (Interim) Managed Fishery
- Pilbara Line Fishery
- **Pilbara Trap Managed Fishery**
- North West Slope Trawl (Commonwealth Managed)
- Western Tuna and Billfish (Commonwealth Managed)

The purpose of this document is to provide additional information for commercial fishers and outline how we can work together with the intent that each can proceed with their business in a safe and efficient manner, and without loss or conflict, by:

- Minimising the extent of interruption by the seismic survey activities on commercial fishing operators' activities to the lowest practicable level;
- Where this is unavoidable, to mitigate the effects of the interruptions, and
- Where commercial fishers may potentially incur additional cost and/or loss, Santos and relevant parties to then proceed to an equitable 'make good' process.

Feedback

Your feedback concerning potential or perceived impacts of the planned seismic survey is important to us.

If you have any queries or concerns regarding the proposed survey and management commitments, please contact us as soon as possible by phone or email.

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Contact

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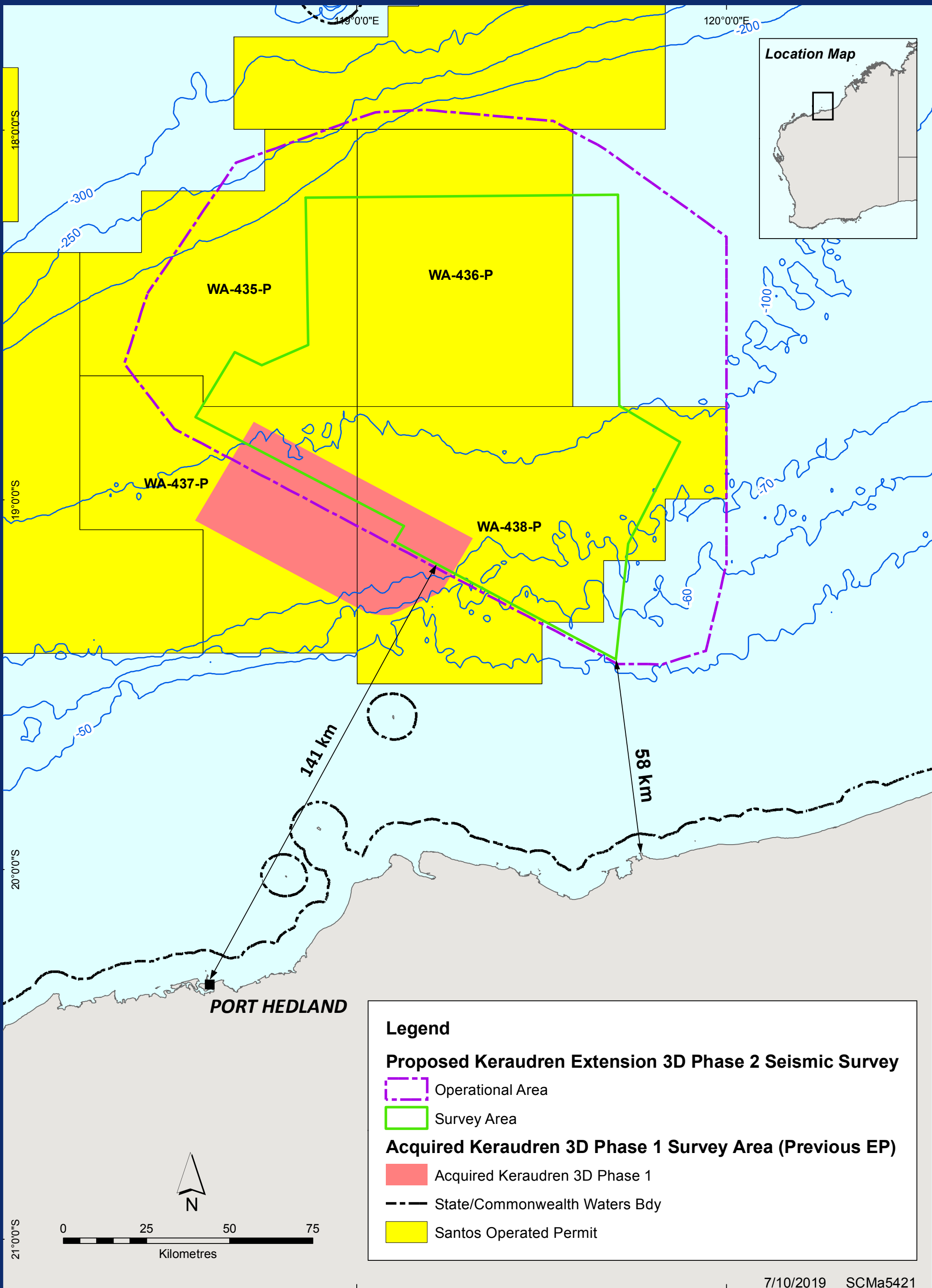
Email: Offshore.Consultation@Santos.com

Keraudren Extension 3D Seismic Survey Location



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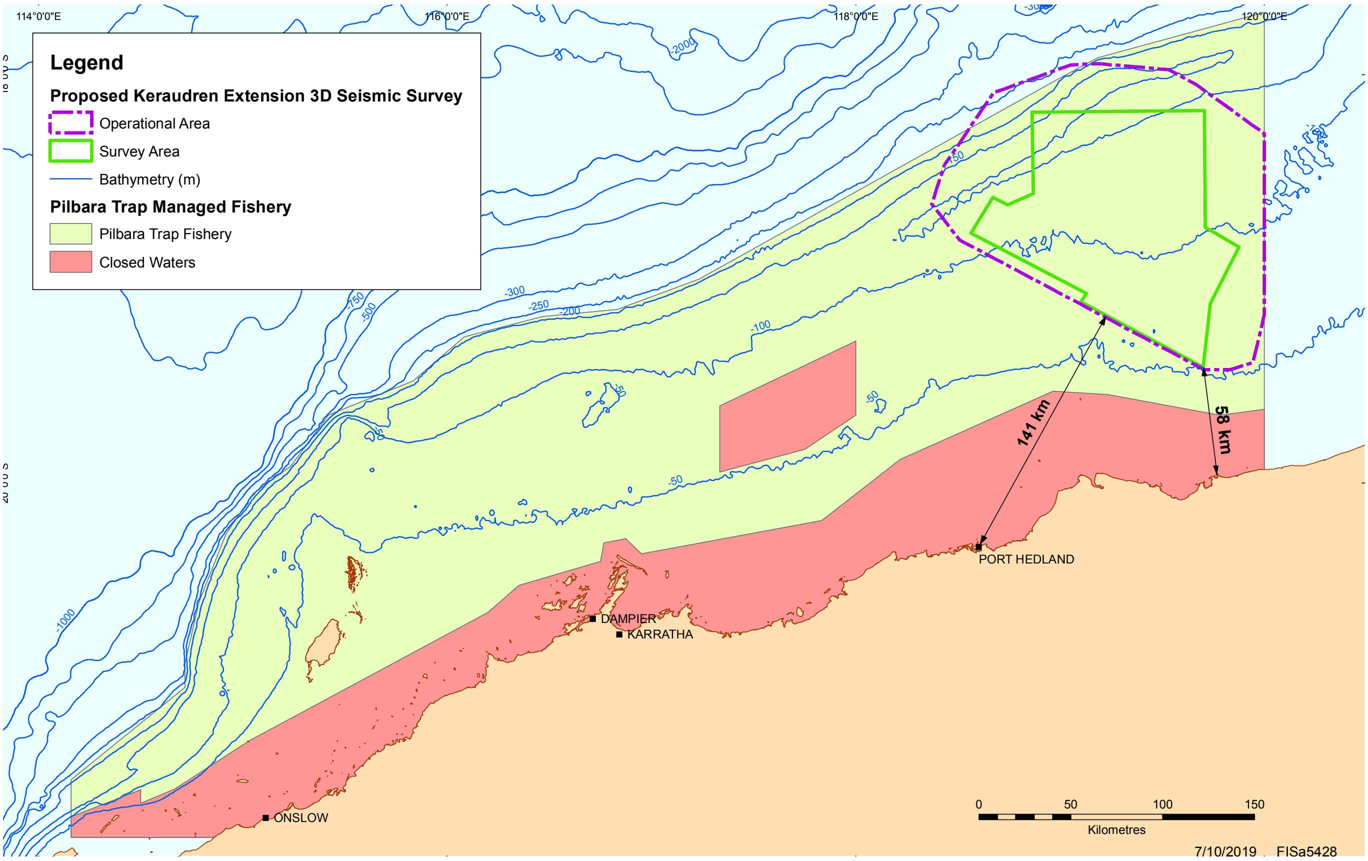
Pilbara Trap Managed Fishery



PILBARA TRAP MANAGED FISHERY	
State managed fisheries	Pilbara Trap Managed Fishery
Does the operational area overlap the fishery?	Yes
Has there been historical fishing effort in the operational area?	Yes
No. of fishery licence holders	6 individual licences 1 to 2 vessels from 2013 - 2017
Target species	Blue spot emperor, red emperor, gold band and snapper
Fishing season[1]	All year
Operational area overlap	Based on a review of Fish Cube[2] data, the Pilbara Trap Managed Fishery has had one or two boats active over the operational area since 2013. Fish Cube data shows that 84,084 km^2 of the Pilbara Trap Managed Fishery has been fished between 2013-2017. The Survey Area overlaps with 11,205 km^2 or 13.33% of this area of recorded fishing effort. This overlap percentage is based on the area of historical fishing effort and not the entire fishery area, which is 115,091 km^2.

1. Fishing season information is based on historical stakeholder consultation with fishers.
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Timing and duration

Key timing and duration considerations:

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Survey acquisition will be via methods and procedures similar to other seismic surveys conducted in Australia:

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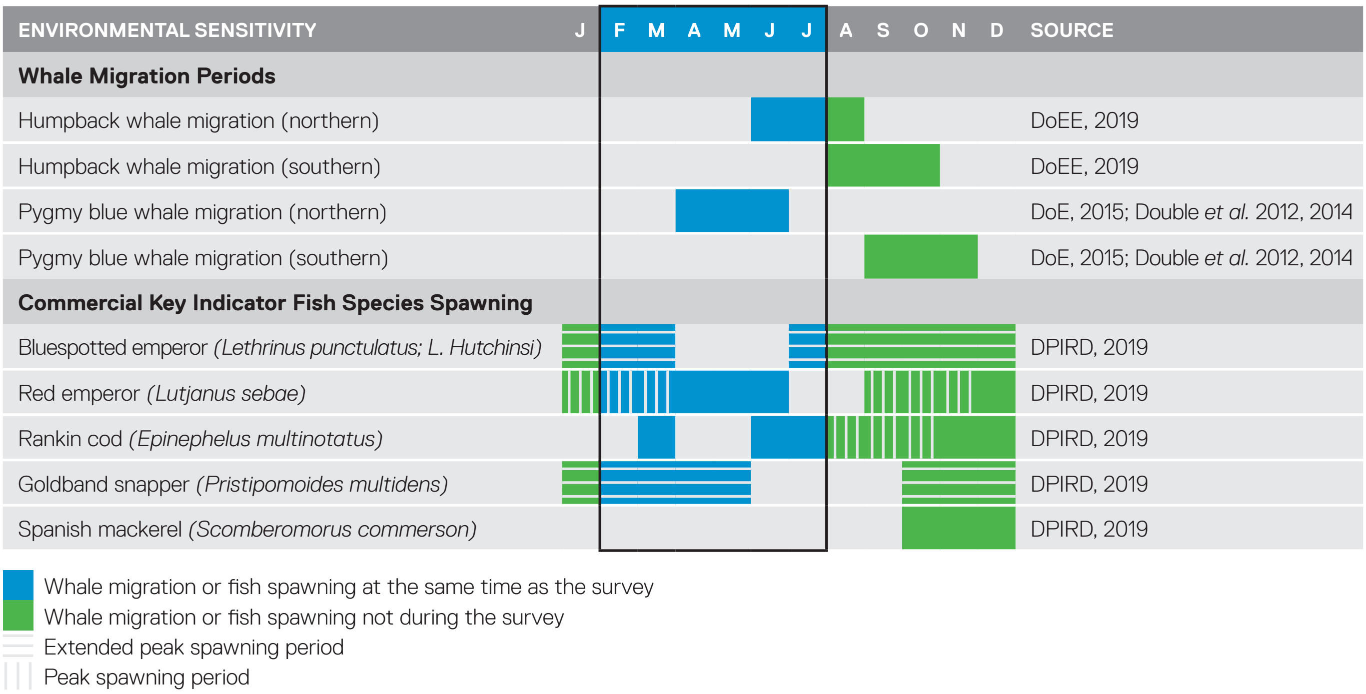

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Support vessels outside of the range of the active seismic survey will avoid commercial vessels that are actively fishing, and avoid schooling fish in the vicinity of active commercial fishing.	Completed daily reports.

Commercial fishery payment ('make good') claims

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While the seismic vessel has yet to be determined, this picture is representative of the type of vessel that will be used.

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Payment to a commercial fishing licence holder for each month there is a loss of catch by the commercial fishing licence holder based on an assessment of what the commercial fishing licence holder would have caught in that month from within the Operational Area "but for" the survey stage.	Records of payment to commercial fishing licence holders.
A loss of catch will be concluded if there is a reduction in the catch per unit of effort for each species calculated over a month, compared to the average historical catch per unit of effort for the same species and corresponding month. Santos' preference is for 10 years of data to determine the average historical catch per unit of effort. However, this will be assessed on a case-by-case basis.	Documented loss of catch assessment and supporting fishing data.
If a loss of catch is substantiated, payments will be calculated based on the reduced kilograms per species caught, multiplied by market price per kilogram at the time the catch would have been sold.	Documented payment calculations and supporting fishing and market data.
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Where a commercial fishing licence holder is displaced from the operational area such that it is required to relocate their operations to another area during a survey stage, Santos will make a one off payment to reimburse operational expenses which are in addition to those the commercial fishing licence holder would have borne "but for" the seismic survey stage.	Records of payment to commercial fishing licence holders.
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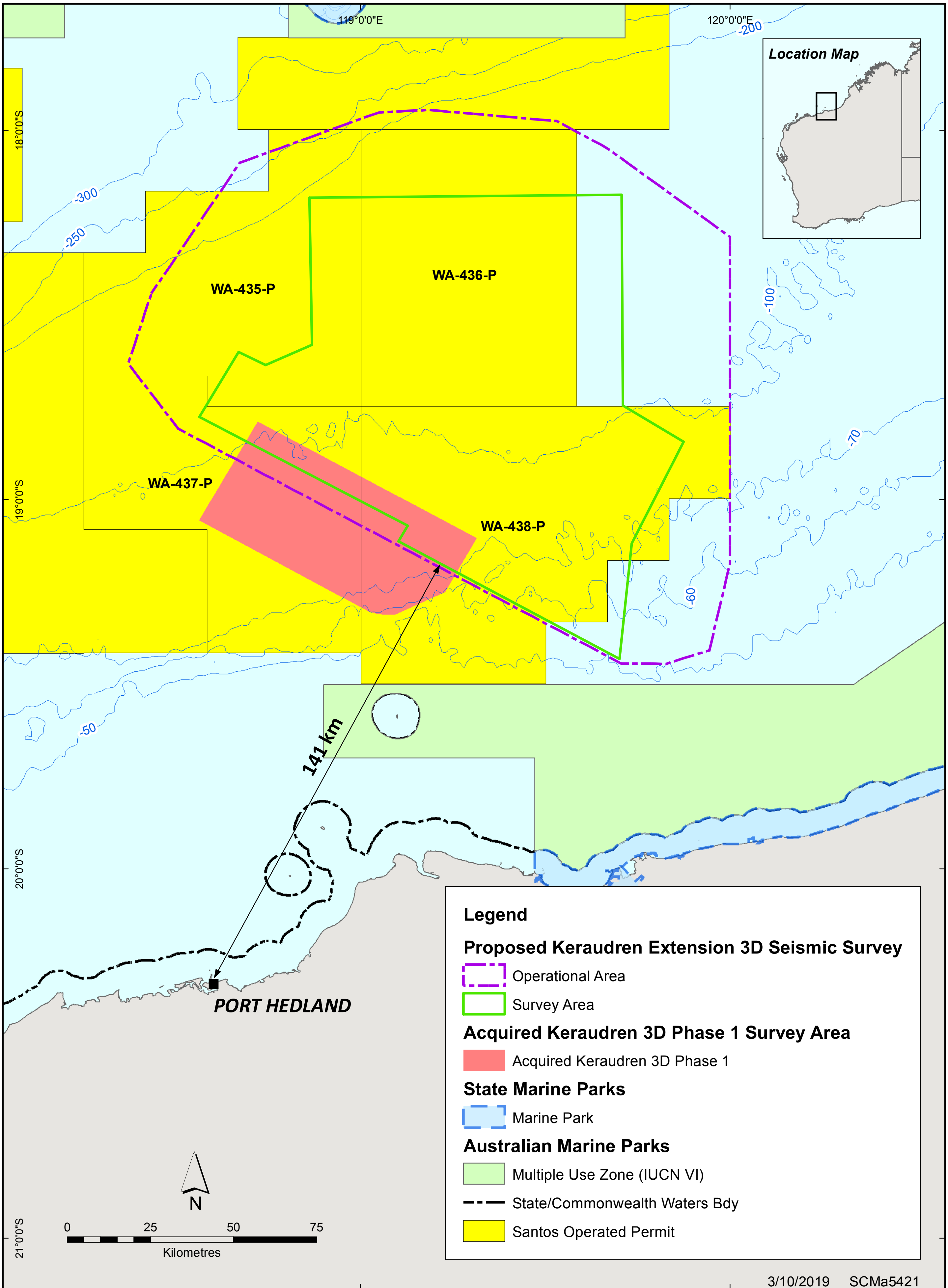
Where a commercial fishing licence holder wants to receive any payment for loss of catch or relocation, they will need to lodge a claim with Santos within 8 months of the survey stage completion. The 8 months is intended to give fishers reasonable time to prepare a claim and to minimise overlap between subsequent survey stages. Noting Santos' preparedness to provide administrative support to collate fishing data for fishers.	Commercial fishing licence holder claim and supporting evidence.
Santos will not accept a claim under this Environment Plan for loss of catch and/or relocation if the claim covers the same time, area and fishing activity made in another claim for a different seismic survey.	Correspondence records.
If there are any issues with the required evidence, loss of catch determination or payment amount, Santos will, in consultation with the commercial fishing licence holder, engage an independent relevant expert to determine the issue.	Consultation with commercial fishing licence holders about appointment of independent expert (if required). Independent relevant expert assessment record (if required).
The loss of catch and relocation payment control measures will apply unless Santos enters into an agreement with a commercial fishing operator in relation to the potential impact of the survey on them. In the event of an agreement, the agreement will replace the loss of catch and/or relocation payment as the control measure.	Agreement with commercial fishing licence holder. Evidence of Santos adherence to terms of the agreement

In the event that a commercial fisher has observed a reduced catch during or immediately following the completed 2019 Keraudren Seismic Survey or is considering making a claim for the completed survey, please contact Santos as soon as possible to discuss the matter.

Santos

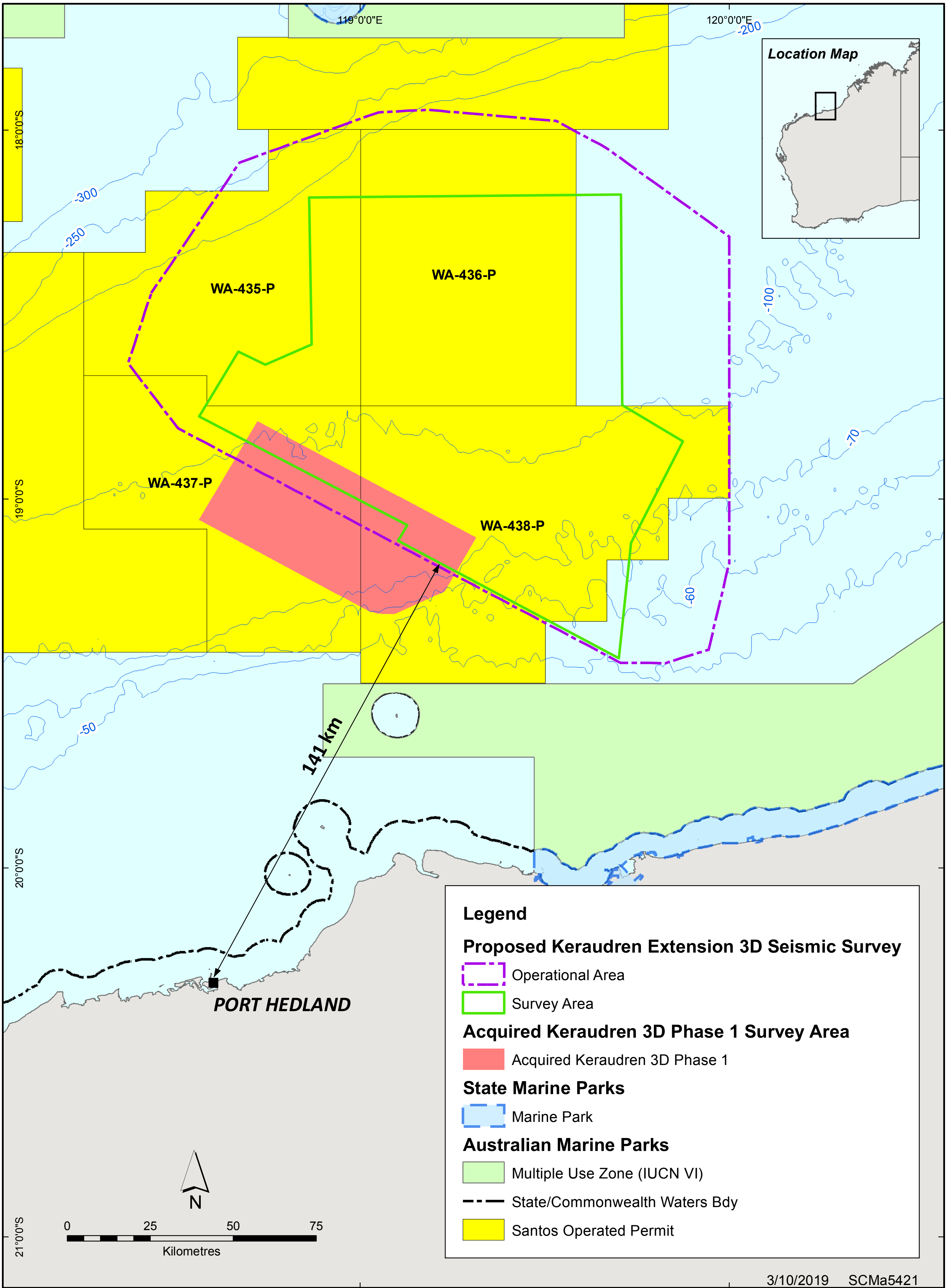
STAKEHOLDER CONSULTATION

Consultation Maps



Santos

KERAUDREN EXTENSION 3D SEISMIC SURVEY LOCATION



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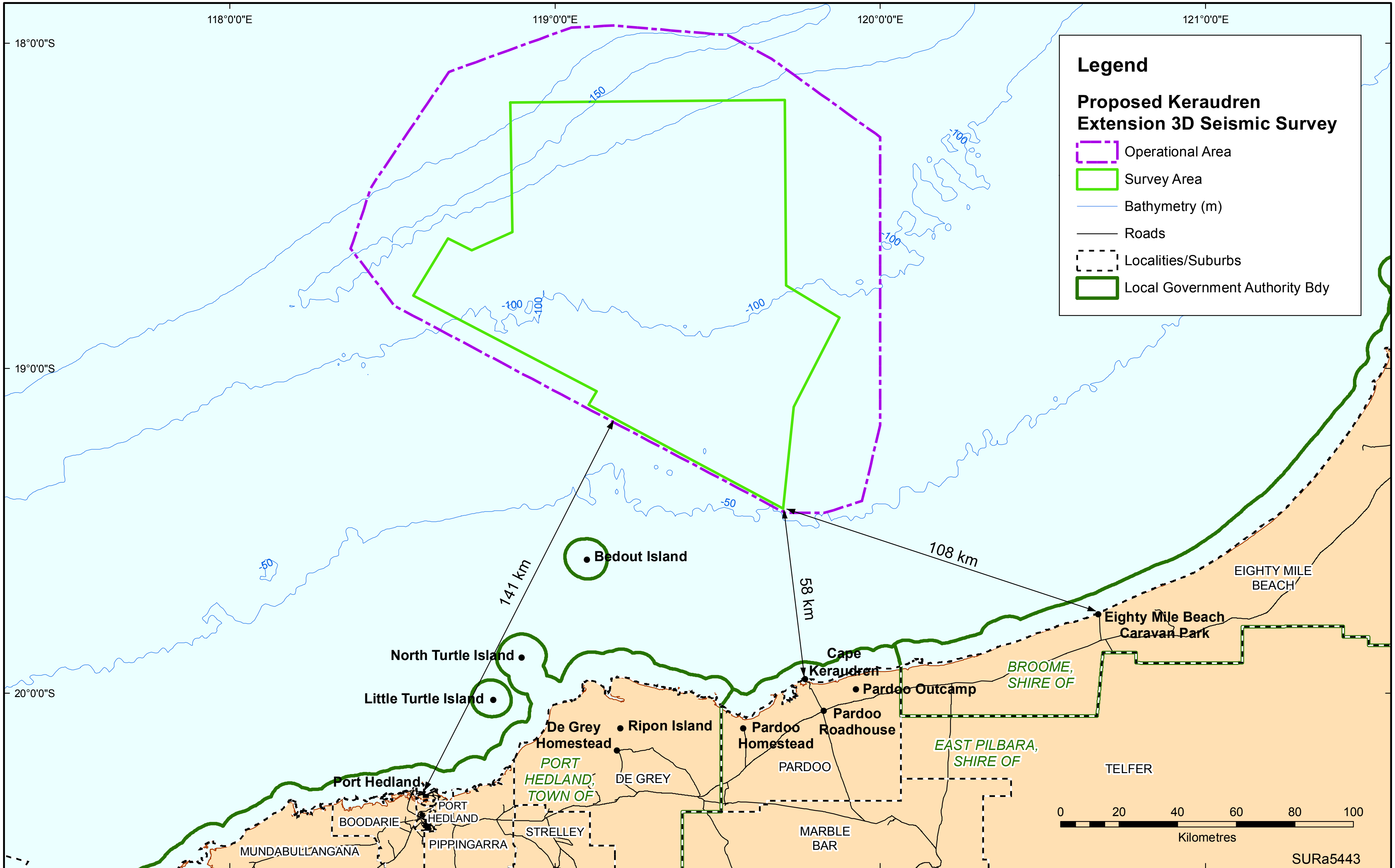
KERAUDREN EXTENSION 3D SEISMIC SURVEY LOCATION



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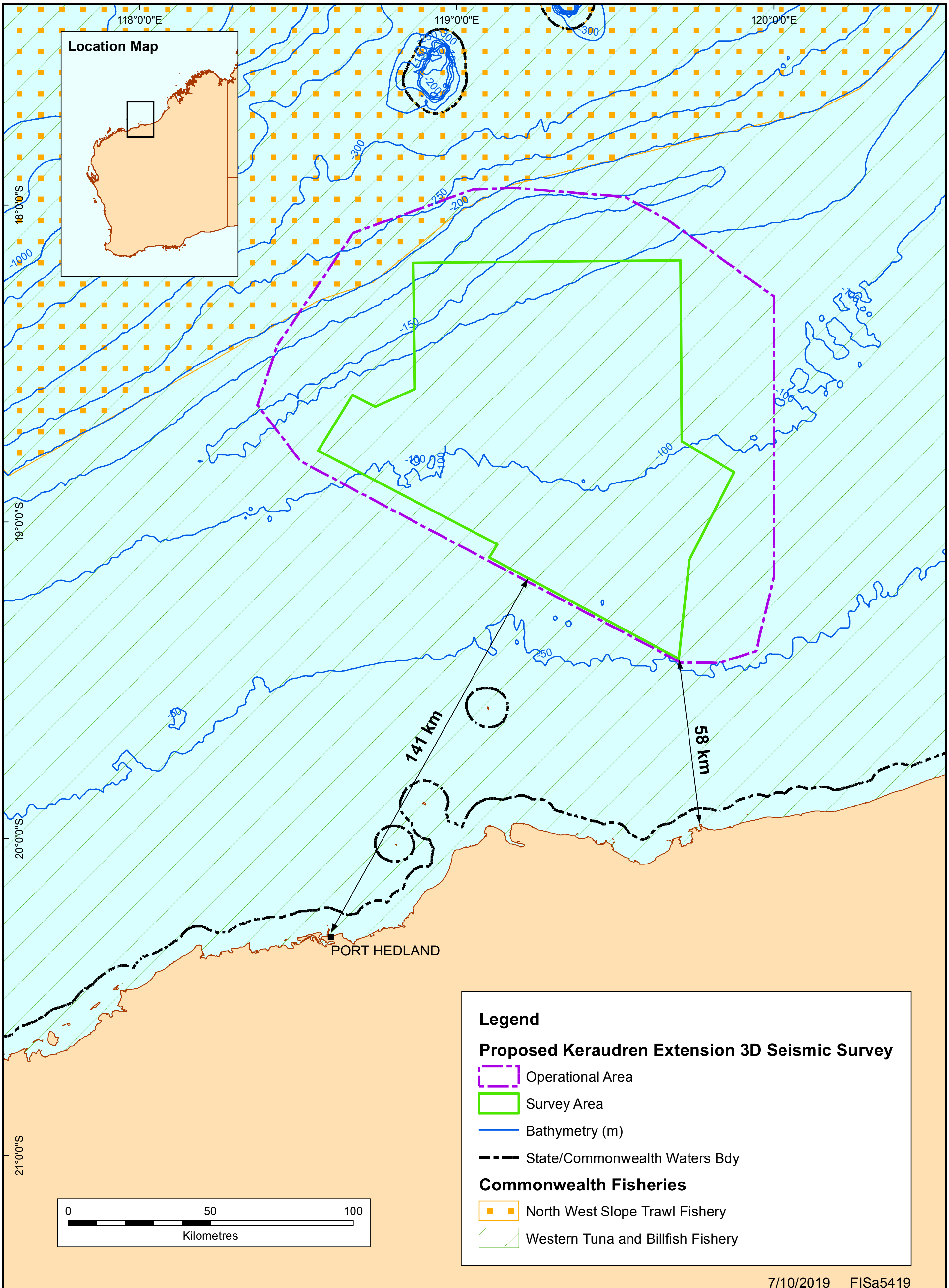
KERAUDREN EXTENSION 3D SEISMIC SURVEY

ONSHORE LOCALITIES



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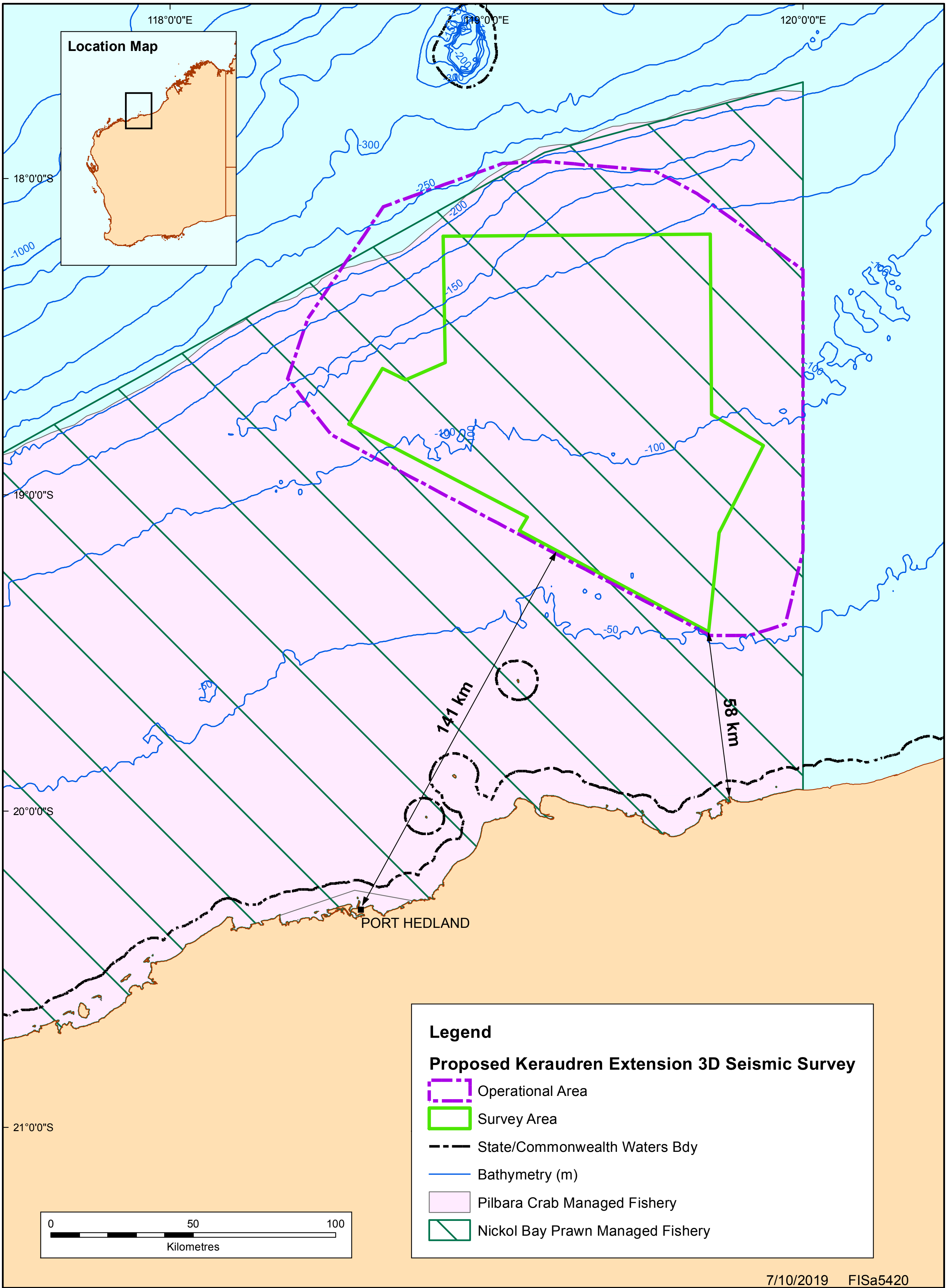
KERAUDREN EXTENSION 3D SEISMIC SURVEY

NORTH WEST SLOPE TRAWL + WESTERN TUNA AND BILLFISH FISHERIES



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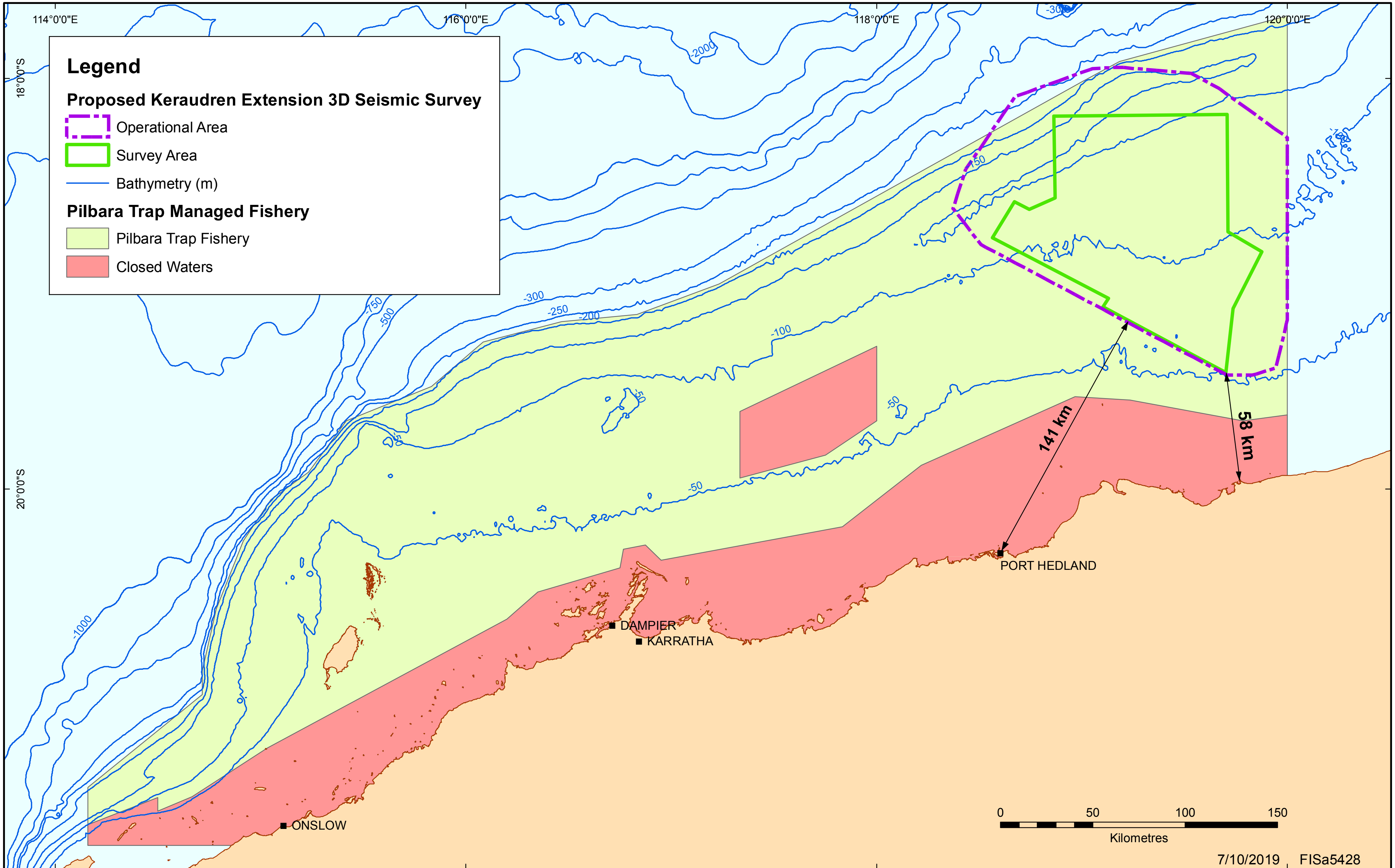
KERAUDREN EXTENSION 3D SEISMIC SURVEY
PILBARA CRAB + NICKOL BAY PRAWN MANAGED FISHERIES



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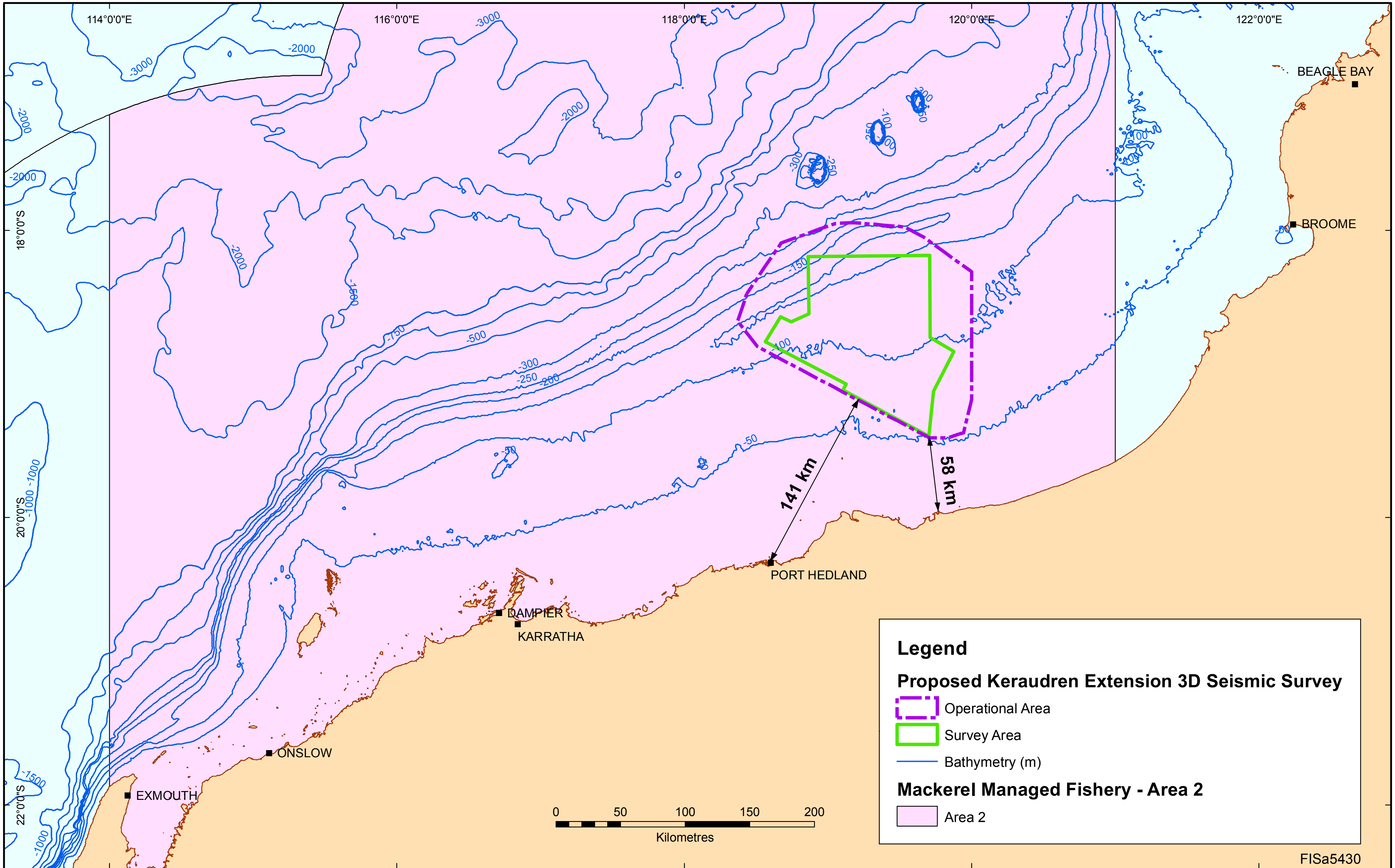
KERAUDREN EXTENSION 3D SEISMIC SURVEY

PILBARA TRAP MANAGED FISHERY



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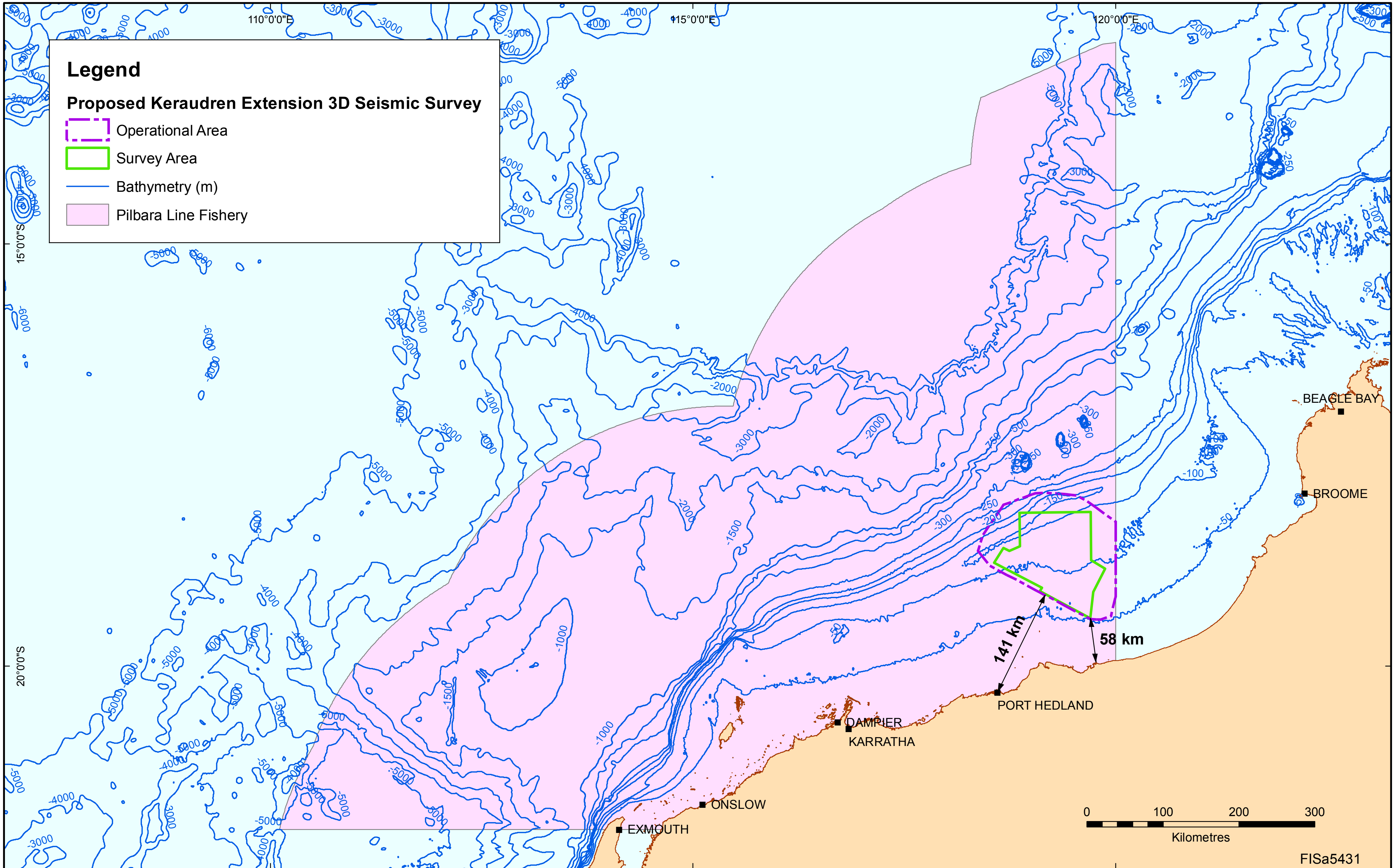
KERAUDREN EXTENSION 3D SEISMIC SURVEY

MACKEREL MANAGED FISHERY - AREA 2



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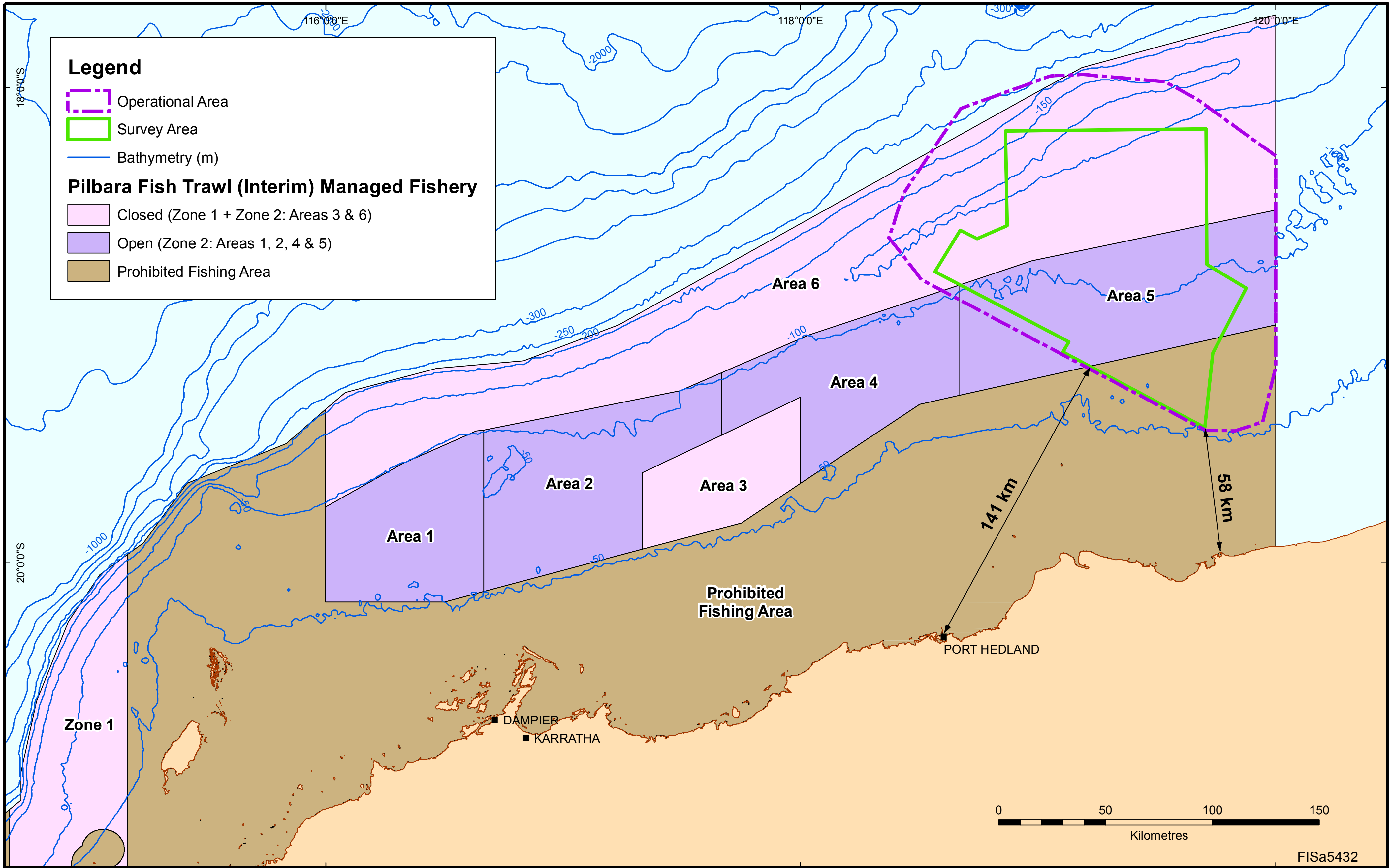
KERAUDREN EXTENSION 3D SEISMIC SURVEY

PILBARA LINE FISHERY



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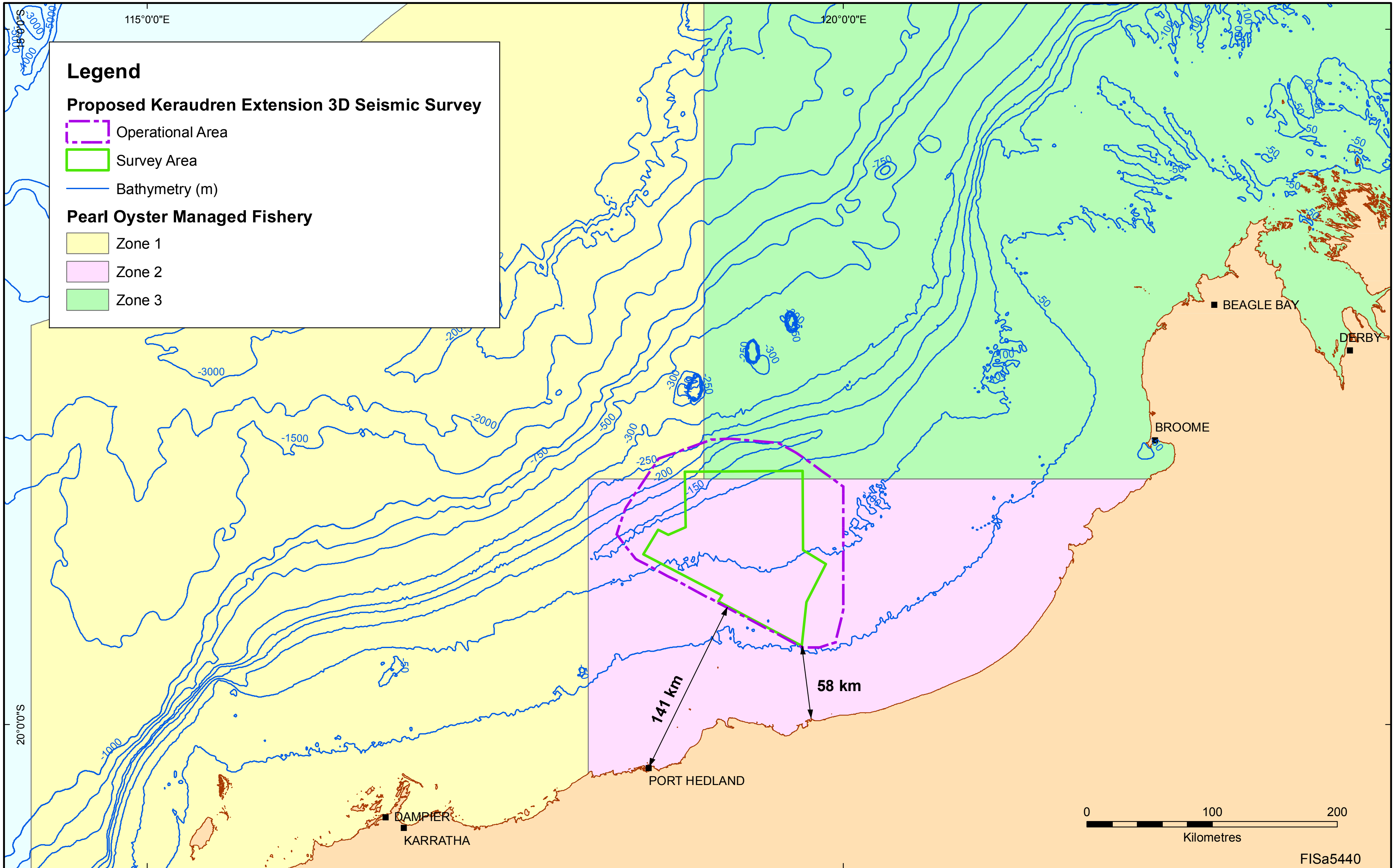
KERAUDREN EXTENSION 3D SEISMIC SURVEY

PILBARA FISH TRAWL (INTERIM) MANAGED FISHERY



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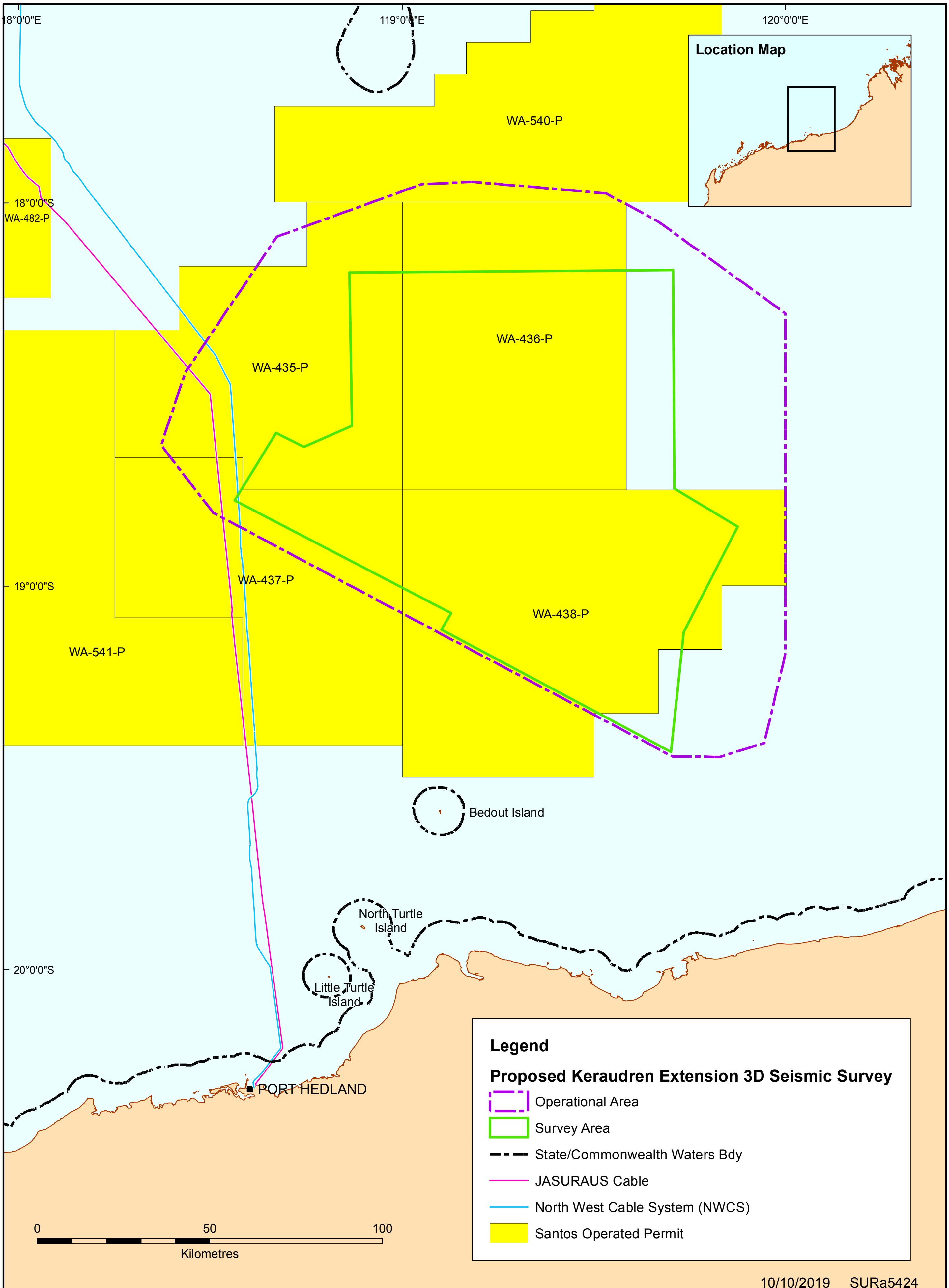
KERAUDREN EXTENSION 3D SEISMIC SURVEY

PEARL OYSTER MANAGED FISHERY



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KERAUDREN EXTENSION 3D SEISMIC SURVEY
SUBMARINE CABLE SYSTEMS

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STAKEHOLDER CONSULTATION

Quarterly Consultation Update

Consultation, [redacted]

From: Consultation, [redacted]
Sent: Wednesday, 23 October 2019 8:43 AM
Subject: Santos Limited | Quarterly Consultation Update
Attachments: Santos Quarterly Consultation Update 22 October 2019.pdf

Good morning,

Please find attached Santos' *Quarterly Consultation Update*, a document providing details of activities Santos plans to undertake from Q4 2019 to Q1 2020.

This document is intended to provide **advanced notification to allow stakeholders to identify activities that may impact them or for which more information is sought**. Information of interest to other marine users (such as commercial fishers), including water depth and exclusion zones, are provided within and a map is provided at the rear of the document.

If you have questions regarding any projects included in this document, please be in touch as soon as possible. If you would like to arrange to meet with Santos staff for a briefing session regarding the upcoming projects program, please do not hesitate to contact us and that meeting will be arranged.

I thank you for your time and continued support, your acknowledgment of receipt of this email is appreciated.

Thank you

Kind regards

Santos

[redacted]
Santos Limited, Level 7 100 St Georges Tce, Perth WA 6000
[redacted] [redacted]

https://www.santos.com/

Quarterly Consultation Update

October 2019

This update outlines planned activities by Santos Limited (Santos) in Western Australia through Q4 2019 to Q1 2020. It is intended to provide advanced notification to enable stakeholders to identify activities that may impact them, or for which more information is sought.

This document is provided in accordance with State and Commonwealth regulatory consultation guidelines, and can be supplemented with detailed project information packages or briefing sessions from Santos by request to the contact details provided below.

Please note that scheduling of the activities described in this update is subject to vessel and equipment availability and receipt of all necessary approvals, therefore the timing indicated may be subject to change. If there are any significant changes made to the scheduling indicated, stakeholders will be advised.

A summary of Santos' current operating facilities is also provided.

The spatial locations of activities described throughout this document can be found in the tables within, and in figures at the end of this update.

Potential impact to stakeholder interests

When reviewing Santos' activities within this document, please consider how they may impact your area of interest as an individual stakeholder.

Impacts to stakeholders may include exclusion zones for short and long term projects. For example, the gazetted exclusion zone around a drilling rig is 500 metres (m), while the exclusion zone around a slow-moving vessel, towing seismic streamers, can be larger.

This may impact access by mariners to an area during a proposed activity. Santos recommends stakeholders assess all information provided and seek additional information if required.

Operational activities relate to operating facilities at Varanus Island, Burrup Pipeline, Devil Creek and the *Ningaloo Vision* FPSO. These facilities have an existing exclusion zone which has been in place for an extended period of time.

Thank you for taking the time to review this update. Stakeholder feedback is valuable before, during and after activities, so if you have any concerns or queries relating to the activities described in this document, please feel free to contact us at the email below.

Contact Us
Santos
Ph: (08) 6218 [redacted]
Email: offshore.consultation@santos.com
Web: http://Santos.com/

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Proposed Western Australia offshore activities

This table gives key information on upcoming activities that are proposed to occur from Q4 2019

Activity Name	Type of Activity	Permit	Latitude	Longitude	Water Depth (approx.)	Start date estimate	Duration estimate	Exclusion zone details
John Brooks / Greater East Spar (Commonwealth Waters)	Inspection Maintenance and Repair (IMR)r	WA-29-L WA-45-L	115° 07' 12.624 E 114° 54' 22.08 E	20° 26' 50.445 S 20° 36' 31.95 S	48 – 110 m	Early November 2019	3-4 days	500 m around vessel
***Ningaloo Vision* FPSO** (Commonwealth Waters)	Shipyard Campaign (International)				N/A	Planned departure Q1/Q2 2020	Estimated return Q3/Q4 2020	
Keraudren Extension (Commonwealth Waters)	Seismic Survey	WA-435-P WA-436-P WA-437-P WA-438-P	Coordinates available on request		>50 – 200 m	Q1 2020	31 July 2020 (Stage 1)	3 nautical miles around vessel

Current offshore activities

Santos provides an update on ongoing activities in Q4 2019.

Activity Name	Type of Activity	Permit Number	Latitude	Longitude	Water Depth	Cessation date	Exclusion zone
Van Gogh Field (Commonwealth Waters)	Inspection Maintenance and Repair (IMR)	WA-35-L	21° 20' 57.29"S	114° 04' 23.613" E	340 m	Anticipated early November 2019	500 m around vessel
Varanus Island Compression and Power Optimisation Project (Onshore)	Facility Installation	PL-29 PL-12	Coordinates available on request		N/A	Anticipated Q3 2021	N/A

Completed offshore activities

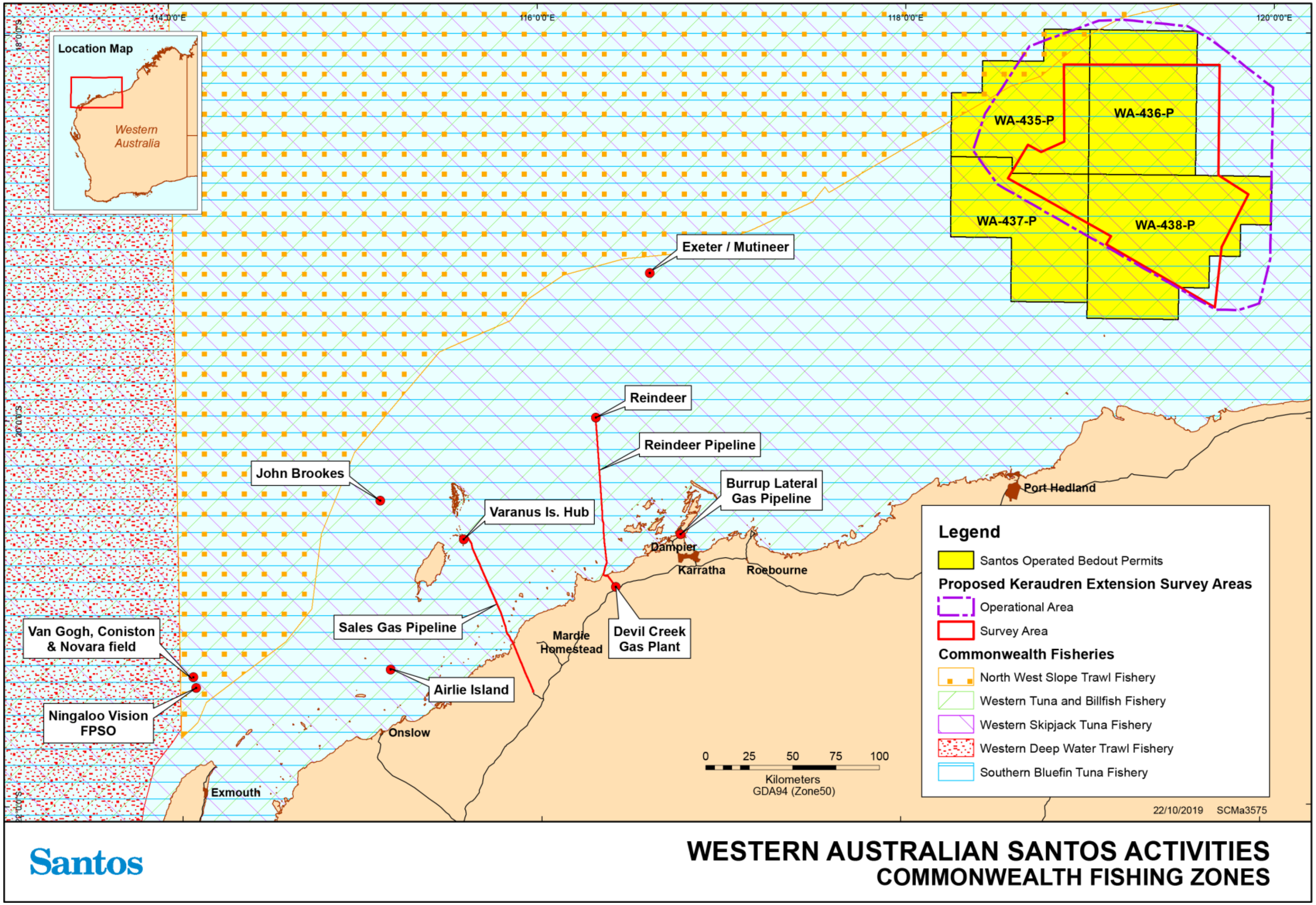
Santos provides an update on activities previously consulted and now completed.

Activity Name	Type of Activity	Permit Number	Water Depth	Latitude	Longitude
Bedout Basin (Commonwealth waters)	Dorado 3 Drilling	WA-437-P	90 m	19° 01’ 49.43” S	118° 43’ 34.13” E
Keraudren Phase 1 (Commonwealth waters)	Seismic Survey	WA-435-P WA-436-P WA-437-P WA-438-P	50 - 135 m	Coordinates available upon request	
Bedout Basin (Commonwealth waters)	Dorado 2 Drilling	WA-437-P	91 m	19° 01’ 19.46” S	118° 45’ 04.19” E
Bedout Basin (Commonwealth waters)	Roc South-1 Drilling	WA-437-P	94 m	18° 58’ 04.75” S	118° 50’ 51.51” E

Santos' West Australian operations

Santos provides an overview of existing operations on the North West Shelf.

Operational Activity Name	Type of Activity	Water depth	Exclusion zone	Update
Devil Creek Gas Plant (Reindeer facility, pipeline and gas plant)	Gas Production	Reindeer platform at 61 m	500 m around Reindeer Platform	Ongoing operations The five yearly regulatory revision of the two Environment Plans (EPs) which govern activities for the Reindeer Wellhead Platform and associated infrastructure have been completed and submitted to the regulators.
Varanus Island Hub (State and Commonwealth waters)	Oil & Gas Production	Various offshore platforms from	500 m around all offshore platforms (coordinates available on request)	Ongoing operations Environmental monitoring program ongoing at Varanus Island. The five yearly regulatory revision of the two Environment Plans (EPs) which govern activities at the Varanus Island Hub have been completed and submitted to the regulators.
Mutineer-Exeter Field	Ceased production	130 – 160 m	None	Production from the field has ceased and subsea infrastructure is currently preserved.
Burrup Lateral Gas	Gas Supply	Onshore	Onshore	Ongoing operations.
***Ningaloo Vision* FPSO**	Oil Production	340 m	500 m around FPSO	Ongoing operations. The five yearly regulatory revision of the *Ningaloo Vision* Operations Environment Plan (EP) is currently underway and due for submission Q2 2020.


Location Map
Western Australia
114°0'0"E
116°0'0"E
118°0'0"E
120°0'0"E
WA-435-P
WA-436-P
WA-437-P
WA-438-P
Exeter / Mutineer
Reindeer
Reindeer Pipeline
John Brookes
Burrup Lateral Gas Pipeline
Varanus Is. Hub
Port Hedland
Dampier
Karratha
Roebourne
Sales Gas Pipeline
Devil Creek Gas Plant
Mardie Homestead
Van Gogh, Coniston & Novara field
Airlie Island
Ningaloo Vision FPSO
Onslow
Exmouth
Legend
Santos Operated Bedout Permits
Proposed Keraudren Extension Survey Areas
Operational Area
Survey Area
Commonwealth Fisheries
North West Slope Trawl Fishery
Western Tuna and Billfish Fishery
Western Skipjack Tuna Fishery
Western Deep Water Trawl Fishery
Southern Bluefin Tuna Fishery
0 25 50 75 100
Kilometers
GDA94 (Zone50)
22/10/2019 SCMa3575
Santos
WESTERN AUSTRALIAN SANTOS ACTIVITIES
COMMONWEALTH FISHING ZONES

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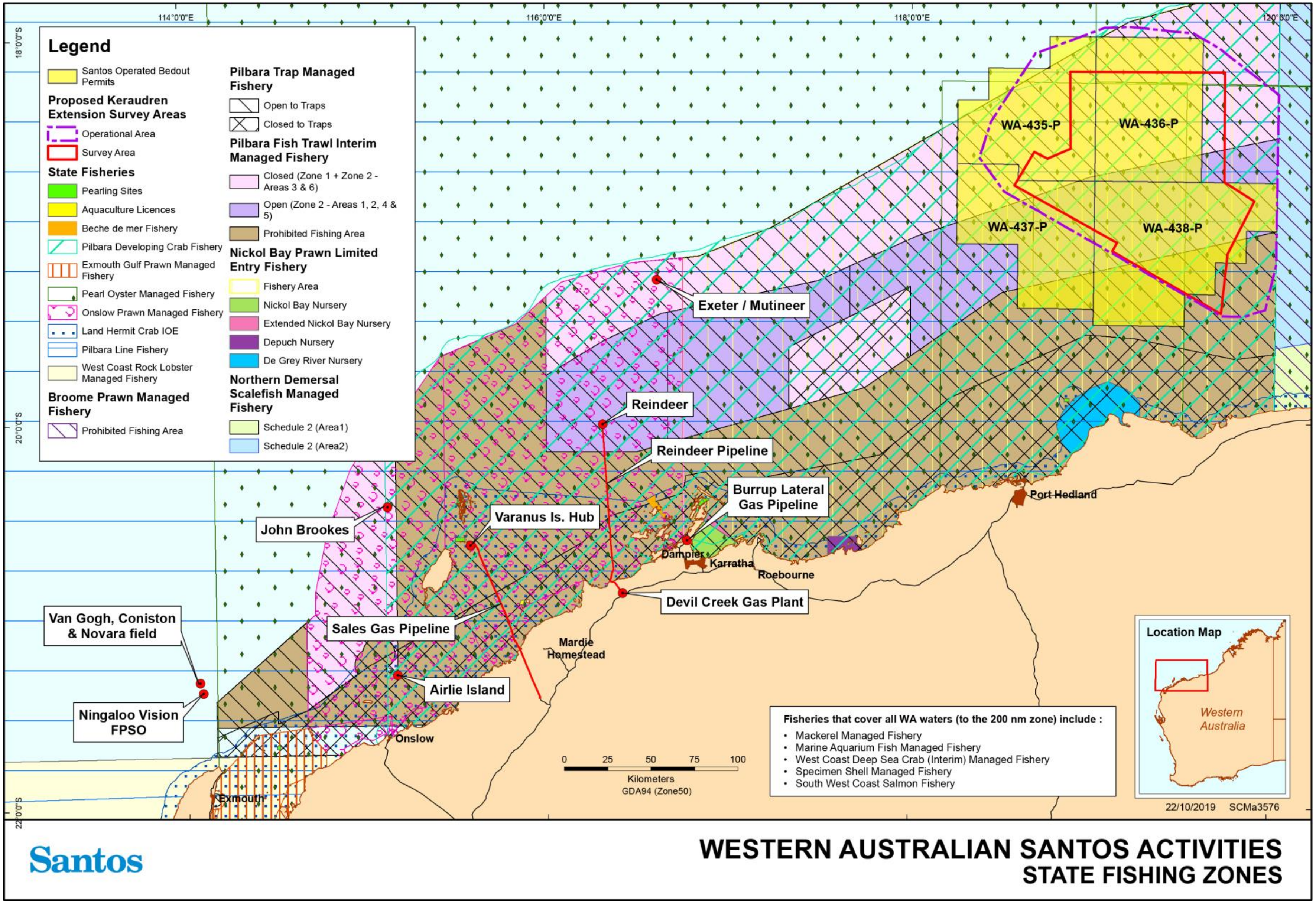

114°0'0"E
116°0'0"E
118°0'0"E
120°0'0"E
18°0'0"S
20°0'0"S
22°0'0"S
Legend
Santos Operated Bedout Permits
Proposed Keraudren Extension Survey Areas
Operational Area
Survey Area
State Fisheries
Pearling Sites
Aquaculture Licences
Beche de mer Fishery
Pilbara Developing Crab Fishery
Exmouth Gulf Prawn Managed Fishery
Pearl Oyster Managed Fishery
Onslow Prawn Managed Fishery
Land Hermit Crab IOE
Pilbara Line Fishery
West Coast Rock Lobster Managed Fishery
Broome Prawn Managed Fishery
Prohibited Fishing Area
Pilbara Trap Managed Fishery
Open to Traps
Closed to Traps
Pilbara Fish Trawl Interim Managed Fishery
Closed (Zone 1 + Zone 2 - Areas 3 & 6)
Open (Zone 2 - Areas 1, 2, 4 & 5)
Prohibited Fishing Area
Nickol Bay Prawn Limited Entry Fishery
Fishery Area
Nickol Bay Nursery
Extended Nickol Bay Nursery
Depuch Nursery
De Grey River Nursery
Northern Demersal Scalefish Managed Fishery
Schedule 2 (Area1)
Schedule 2 (Area2)
WA-435-P
WA-436-P
WA-437-P
WA-438-P
Exeter / Mutineer
Reindeer
Reindeer Pipeline
Burrup Lateral Gas Pipeline
Port Hedland
Varanus Is. Hub
John Brookes
Dampier
Karratha
Roebourne
Devil Creek Gas Plant
Van Gogh, Coniston & Novara field
Sales Gas Pipeline
Mardie Homestead
Airlie Island
Ningaloo Vision FPSO
Onslow
Exmouth
0 25 50 75 100
Kilometers
GDA94 (Zone50)
Fisheries that cover all WA waters (to the 200 nm zone) include :
• Mackerel Managed Fishery
• Marine Aquarium Fish Managed Fishery
• West Coast Deep Sea Crab (Interim) Managed Fishery
• Specimen Shell Managed Fishery
• South West Coast Salmon Fishery
Location Map
Western Australia
22/10/2019 SCMa3576
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WESTERN AUSTRALIAN SANTOS ACTIVITIES
STATE FISHING ZONES

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Appendix G – Santos Risk Matrix and Consequence Table

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			SEVERITY					
			1. Negligible	2. Minor	3. Moderate	4. Major	5. Critical	
			First Aid Case	Medical Treatment Case / Restricted Work Day Case	Lost Time Injury	Severe Injury[1], Permanent Disability, Single Fatality	Multiple Fatalities	**Health & Safety**
			Environmental impact lasting days up to 1 week	Environmental impact lasting weeks up to 12 months	Environmental impact lasting from 1 to 10 years	Environmental impact lasting 10 to 20 years	Environmental impact lasting more than 20 years to no recovery	**Environmental**
			Impact less than $500k	Impact of $500k to $10M	Impact of $10M to $50M	Impact of $50M to $500M	Impact greater than $500M	**Financial (AUD)**
			Short term local concern (community), no legal or reputation impact	Short term regional/ community concern (WA), local press, potential impact on reputation	Short term national coverage, JV oversight impact, short term impact on reputation but no legal proceedings	National coverage, short term brand impact, litigation almost certain, serious damage to reputation with adverse publicity	International coverage, long term brand impact, litigation, sustained serious damage to reputation	**Reputation**
LIKELIHOOD	**5. Probable**	1. Event has occurred frequently within the Company 2. Between 1 and 10 incidents every 10 years (i.e. up to frequency 1/year)						
	4. Likely	1. Event has occurred frequently within Industry 2. Between 1 and 10 incidents every 100 years (i.e. up to frequency 10^{-1}/year)						
	3. Unlikely	1. Event has occurred occasionally within the Company 2. Between 1 and 10 incidents every 1000 years (i.e. up to frequency 10^{-2}/year)						
	2. Very Unlikely	1. Has occasionally occurred within the Industry 2. Between 1 and 10 incidents every 10,000 years (i.e. up to frequency 10^{-3}/year)						
	1. Rare	1. Could happen under exceptional circumstances only 2. Between 1 and 10 incidents every 100,000 years (i.e. up to frequency 10^{-4}/year)						

High Risk - reduction of risk required

Medium Risk - reduction of risk required based on ALARP principle

Low Risk - deemed acceptable based on standard risk controls in place

Notes:
1. As per Injury Severity Score
2. Worst case Severity category shall be used if multiple categories are applicable
3. All fields bordering high (red) risks require special attention and effort to reduce to a lower risk.
4. Financial loss shall be a potential pre-tax loss in the reporting period including cash leakage, value of lost production, potential write downs in asset values, uplifts to liabilities/provisions, reduction in QE equity value, etc. All losses shall be gross (QE and JVP share) and in AUD. This excludes insurances offsets.
5. Refer to Risk Management Procedure QE-91-IF-10052 for guidance on the use of this matrix.

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	Consequence level	A – Negligible	B – Minor	C – Moderate	D – Major	E – Critical
	Acceptability	Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable
	Severity	*No impact or negligible impact.* *Environmental impact lasting days up to 1 week*	*Detectable but insignificant change to local population, industry or ecosystem factors. Localised effect* *Environmental impact lasting weeks up to 12 months*	*Significant impact to local population, industry or ecosystem factors.* *Environmental impact lasting 1 to 10 years*	*Major long-term effect on local population, industry or ecosystem factors.* *Environmental impact lasting 10 to 20 years*	*Complete loss of local population, industry or ecosystem factors AND/ OR major wide-spread regional impacts with slow to no full recovery.* *Environmental impact lasting more than 20 years to no recovery*
Environmental Receptors	**Fauna** In particular, EPBC Act listed threatened/migratory fauna or WA Wildlife Conservation Act 1950 specially protected fauna	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity; No decrease in local population size; No reduction in area of occupancy of species; No loss/disruption of habitat critical to survival of a species; No disruption to the breeding cycle of any individual; No introduction of disease likely to cause a detectable population decline.	Detectable but insignificant decrease in local population size (excluding protected species); Insignificant reduction in area of occupancy of species; Insignificant loss/disruption of habitat critical to survival of a species; Insignificant disruption to the breeding cycle of local population.	Significant decrease in local population size but no threat to overall population viability; Significant behavioural disruption to local population; Significant disruption to the breeding cycle of a local population; Significant reduction in area of occupancy of species; Significant loss of habitat critical to survival of a species; Modify, destroy, remove, isolate or decrease availability of quality of habitat to the extent that a significant decline in local population is likely; Introduce disease likely to cause a significant population decline.	Long term decrease in local population size and threat to local population viability; Major disruption to the breeding cycle of local population; Major reduction in area of occupancy of species; Fragmentation of existing population; Major loss of habitat critical to survival of a species; Modify, destroy, remove, isolate or decrease availability of quality of habitat to the extent that a long term decline in local population is likely; Introduce disease likely to cause a long term population decline	Complete loss of local population; Complete loss of habitat critical to survival of local population; Wide spread (regional) decline in population size or habitat critical to regional population.
Environmental Receptors	**Physical Environment / Habitat** Includes: air quality; water quality; benthic habitat (biotic/abiotic), particularly habitats that are rare or unique; habitat that represents a Key Ecological Feature[4]; habitat within a protected area; habitats that include benthic primary producers[5] and/ or epi-fauna[6]	No or negligible reduction in physical environment / habitat area/function.	Detectable but localised and insignificant loss of area/function of physical environment / habitat. Rapid recovery evident within ~ 1 year (seasonal recovery)	Significant loss of area and/or function of local physical environment / habitat. Recovery over medium term (2–10 years)	Major, large-scale loss of area and/or function of physical environment / local habitat. Slow recovery over decades.	Complete destruction of local physical environment / habitat with no recovery; Long term (decades) and wide spread loss of area or function primary producers on a regional scale
Environmental Receptors	**Threatened ecological communities** (EPBC Act listed ecological communities)	No decline in threatened ecological community population size, diversity or function; No reduction in area of threatened ecological community; No introduction of disease likely to cause decline in threatened ecological community population size, diversity or function.	Detectable but insignificant decline in threatened ecological community population size, diversity or function; Insignificant reduction in area of threatened ecological community.	Significant decline in threatened ecological community population size, diversity or function; Significant reduction in area of threatened ecological community; Introduction of disease likely to cause significant decline in threatened ecological community population size, diversity or function.	Major long term decline in threatened ecological community population size, diversity or function Major reduction in area of threatened ecological community Fragmentation of threatened ecological community Introduce disease likely to cause long term decline in threatened ecological community population size, diversity or function	Complete loss of threatened ecological community
Environmental Receptors	**Protected Areas** Includes: World Heritage Properties; Ramsar wetlands; Commonwealth/ National Heritage Areas; Land/ Marine Conservation Reserves.	No or negligible impact on protected area values; No decline in species population within protected area; No or negligible alteration, modification, obscuring or diminishing of protected area values.*	Detectable but insignificant impact on one of more of protected area's values. Detectable but insignificant decline in species population within protected area. Detectable but insignificant alteration, modification, obscuring or diminishing of protected area values*	Significant impact on one of more of protected area's values; Significant decrease in population within protected area; Significant alteration, modification, obscuring or diminishing of protected area values.	Major long term effect on one of more of protected area's values Long term decrease in species population contained within protected area and threat to that population's viability Major alteration, modification, obscuring or diminishing of protected area values	Complete loss of one of more of protected area's values; Complete loss of species population contained within protected area.
Environmental Receptors	**Socio-economic receptors** Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping.	No or negligible loss of value of the local industry; No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry; Significant medium term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry; Permanent loss of key natural features or populations supporting the local industry.

* Excluding World Heritage Areas

[4] As defined by the Department of Environment (DoE)
[5] Benthic photosynthetic organisms such as seagrass, algae, hard corals and mangroves
[6] Fauna attached to the substrate including sponges, soft corals and crinoids.

Appendix H – JASCO Keraudren Extension 3D Marine Seismic Survey Acoustic Modelling

Keraudren Extension 3-D Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

Submitted to:

Nick Phillips

Santos WA Energy Limited
PO: 4300107526

Authors:

Matthew Koessler
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4 December 2019

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Version 1.0

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Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

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Executive Summary

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned Keraudren Extension 3-D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, sponges, coral, and plankton. Modelling considered six comparably sized seismic arrays with volumes up to 3480 in^3. The three loudest arrays based upon the modelled far-field source levels, were coupled with single impulse propagation modelling to determine the array most likely to produce the largest ranges to thresholds, which was determined to be a 3260 in^3 seismic source with a 7 m tow depth. Therefore, the modelling considered this 3260 in^3 seismic source in a triple source configuration, towed at 7 m depth behind a single vessel.

A specialised airgun array source model was used to predict the acoustic signature of the seismic source, and complementary underwater acoustic propagation models were used in conjunction with the modelled array signature to estimate sound levels over a large area around the source. Single-impulse sound fields were predicted at eight sites within the Full Power Zone, with water depths between 38 and 157 m. Accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 hours.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. A conservative sound speed profile that would be most supportive of sound propagation conditions for the period of the survey was defined and applied to all modelling.

The analysis considered the distances away from the seismic source at which several effects criteria or relevant sound levels were reached. The results are summarised below for the representative single-impulse sites and accumulated SEL scenarios.

Marine mammal injury and behaviour

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 5.66 and 8.84 km.
- The results for marine mammal injury considered the criteria from the National Marine Fisheries Service (NMFS 2018) technical guidance. NMFS (NMFS 2018) allows for two metrics in the criteria (PK and SEL_{24h}) for the assessment of marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS). The longest distance associated with either metric is required to be applied for assessment. Table 1 summarises the maximum distances for PTS, along with the relevant metric associated with the maximum PTS distance; the farthest distances were associated with Scenario 2, in deeper water.
- The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding SEL_{24h} radii for low-frequency cetaceans were larger than those for peak pressure criteria, but they represent an unlikely worst-case scenario. More realistically, marine mammals (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with injury (either PTS or TTS) if it remained in that location for 24 hours.

Table 1. Summary of maximum marine mammal PTS onset distances for modelled scenarios.

Hearing group	Metric associated with longest distance to PTS onset	R_{max} (km)
Low-frequency cetaceans†	SEL_{24h}	3.08
Mid-frequency cetaceans	SEL_{24h}	0.02
High-frequency cetaceans	PK	0.43

† The model does not account for shutdowns.

Turtles

- The PK turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metric was 120 m for PTS onset and 1.34 km for TTS onset (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- Table 2 summarises the distances to where the NMFS criterion (NSF 2011) for behavioural response of turtles to the 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000b, McCauley et al. 2000a) could be exceeded.

Table 2. Summary of distances to turtle behavioural response criteria.

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Minimum	Maximum
175†	1.04	1.27
166‡	2.92	4.30

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b, McCauley et al. 2000a).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:
    - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
    - Fish with a swim bladder that do not use it for hearing
    - Fish that use their swim bladders for hearing
    - Fish eggs and fish larvae
- Table 3 summarises distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric.

Table 3. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios.

Relevant hearing group	Effect criteria	Water column		Seafloor	
		Metric associated with longest distance to criteria	R_{max} (km)	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.07	PK	0.09
	TTS	SEL_{24h}	6.32	SEL_{24h}	6.18
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.28	SEL_{24h}	0.28
	TTS	SEL_{24h}	6.32	SEL_{24h}	6.18
Fish eggs, and larvae	Injury	PK	0.23	PK	0.16

Benthic invertebrates, Sponges, Coral, and Plankton

To assist with assessing the potential effects on these receptors, the following results were determined:

- Bivalves: The distance where a particle acceleration of 37.57 ms^{-2} at the seafloor could occur was determined for comparing to results presented in Day et al. (2016a). The maximum distance to this particle acceleration level was 55 m.
- Crustaceans: The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008) was considered for seafloor sound levels; the sound level was reached at ranges between 351 and 685 m depending on the modelled site.
- Sponges and coral: The PK sound level at the seafloor directly underneath the seismic source was estimated at all modelled sites and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); the threshold was reached within a 5 m horizontal range from the acoustic centre of the source at the shallowest modelled site, at 38 m water depth.
- Plankton: The distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at all modelled sites through full-waveform modelling; the results ranged from 6.82 to 7.92 km.

1. Introduction

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned Keraudren Extension 3-D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, plankton, sponges and corals.

JASCO's specialised Airgun Array Source Model (AASM) was used to predict acoustic signatures and spectra for six comparably sized source arrays under initial consideration for the Keraudren Extension 3-D MSS. AASM accounts for individual airgun volumes, airgun bubble interactions, and array geometry to yield accurate source predictions. Out of these six arrays, a single nominal source location within the survey area was used to compare single impulse received levels from the three arrays with the loudest source signatures and determine received levels when environmental effects were considered. This allowed the worst-case seismic source to be determined based upon both the source signature and the survey specific environment.

Complementary underwater acoustic propagation models were used in conjunction with the selected array signature to estimate sound levels considering environmental effects. Single-impulse sound fields were predicted at eight defined locations within the Full Power Zone (FPZ), and accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 h with the worst-case source (Section 2). A conservative sound speed profile that would be most supportive of sound propagation conditions for the potential survey period was defined and applied throughout. Results are in part presented as maps to assist with understanding the acoustic impact and potential effects spatially, such as to the Ancient Coastline at 125 m Key Ecological Feature (KEF), the Pearl Oyster Fishery region shallower than the 70 m contour, the Flatback Turtle Interesting Biologically Important Area (BIA), the Pygmy Blue Whale Migration BIA, and the Humpback Whale Migration BIA.

The modelling methodology considered source directivity and range-dependent environmental properties. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria.

Section 3 explains the metrics used to represent underwater acoustic fields and the impact criteria considered. Section 0 details the methodology for predicting the source levels and modelling the sound propagation, including the specifications of the seismic source and all environmental parameters the propagation models require. Section 5 presents the results, which are then discussed and summarised in Section 6.

2. Modelling Scenarios

Eight standalone single impulse sites and two likely scenarios for survey operations over 24 hours to assess accumulated SEL were modelled. The locations of all modelled sites are provided in Table 4, with all sites and the acquisition lines shown in Figure 1 along with the survey boundaries. The modelling assumed that a survey vessel sailed along survey lines at ~4.5 knots, with an impulse interval of 8.33 m. Two representative scenarios (Scenario 1 and 2) for acquisition were considered for 24 hours of operation. Scenario 1 considered two survey sail lines in the southeast corner of the FPZ, and Scenario 2 considered three sail lines in the northern area of the FPZ.

The single impulse sites and accumulated SEL scenarios were selected based on a proposed survey line plan option, whereby the southern part of the FPZ will be acquired along survey lines orientated 30/120°, and the northern part of the FPZ will be acquired along survey lines orientated 90/270°. The locations of these scenarios are considered representative of the range of water depths that will be covered during the Santos Keraudren Extension 3-D MSS and the potential sound propagation characteristics that may arise at various locations within the FPZ. The orientations of the single impulse sites and line scenarios were selected as they provide for the greatest sound propagation radii broadside from the seismic source towards both shallow water receptors and deep-water receptors relevant to the survey. These receptors include but are not limited to biologically important areas (BIAs) for migrating humpback whales and internesting marine turtles in nearshore waters, and a BIA for migrating pygmy blue whales in deeper, offshore waters.

A second proposed survey line plan option was also considered, whereby all survey lines (including the northern part of the FPZ) may be orientated 30/120°. However, this line plan option was not modelled in the northern part of the FPZ, as the orientation of single impulses in the 90/270° is generally expected to result in the greatest broadside sound propagation.

For Scenario 1, acquisition of two lines took ~13 h and 5 h (each) to traverse with ~3.5 h of turn time required between the lines. For Scenario 2, three lines were modelled for a 24-hour period, where the first two acquisition lines line took 8 h (each) to traverse and the third, which was a partial segment of a full acquisition line, took 1.8 h to traverse. The time to complete a turn was ~3 h per turn for Scenario 2. These scenarios accounted for 18331 impulses for Scenario 1 and 17887 impulses for Scenario 2 during the respective 24 h periods of acquisition. During line turns, the seismic source was not operating.

Figures 2–3 show the static receiver locations spaced along a transect perpendicular to a survey line at:

- 50 m increments between distances of 50 to 500 m,
- 100 m increments between 600 m to 6 km,
- 8 km, and
- 5 km increments between 10 and 30 km.

These static receivers were considered for a modelled time history of sound exposure accumulation and for discussing the influence of accumulated sound levels on fish.

Table 4. Location details for the single impulse modelled sites.

Scenario	Site	Latitude (S)	Longitude (E)	MGA* Zone 50		Water depth (m)	Tow direction (°)
				x (m)	*y* (m)		
1	1	19° 15' 5.3632"	119° 27' 42.4018"	758773	7869512	38	300
	2	19° 17' 5.8746"	119° 37' 10.5498"	775315	7865562	58	120 & 300
	3	19° 7' 49.7041"	119° 14' 26.5799"	735698	7883225	79	120 & 300
	4	19° 0' 58.0898"	119° 6' 55.1720"	722656	7896047	84	120
	5	18° 51' 54.7188"	118° 49' 57.0092"	693052	7913089	101	120
2	6	18° 19' 29.9993"	119° 2' 9.9414"	715185	7972655	157	90 & 270
	7	18° 19' 19.1599"	119° 17' 17.5896"	741845	7972672	137	90 & 270
	8	18° 18' 52.7961"	119° 33' 41.3365"	770753	7973098	125	90 & 270

* Map Grid of Australia (MGA)

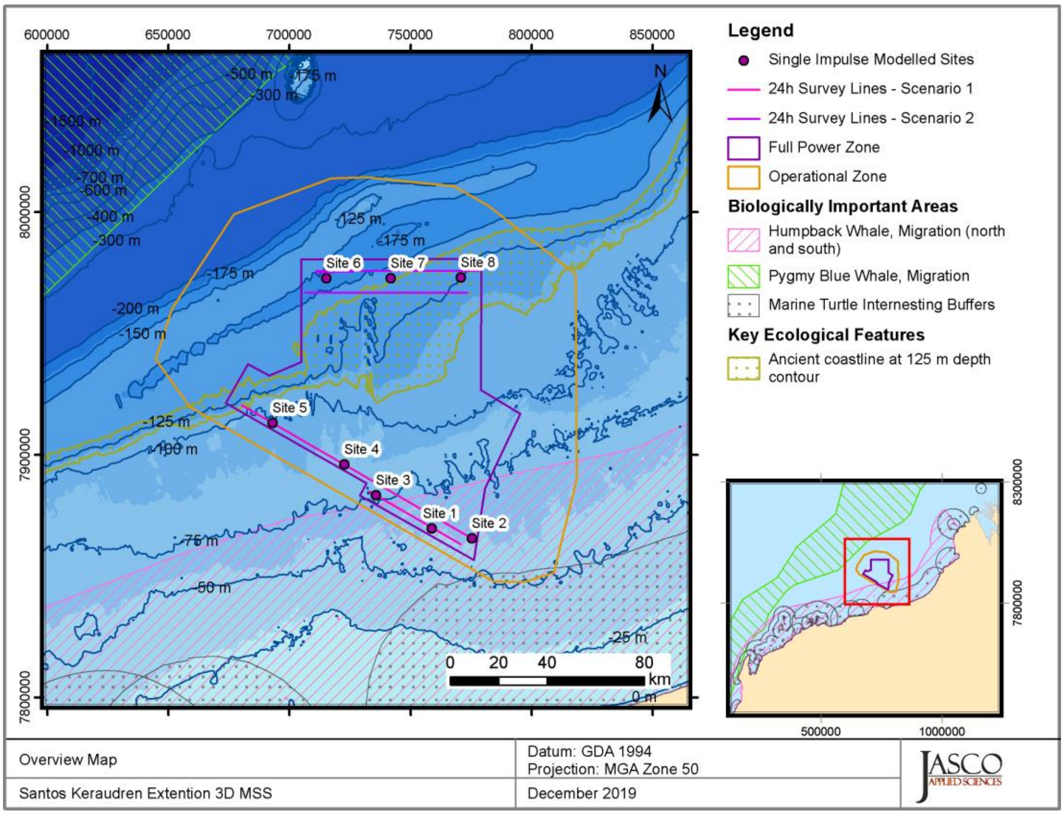

Figure 1. Overview of the modelled sites, acquisition lines, and features for the Santos Keraudren Extension 3-D MSS.

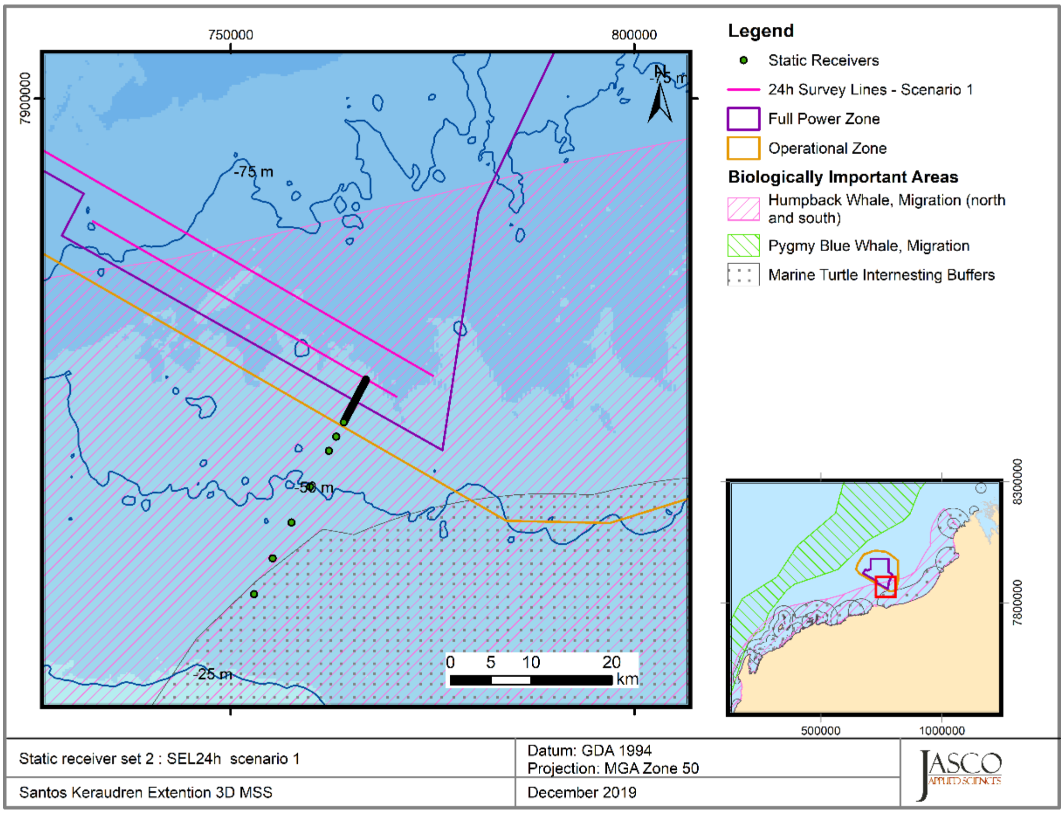

Figure 2. *Scenario 1*: Acquisition lines and static receiver locations considered for SEL_{24h} calculations.

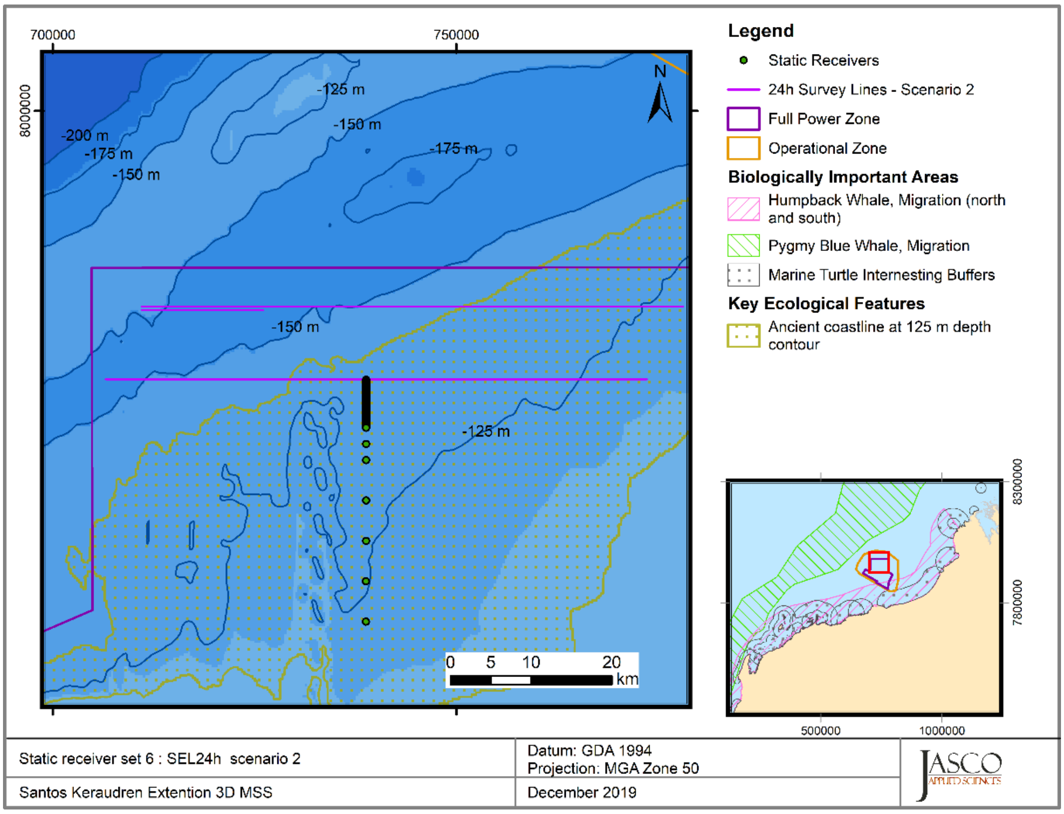

Figure 3. *Scenario 2*: Acquisition lines and static receiver locations considered for SEL_{24h} calculations.

3. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as from seismic airguns, is not generally proportional to the instantaneous acoustic pressure. Rather, perceived loudness depends on the pulse rise-time and duration, and the frequency content. Several sound level metrics, such as PK, SPL, and SEL, are commonly used to evaluate noise and its effects on marine life (Appendix A). The period of accumulation associated with SEL is defined, with this report referencing either a “per pulse” assessment or over 24 h. Appropriate subscripts indicate any applied frequency weighting; unweighted SEL is defined as required. The acoustic metrics in this report reflect the updated ISO standard for acoustic terminology, ISO/DIS 18405:2017 (2017).

Whether acoustic exposure levels might injure or disturb marine mammals is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), and United States National Marine Fisheries Service (NMFS 2018). The number of studies that have investigated the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

We chose the following noise criteria and sound levels for this study because they include standard thresholds, thresholds suggested by the best available science, and sound levels presented in literature for species with no suggested thresholds (Sections 3.1–3.3 and Appendix A):

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from the U.S. National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2018) for the onset of Permanent Threshold Shift (PTS) in marine mammals.
2. Marine mammal behavioural threshold based on the current U.S. National Marine Fisheries Service (NMFS) (2014) of 160 dB re 1 µPa SPL (L_p) for impulsive sound sources.
3. Sound exposure guidelines for fish, fish eggs and larvae, and turtles (Popper et al. 2014).
4. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in turtles.
5. Turtle behavioural response threshold of 166 dB re 1 µPa SPL (L_p) (NSF 2011), as applied by the US NMFS, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL) (McCauley et al. 2000b, 2000a).
6. A sound level 178 dB re 1 µPa PK-PK in the water column, reported for comparison to the results in McCauley et al. (2017) for plankton.
7. Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and particle acceleration at the seafloor to help assess effects of noise on crustaceans and bivalves through comparing to results in Day et al. (2016a), Day et al. (2019), Day et al. (2016b), Day et al. (2017) and Payne et al. (2008).
8. A sound level of 226 dB re 1 µPa PK (L_{pk}) reported for comparing to Heyward et al. (2018) for sponges and corals.

Additionally, to assess the size of the low-power zone required under the Australian Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, Department of the Environment, Water, Heritage and the Arts (DEWHA 2008), the distance to an unweighted per-pulse SEL of 160 dB re 1 µPa^2·s is reported.

The following subsections expand on the thresholds and sound levels for marine mammals, fish, turtles, fish eggs, fish larvae, and benthic invertebrates.

3.1. Marine Mammals

The criteria applied in this study to assess possible effects of airgun noise on marine mammals are summarised in Table 5 and detailed in Sections 3.1.1 and 3.1.2, with frequency weighting explained in Appendix A.4.

Table 5. Unweighted SPL, SEL_{24h}, and PK thresholds for acoustic effects on marine mammals.

Hearing group	NMFS (2014)	NMFS (2018)			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
Mid-frequency cetaceans		185	230	170	224
High-frequency cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_{pk}, flat–peak denotes a sound pressure that is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa²s.
Subscripts indicate the designated marine mammal auditory weighting.

3.1.1. Behavioural Response

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds. Their review found that most marine mammals exhibited varying responses between 140 and 180 dB re 1 µPa SPL, but inconsistent results between studies made choosing a single behavioural threshold difficult. Studies varied in their lack of control groups, imprecise measurements, inconsistent metrics, and that animal responses depended on study context, which included the animal's activity state. To create meaningful quantitative data from the collected information, Southall et al. (2007) proposed a severity scale that increased with increasing sound levels.

NMFS has historically used a relatively simple sound level criterion for potentially disturbing a marine mammal. For impulsive sounds, this threshold is 160 dB re 1 µPa SPL for marine mammals (NMFS 2014), which has been applied for this report.

3.1.2. Injury and Hearing Sensitivity Changes

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs and temporary threshold shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To assist in assessing the potential for injuries to marine mammals, this report applies the criteria recommended by NMFS (2018), considering both PTS and TTS, to help assess the potential for injuries to and hearing sensitivity changes in marine mammals. Appendix A.3 provides more information about the NMFS (2018) criteria.

3.2. Fish, Turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and turtles, work begun by a panel convened by NOAA two years earlier. The resulting guidelines included specific thresholds for different levels of effects and for different groups of species (Popper et al. 2014). These guidelines defined quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death.
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma.
- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. These effects are not assessed in this report. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure varies depending on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Turtles, fish eggs, and fish larvae are considered separately. Table 6 lists relevant effects thresholds from Popper et al. (2014). In general, any adverse effects of seismic sound on fish behaviour depends on the species, the state of the individuals exposed, and other factors. We note that, despite mortality being a possibility for fish exposed to airgun sounds, Popper et al. (2014) do not reference an actual occurrence of this effect. Since the publication of that work, newer studies have further examined the question of possible mortality. Popper et al. (2016) adds further information to the possible levels of impulsive seismic airgun sound to which adult fish can be exposed without immediate mortality. They found that the two fish species in their study, with body masses in the range 200–400 g, exposed to a single-impulse of a maximum received level of either 231 dB re 1 μPa (PK) or 205 dB re 1 $\mu Pa^2 \cdot s$ (SEL), remained alive for 7 days after exposure and that the probability of mortal injury did not differ between exposed and control fish.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, it is required to define a time. Popper et al. (2014) recommend applying a standard period, where this is either defined as a justified fixed period or the duration of the activity; however, Popper et al. (2014) also included caveats about how long the fish will be exposed because they can move (or remain in location) and so can the source. Popper et al. (2014) summarises that in all TTS studies considered, fish that showed TTS recovered to normal hearing levels within 18–24 hours. Due to this, a period of accumulation of 24 hours has been applied in this study for SEL, which is similar to that applied for marine mammals in NMFS (2016, 2018).

In the discussion of the criteria, Popper et al. (2014) discuss the complications in determining a relevant period of mobile seismic surveys, as the received levels at the fish change between impulses because the source is moving, and that in reality a revised guideline based on the closest PK or the per-pulse SEL might be more useful than one based on accumulated SEL. This is because exposures at the closest point of approach (CPA) are the primary exposures contributing to a receiver's accumulated level (Gedamke et al. 2011). Additionally, several important factors determine the likelihood and duration a receiver is expected to be in close proximity to a sound source (i.e., overlap in space and time between the source and receiver). For example, accumulation time for fast moving (relative to the receiver) mobile sources is driven primarily by the characteristics of the source (i.e., speed, duty cycle; NMFS 2016, 2018).

As discussed in Popper (2018), many fish species move around, some over large distances. The author suggests that it is reasonable to think that if the sound of a seismic source becomes too loud, the fish will move away from the source because they are able to determine the direction of a sound source. If the fish moves away, the amount of energy to which it is exposed is likely to be one or a few seismic pulses, and these would not likely be loud enough to result in any effect because the fish would move away at a much lower level signal than could cause harm. Data on TTS for fish are very limited, with the only study that examined recovery from seismic impulses being Popper et al. (2005). Popper (2018) states that if this study had been conducted on wild, free-swimming fish instead of caged ones, there would have been no effect whatsoever because they were likely to have moved away from the source as it approached them, as would happen with normally free-moving demersal and pelagic fish species associated with a 3-D seismic survey in northern Australian waters, extrapolating from the Bethany 3-D assessed in Popper (2018).

Therefore, the time over which energy should be accumulated in each individual fish in the survey area should be limited to the time over which fish receives the maximum exposure, and 24 h is likely too long a period for calculating the accumulation of energy in determining potential harm (e.g., damage or TTS) (Popper 2018). Even if fish do show some TTS, recovery will start as soon as the most intense sounds end, and recovery is likely to even occur, to a limited degree, between seismic pulses. Based on very limited data, recovery within 24 h (or less) is very likely. If TTS does occur, the duration of exposure to the most intense sounds that could result in TTS will be over just a few hours. Thus, energy accumulating over longer periods than a few hours is probably inappropriate (Popper 2018).

Following this, the analysis for the Keraudren Extension 3-D MSS has considered time periods of 1–4 and 24 h for the accumulation of SEL, to examine the time over which the maximum exposure occurs at difference ranges, and the point from which recovery might start to occur. This is to help contextualise the potential effects on both site-attached and pelagic fish species.

Table 6. Criteria for seismic noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish I: No swim bladder (particle motion detection)	>219 dB SEL_{24h} or >213 dB PK	>216 dB SEL_{24h} or >213 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish II: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish III: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Fish eggs and fish larvae	>210 dB SEL_{24h} or >207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Notes: Peak sound level (PK) dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s. All criteria are presented as sound pressure, even for fish without swim bladders, since no data for particle motion exist. Relative risk (high, moderate, or low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

3.2.1. Turtles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. McCauley et al. (2000b) observed the behavioural response of caged turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). At that time, and in the absence of any data from which to determine the sound levels that could injure an animal, TTS or PTS onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (McCauley et al. 2000b, McCauley et al. 2000a), but the received levels were unknown, and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 166 and 180 dB re 1 µPa (SPL) for behavioural response and injury, respectively. Popper et al. (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa²·s (SEL_{24h}). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of meters) from the airgun.

Finneran et al. (2017) presented revised thresholds for turtle injury, considering both PK and frequency weighted SEL, which have been applied in this study, along with the NMFS criterion for behavioural response (SPL of 166 dB re 1 µPa), and a criterion for behavioural disturbance (SPL of 175 dB re 1 µPa) (McCauley et al. 2000b, McCauley et al. 2000a) (Table 7).

Table 7. Acoustic effects of impulsive noise on turtles: Unweighted SPL, SEL_{24h}, and PK thresholds.

Effect type	Criterion	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Behaviour	NSF (2011)	166	NA	
	McCauley et al. (2000a)	175		
PTS onset thresholds* (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds* (received level)			189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_{pk}, flat denotes peak sound pressure that is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa²s.

3.3. Benthic Invertebrates (Crustaceans and Bivalves)

Research is ongoing into the relationship between sound and its effects on crustaceans, including the relevant metrics for both effect and impact. Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing. Water depth, seabed material, and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves.

At the seafloor interface, crustaceans and bivalves are subject to particle motion stimuli from several acoustic or acoustically induced waves. These include the particle motion associated with an impinging sound pressure wave in the water column (the incident, reflected, and transmitted portions), substrate acoustic waves, and interface waves of the Scholte type. However, it is unclear which aspect(s) of these waves is/are most relevant to the animals, either when they normally sense the environment or their physiological responses to loud sounds so there is not enough information to establish similar criteria and thresholds as done for marine mammals and fish. Including recent research, such as Day et al. (2016a), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes the consideration of what particle motion levels lead to a behavioural response, or mortality. Therefore, at this stage, we cannot propose authoritative thresholds to inform the impact assessment. However, levels can be determined for pressure metrics presented in literature to assist the assessment.

For crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is considered to be associated with no impact, and it is therefore applied in this assessment. Additionally for context, the PK-PK sound levels determined for crustaceans in Day et al. (2016a), Day et al. (2016b), and Day et al. (2019) 209–213 dB re 1 µPa are also included.

For bivalves, PK-PK sound levels of 191, 212, and 213 are presented to allow comparison to the maximum sound levels measured in Day et al. (2016a) and Day et al. (2017) for scallops and pearl shell oyster. For bivalves, literature does not present a sound level associated with no impact, and as particle motion is the more relevant metric, particle acceleration from the seismic source has been presented for comparing the results in Table 7 of Day et al. (2016b). The maximum particle acceleration assessed for scallops was 37.57 ms^{-2}, considered appropriate for pearl shell oyster.

4. Methods

4.1. Acoustic Source Model

The pressure signature of the individual airguns and the composite 1/3-octave-band point-source equivalent directional levels (i.e., source levels) of the seismic sources were modelled with JASCO's Airgun Array Source Model (AASM). Although AASM accounts for notional pressure signatures of each seismic source with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

AASM considers:

- Array layout.
- Volume, tow depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

All seismic sources considered were modelled over AASM's full frequency range, up to 25 kHz. Appendix BB.1 details this model.

4.2. Parameter Overview

The specifications of the seismic source and the environmental parameters used in the propagation models are described in detail in Appendix D. A single sound speed profile for July was considered in this modelling study; this was identified as the seasonal period that would provide the farthest propagation (Appendix D.3.2) due to the presence of a slightly upward refracting sound speed profile.

Seabed sediments in the survey area were modelled with two discrete seabed types. On the inner and middle continental shelf a seabed consisting of a thin sand layer underlain by cemented limestone was used for sites in water less than 100 m depth (Sites 1–4, Table 4, see profile in Table D-1). For deeper modelled sites (>100 m, Sites 5–8, Table 4) on the outer shelf, the seabed was modelled as a succession from soft to hard sediments (unconsolidated carbonate sediment to cemented limestone, Table D-2).

4.3. Sound Propagation Models

Three sound propagation models were used to predict the acoustic field around the seismic source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 10 Hz to 25 kHz).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 5 to 1024 Hz).
- Wavenumber integration model (VSTACK, 10 to 1024 Hz).

The models were used in combination to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK, and PK-PK. Appendix C details each model. MONM-BELLHOP was used to calculate SEL of a 360° area around each source location. FWRAM was used to model synthetic seismic pulses and to generate a generalised range-dependent SEL to SPL conversion function for the considered modelled sites. The range-dependent conversion function was applied to predicted per-pulse SEL results from MONM-BELLHOP to estimate SPL values. FWRAM was also used to calculate water column PK and PK-PK levels.

VSTACK was used to calculate close range PK, PK-PK, and particle motion levels along transects at the seafloor from the loudest direction of the seismic source at the shallowest modelled site (Site 1) as well as two deeper modelled sites (Site 4 and Site 7). VSTACK was also used estimate particle acceleration and velocity.

Although MONM accounts for the partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, it is unstable for seabed environments with high seabed shear speed (greater than ~600 m/s) such as those present in parts of the study area due to the presence of a calcarenite layer. For environments where the seabed contains material with higher shear speed material, such as the shallow water (<100 m) modelled sites considered in this study, a correction is applied to the broadband levels predicted from MONM and FWRAM. The correction consists of using output from the VSTACK model at short ranges and measurement data from an acoustic study (McCauley et al. 2016) at long ranges. VSTACK, which treats layers high shear speed exactly, was used to adjust at ranges up to a kilometre. At ranges longer than a kilometre, measurement data was used.

4.4. Accumulated SEL

During a seismic survey, new sound energy is introduced into an environment with each pulse from the seismic source. While some impact criteria are based on the per-pulse energy released, others, such as the marine mammal and fish SEL criteria used in this report (Sections 3.1–3.3), account for the total acoustic energy marine fauna is subjected to over a specified duration, defined in this report as 24 h. An accurate assessment of the accumulated sound energy depends not only on the parameters of each seismic impulse but also on the number of impulses delivered in a duration and the relative positions of the impulses.

When there are many seismic pulses, it becomes computationally prohibitive to perform sound propagation modelling for every single event. The distance between the consecutive seismic impulses is small enough, however, that the environmental parameters that influence sound propagation are virtually the same for many impulse points. The acoustic fields can, therefore, be modelled for a subset of seismic pulses and estimated at several adjacent ones. After sound fields from representative impulse locations are calculated, they are adjusted to account for the source position for nearby impulses.

Although estimating the cumulative sound field with the described approach is not as precise as modelling sound propagation at every impulse location, small-scale, site-specific sound propagation features tend to blur and become less relevant when sound fields from adjacent impulses are summed. Larger scale sound propagation features, primarily dependent on water depth, dominate the cumulative field. The accuracy of the present method acceptably reflects those large-scale features, thus providing a meaningful estimate of a wide area SEL field in a computationally feasible framework.

To produce the map of accumulated received sound level distributions and calculate distances to specified sound level thresholds, the maximum-over-depth level was calculated at each sampling point within the modelled region. The radial grids of maximum-over-depth and seafloor sound levels for each impulse were then resampled (by linear triangulation) to produce a regular Cartesian grid. The sound field grids from all impulses were summed (Equation A-5) to produce the cumulative sound field grid with cell sizes of 20 m. The contours and threshold ranges were calculated from these flat Cartesian projections of the modelled acoustic fields. The single-impulse SEL fields were computed over model grids approximately 200 × 200 km in range, which encompasses the full area of the cumulative grid (the entire survey area).

The unweighted (fish) and frequency-weighted SEL_{24h} results were rendered as contour maps, including contours that focus on the relevant criteria-based thresholds. Only contours at ranges larger than the nearfield of the seismic source were rendered.

Additional context on the accumulation of SEL over each considered scenario is presented in Section 5.3.3, detailing how the sound field is sampled at the static receivers, located perpendicular to the modelled survey lines (described in Section 2). At a given static spatial location, the per-pulse and accumulated time history can be plotted using similar methods to estimate the cumulative sound exposure grids as described above. As the seismic source (and vessel) moves along the survey line, different sound fields from the single impulse sites were used to represent the acoustic footprint at that impulse location. Based on the speed of the vessel and the impulse interval between consecutive impulses a time history of the per-pulse and accumulated received SEL can be obtained at a receiver point.

The per-pulse levels at each receiver location were then summed over the assessment time period, 1, 2, 3, and 4 h windows centred on the CPA or 24 h, to provide context on the spatial and temporal dependence of the accumulated sound field.

4.5. Geometry and Modelled Regions

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances of 100 km from the source in each cardinal direction, with a horizontal separation of 20 m between receiver points along the modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta = 2.5°$ for a total of $N = 144$ radial planes. Receiver depths were chosen to span the entire water column over the modelled areas, from 2 m to a maximum of 2000 m, with step sizes that increased with depth. To supplement the MONM results, high-frequency results for propagation loss were modelled using BELLHOP for frequencies from 2.5 to 25 kHz. The MONM and Bellhop results were combined to produce results for the full frequency range of interest.

FWRAM was run to 100 km, but along only four radials (fore and aft endfire, and port and starboard broadside) for computational efficiency. This was done to compute SEL-to-SPL conversions (Appendix D.2) but also to quantify water column PK and PK-PK. The horizontal range step is dependent on frequency and ranges from 50 m at lower frequencies to 10 m above 800 Hz.

The maximum modelled range for VSTACK was 1000 m, and a variable receiver range increment that increased away from the source was used, which increased from 10 to 25 m. Received levels were computed for receivers at the seafloor.

5. Results

5.1. Acoustic Source Levels and Directivity

AASM (Section 4.1) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic source, with results provided in Appendix B.2 along with the horizontal directivity plots.

Preliminary source modelling was conducted to determine the source with the highest equivalent far-field acoustic output of six comparable source arrays, which were defined as being between 2900–3500 in^3 as required to meet the technical specification and objectives of the Keraudren Extension 3-D MSS. The three loudest arrays were coupled with single impulse propagation modelling (Appendix E), to determine the array most likely to produce the largest ranges to thresholds. This was determined to be a 3260 in^3 seismic source with a 7 m tow depth (see Appendix D.4 for details on this source)

Table 8 shows the PK and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the tow direction), endfire (along the tow direction), and vertical directions. The vertical source level that accounts for the “surface ghost” (the out of phase reflected pulse from the water surface) is also presented to make it easier to compare the output of other seismic source models.

Figure B-1 shows the broadside, endfire, and vertical overpressure signature and corresponding power spectrum levels for the source. The signature consists of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy was produced at frequencies below 400 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the source and correspond with the volumes and relative locations of the airguns to each other.

Table 8. Far-field source level specifications for the 3260 in^3 source, for a 7 m tow depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 µPa^{2}m^{2}s)	
		10–2000 Hz	2000–25000 Hz
Broadside	249.7	225.0	187.2
Endfire	246.2	223.4	187.1
Vertical	255.6	228.5	194.7
Vertical (surface affected source level)	255.6	231.0	197.7

5.2. Per-pulse Sound Fields

5.2.1. Tabulated results

Tables 9–14 list per-pulse results for the 3260 in³ seismic source towed at 7 m are presented for SPL, SEL, PK, and PK-PK, including seafloor PK and PK-PK.

5.2.1.1. Entire water column

Table 9. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 3260 in³ seismic source to modelled maximum-over-depth unweighted per-pulse SEL isopleths from the modelled single impulse sites, with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 1 (38 m)		Site 2 (58 m)		Site 3 (79 m)		Site 4 (84 m)		Site 5 (101 m)		Site 6 (157 m)		Site 7 (137 m)		Site 8 (125 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.13	0.12	0.13	0.12	0.13	0.12	0.13	0.12	0.05	0.05	0.04	0.04	0.04	0.04	0.10	0.10
180	0.48	0.41	0.45	0.38	0.41	0.38	0.42	0.37	0.17	0.15	0.16	0.14	0.16	0.15	0.4	0.34
170	1.07	0.9	1.05	0.90	1.02	0.90	0.99	0.85	0.79	0.66	0.88	0.77	0.84	0.77	0.92	0.79
160†	3.28	2.51	2.95	2.49	3.04	2.55	3.23	2.64	3.24	2.63	3.04	2.41	3.16	2.55	3.06	2.65
150	10.5	8.22	7.24	5.85	7.87	6.34	8.14	6.64	9.45	7.56	9.27	8.01	10.9	8.23	8.92	7.36
140	29.1	23.1	16.7	14.0	19.3	15.3	19.2	15.5	19.9	16.4	21.4	17.9	28.2	22.2	20.2	15.9
130	73.0	58.3	40.6	33.6	42.6	33.6	41.0	33.9	44.9	35.8	41.1	33.7	49.1	39.0	41.3	33.6
120	>100	/	>100	/	>100	/	>100	/	90.3	69.9	89.2	71.1	>100	/	79.2	65.1

† Low power zone assessment criteria DEWHA (2008).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 10. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 3260 in³ seismic source to modelled maximum-over-depth SPL isopleths from the modelled single impulse sites, with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 1 (38 m)		Site 2 (58 m)		Site 3 (79 m)		Site 4 (84 m)		Site 5 (101 m)		Site 6 (157 m)		Site 7 (137 m)		Site 8 (125 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.13	0.11	0.12	0.11	0.10	0.11	0.07	0.07	0.05	0.05	0.04	0.04	0.04	0.04	0.06	0.06
190	0.41	0.36	0.38	0.33	0.37	0.33	0.37	0.32	0.14	0.13	0.14	0.12	0.14	0.12	0.34	0.29
180	0.85	0.74	0.85	0.74	0.81	0.74	0.78	0.69	0.71	0.62	0.78	0.68	0.78	0.69	0.70	0.63
175#	1.22	1.05	1.24	1.06	1.14	1.06	1.16	0.98	1.27	1.04	1.14	0.96	1.20	0.99	1.04	0.92
170	1.88	1.56	1.98	1.63	1.80	1.63	1.71	1.51	2.64	2.29	2.50	2.11	2.52	2.11	1.69	1.47
166†	3.40	2.57	2.99	2.49	2.95	2.49	3.14	2.40	4.22	3.67	4.08	3.52	4.3	3.52	2.92	2.44
160‡	8.84	6.92	5.84	4.69	5.66	4.69	5.80	4.57	7.94	6.64	8.73	6.74	8.63	7.00	6.18	5.14
150	26.1	20.7	14.8	12.2	16.3	13.0	16.3	13.2	16.5	13.9	18.2	15.1	21.6	16.7	17.4	13.6
140	65.9	52.6	39.3	31.4	39.5	31.4	38.9	31.3	38.9	29.7	33.6	28.6	42.6	34.3	39.8	31.3
130	>100	/	>100	/	>100	/	95.6	75.9	79.5	63.1	84.2	65.0	90.6	71.0	76.3	62.0

Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
† Threshold for turtle behavioural response to impulsive noise (NSF 2011).
‡ Marine mammal behavioural threshold for impulsive sound sources (NMFS 2014).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 11. Maximum (R_{max}) horizontal distances (in km) from the 3260 in^3 array to modelled maximum-over-depth peak pressure level (PK) thresholds based on the NOAA Technical Guidance (NMFS 2018) for marine mammals, and Popper et al. (2014) for fish and Finneran et al. (2017) for turtles, at three modelled sites (Table 4), with water depth indicated.

Hearing group	**PK threshold (L_{pk}; dB re 1 µPa)**	**Distance R_{max} (km)**		
		Site 2 (58 m)	Site 4 (84 m)	Site 7 (137 m)
Low-frequency cetaceans (PTS)	219	0.04	0.04	0.04
Low-frequency cetaceans (TTS)	213	0.06	0.07	0.07
Mid-frequency cetaceans (PTS)	230	—	—	—
Mid-frequency cetaceans (TTS)	224	0.02	0.02	0.02
High-frequency cetaceans (PTS)	202	0.41	0.43	0.23
High-frequency cetaceans (TTS)	196	0.69	0.78	0.69
Turtles (PTS)	232	—	—	—
Turtles (TTS)	226	—	—	—
Fish: No swim bladder (also applied to sharks)	213	0.06	0.07	0.07
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.22	0.23	0.14

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 12. Maximum (R_{max}) horizontal distances (in km) from the 3260 in^3 array to modelled maximum-over-depth peak-peak pressure level threshold (178 dB re 1µPa, PK-PK), assessed along the four FWRAM modelling transects (maximum presented) at three modelled sites (Table 4), with water depth indicated.

PK-PK (L_{pk-pk}; dB re 1 µPa)	**Distance R_{max} (km)**		
	Site 2 (58 m)	Site 4 (84 m)	Site 7 (137 m)
178	7.61	7.92	6.82

5.2.1.2. Seafloor

Table 13. Maximum (R_{max}) horizontal distances (in m) from the 3260 in^3 array to modelled seafloor peak pressure level thresholds (PK) from three single-impulse modelled sites (Table 4), with water depth indicated.

Hearing group/animal type	**PK threshold (L_{pk}; dB re 1 µPa)**	**Distance R_{max} (m)**		
		Site 1 (38 m)	Site 4 (84 m)	Site 7 (137 m)
Sound levels for sponges and corals†	226	5	*	*
Fish: No swim bladder (also applied to sharks)	213	87	73	38
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	142	148	157

† Heyward et al. (2018)
An asterisk indicates that the sound level was not reached.

Table 14. Maximum (R_{max}) horizontal distances (in m) from the 3260 in^3 seismic source to modelled seafloor peak-peak pressure levels (PK-PK) from three single-impulse modelled sites (Table 4), with water depth indicated. Results included in relation to benthic invertebrates (Section 3.3).

PK-PK (L_{pk-pk}; dB re 1 µPa)	Distance R_{max} (km)		
	Site 1 (38 m)	Site 4 (84 m)	Site 7 (137 m)
213[a,b,c]	141	139	141
212[b,c]	151	155	167
210[a,b]	175	221	209
209[a,b]	187	241	241
202[d]	351	402	685

[a] Day et al. (2019), lobster
[b] Day et al. (2016a), lobster and scallops
[c] Day et al. (2017), scallops.
[d] Payne et al. (2008), lobster

5.2.2. Sound field maps and graphs

5.2.2.1. Sound level contour maps

Figures 4–11 show maps of the estimated sound fields, threshold contours, and isopleths of interest for the per-pulse SPL sound fields at all modelled sites (Table 4).

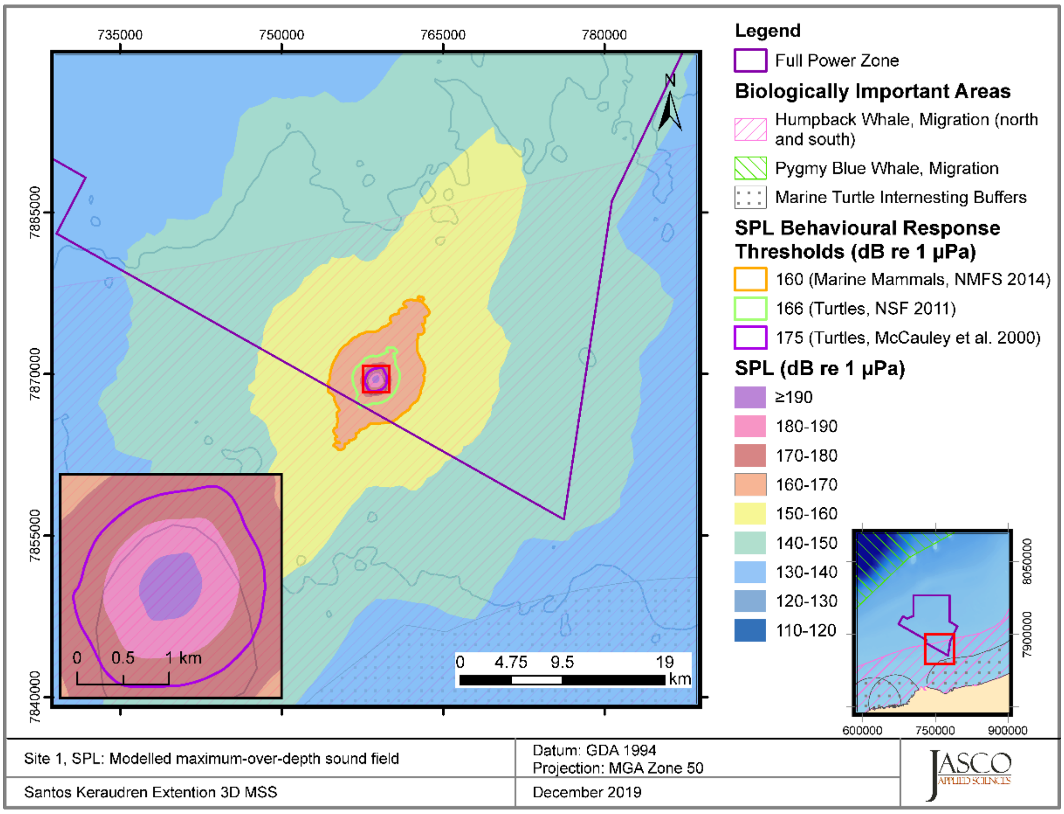

Figure 4. *Site 1, SPL:* Sound level contour map of unweighted maximum-over-depth results.

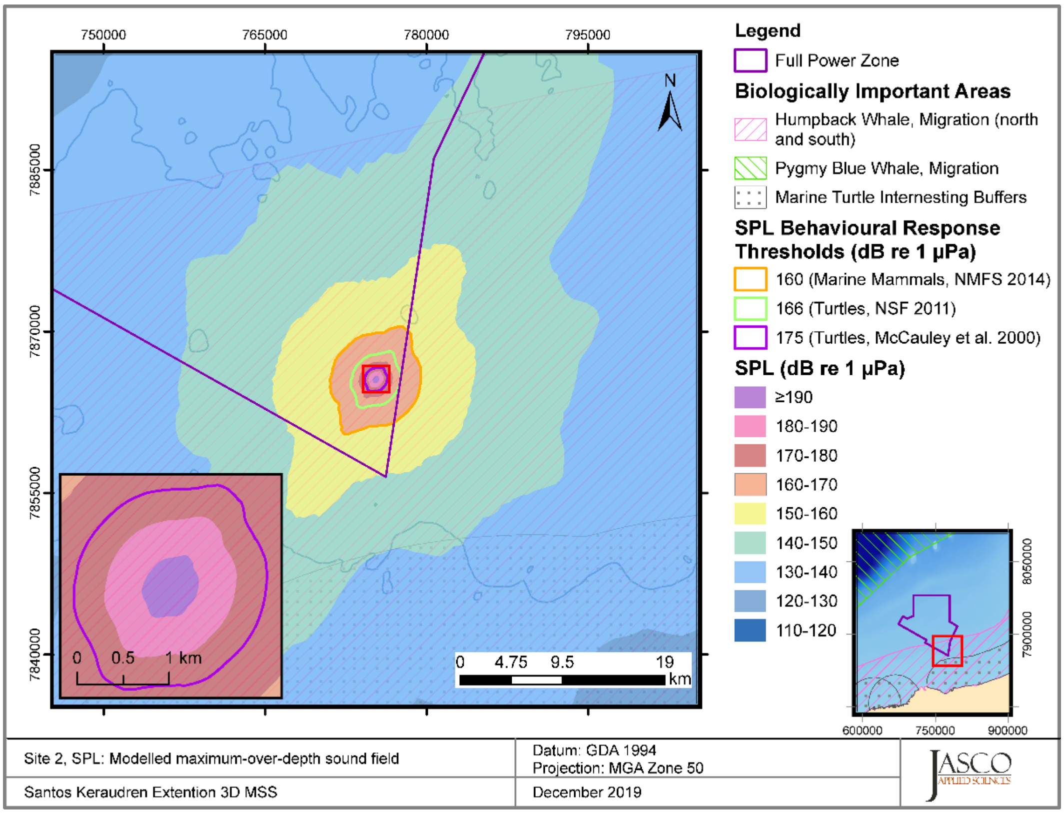

Figure 5. *Site 2, SPL:* Sound level contour map of unweighted maximum-over-depth results.

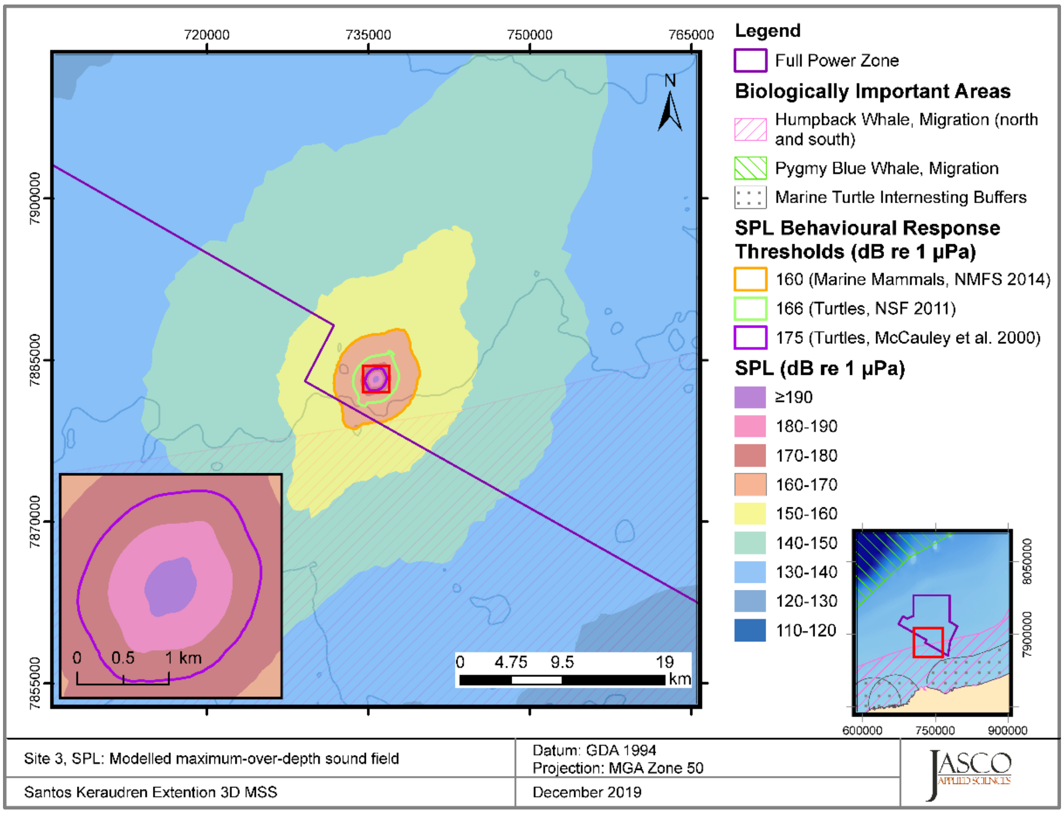

Figure 6. *Site 3, SPL:* Sound level contour map of unweighted maximum-over-depth results.

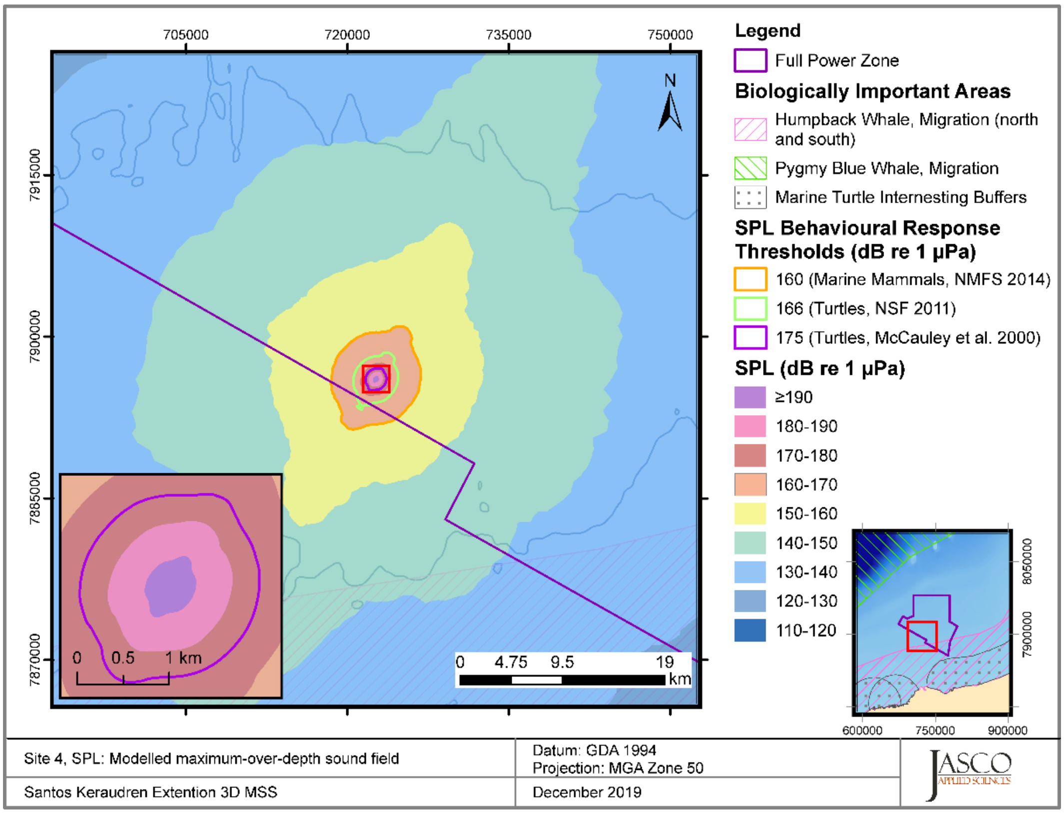

Figure 7. *Site 4, SPL:* Sound level contour map of unweighted maximum-over-depth results.

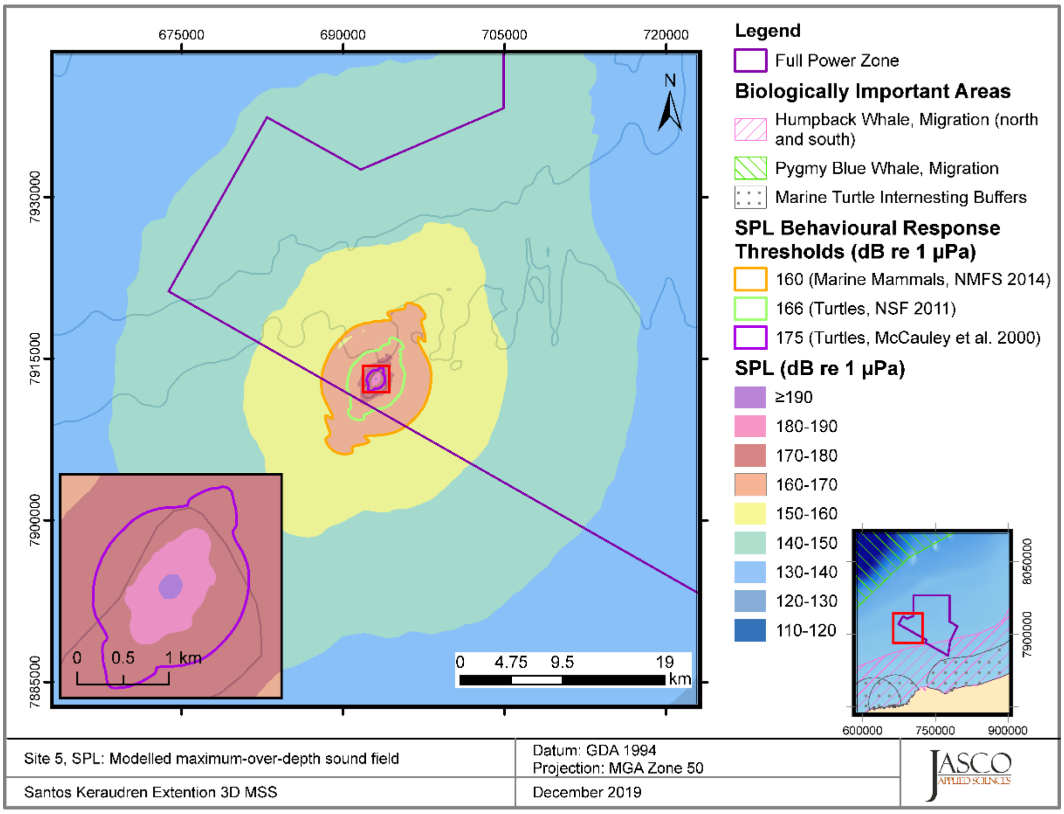

Figure 8. *Site 5, SPL:* Sound level contour map of unweighted maximum-over-depth results.

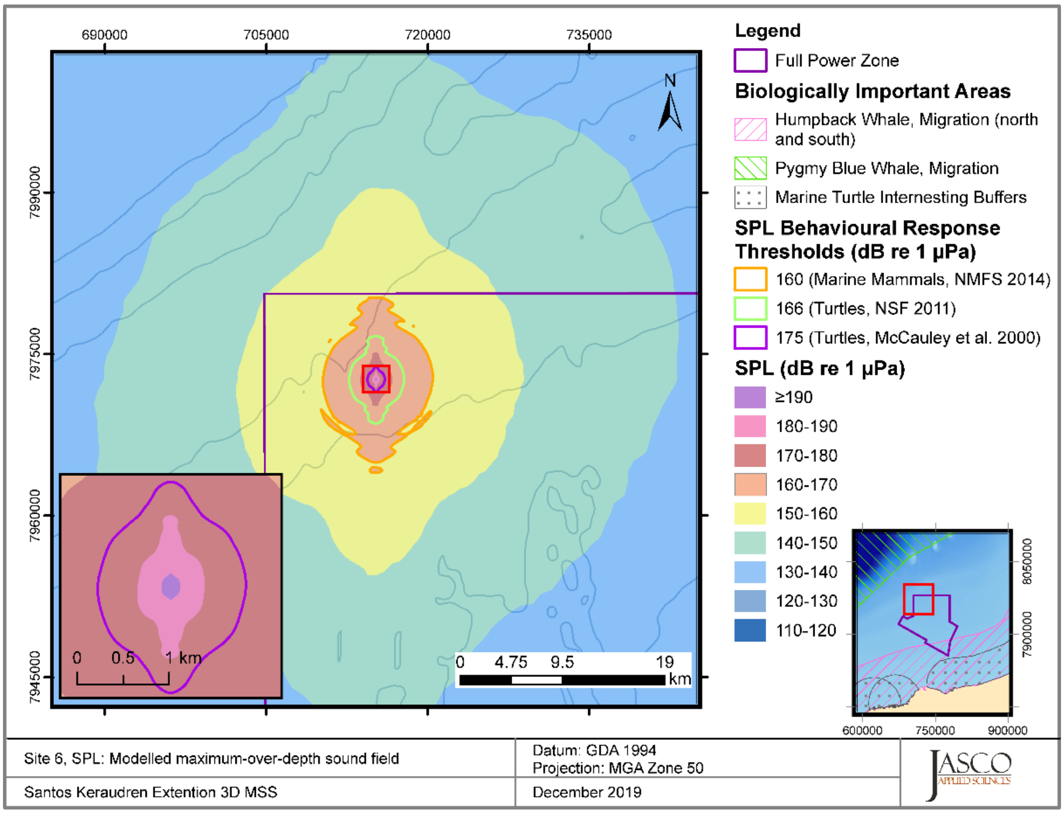

Figure 9. *Site 6, SPL:* Sound level contour map of unweighted maximum-over-depth results.

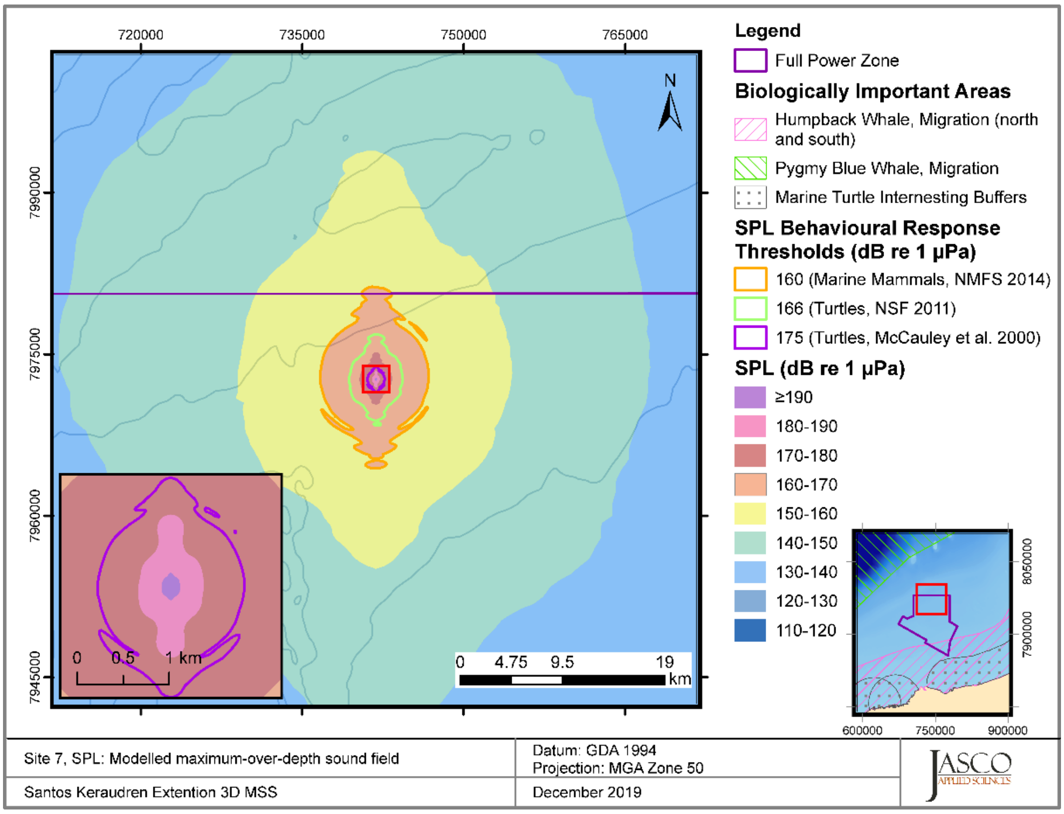

Figure 10. *Site 7, SPL:* Sound level contour map of unweighted maximum-over-depth results.

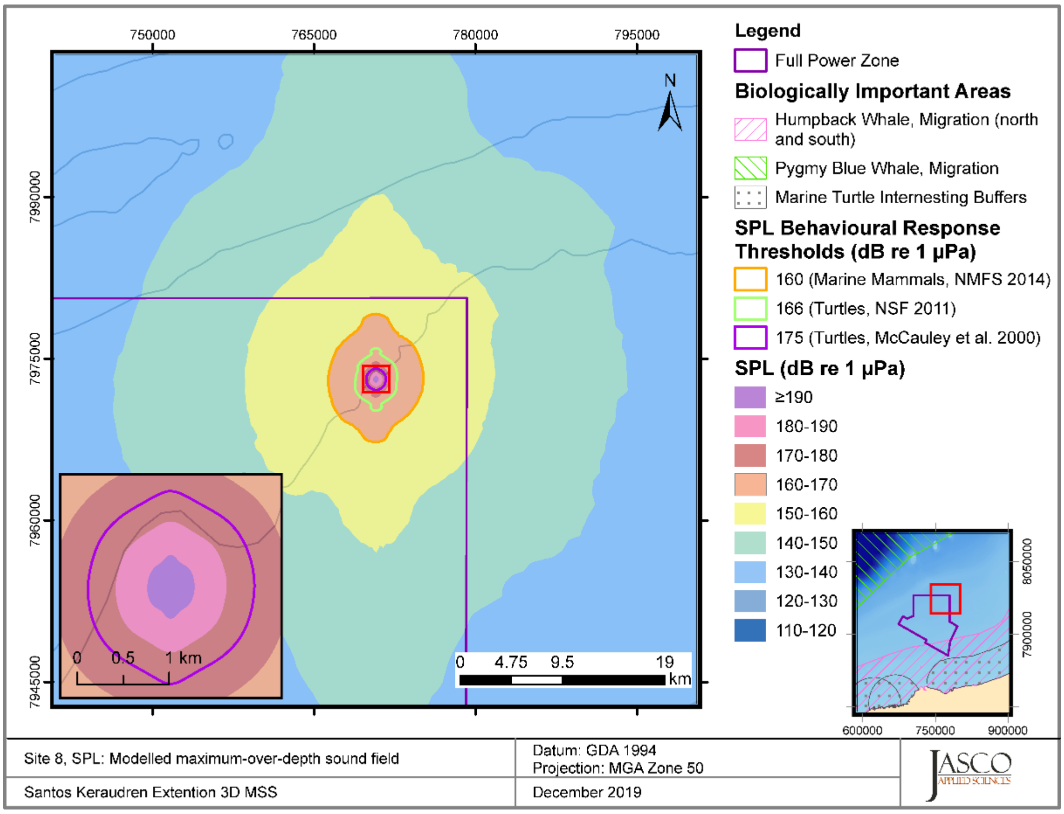

Figure 11. *Site 8, SPL:* Sound level contour map of unweighted maximum-over-depth results.

5.2.2.2. Vertical slices of modelled sound fields

Figures 12–19 show vertical slices of the SPL sound fields for the 3260 in^3 seismic source.

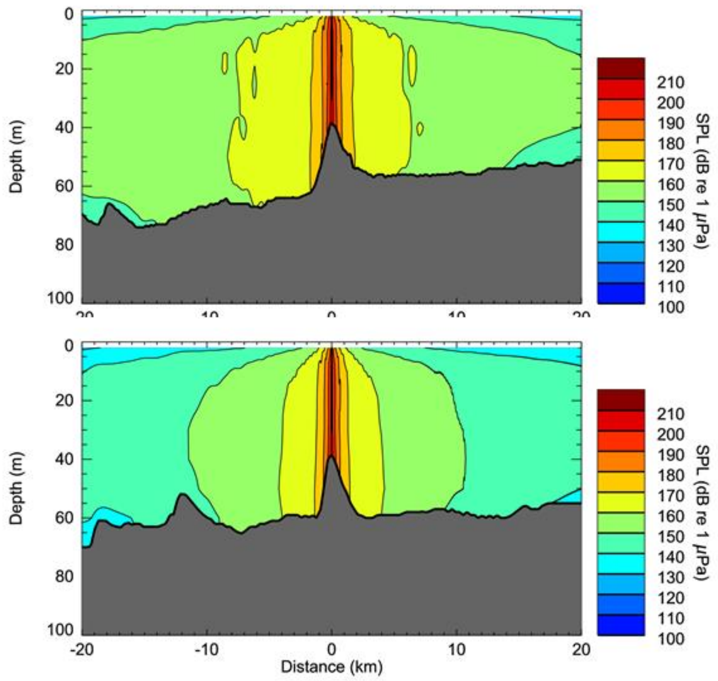

Figure 12. *Site 1, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

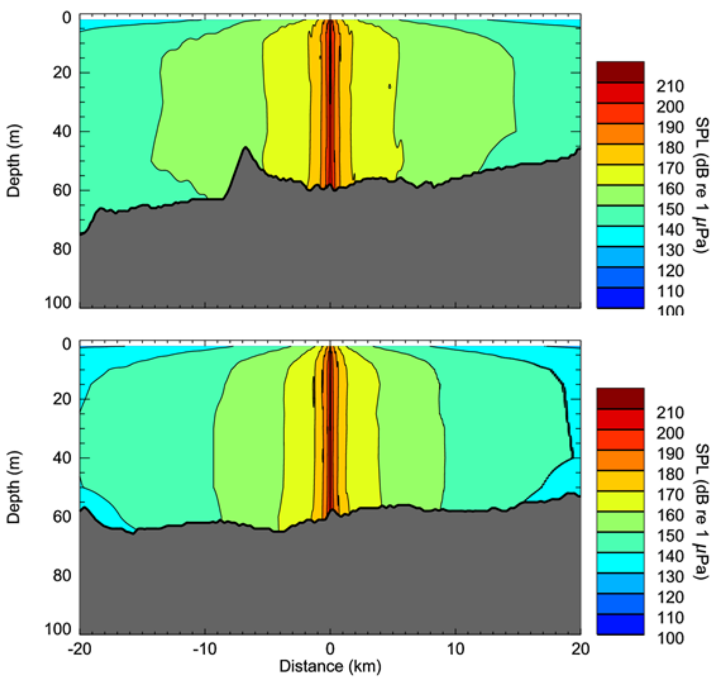

Figure 13. *Site 2, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

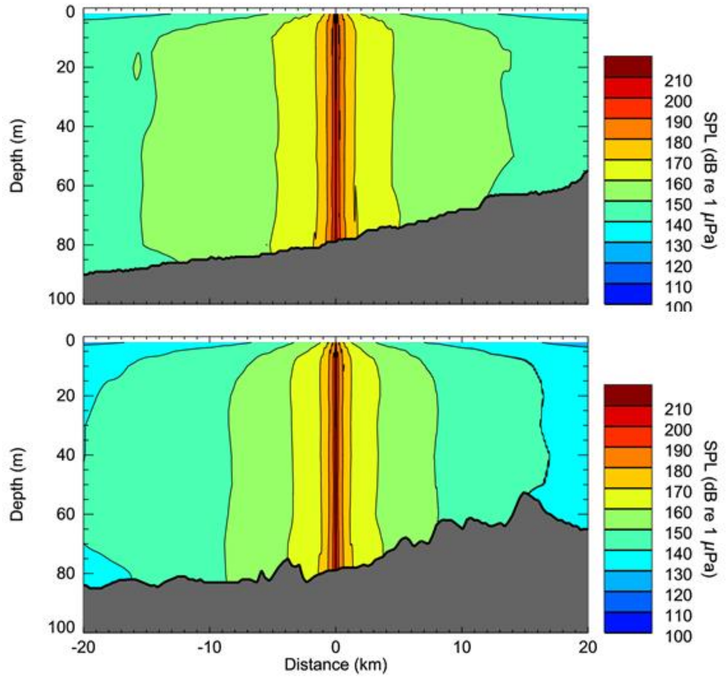

Figure 14. *Site 3, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

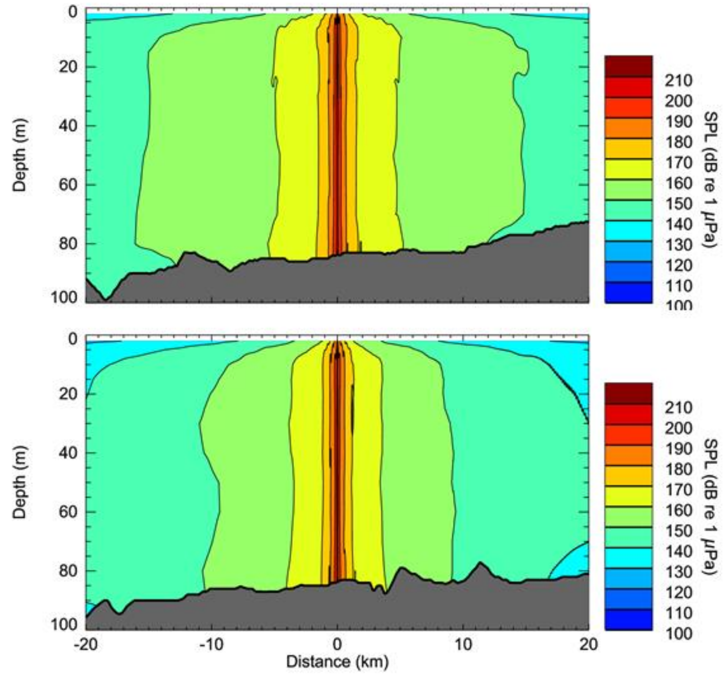

Figure 15. *Site 4, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

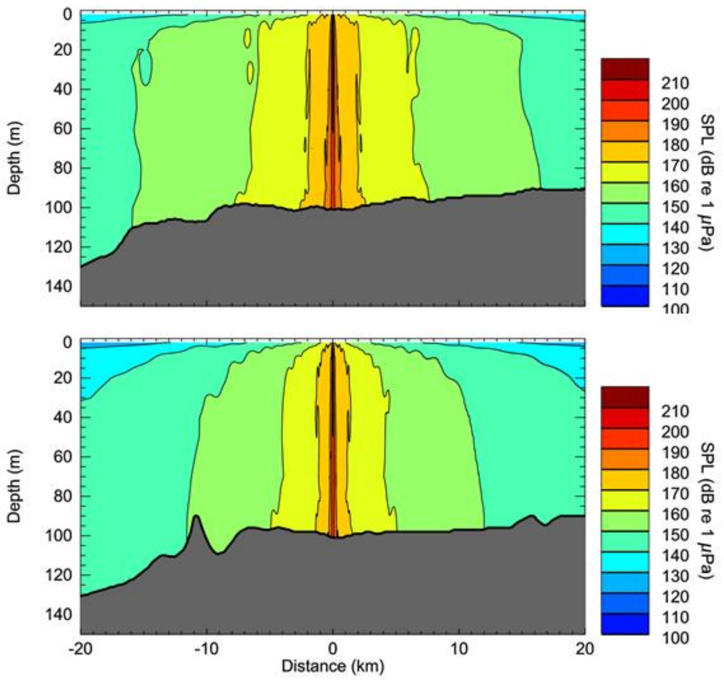

Figure 16. *Site 5, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

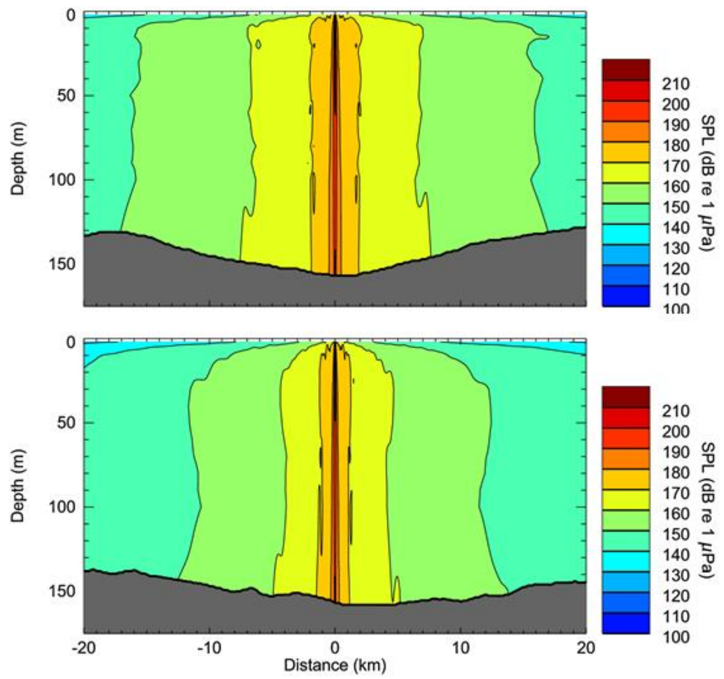

Figure 17. *Site 6, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

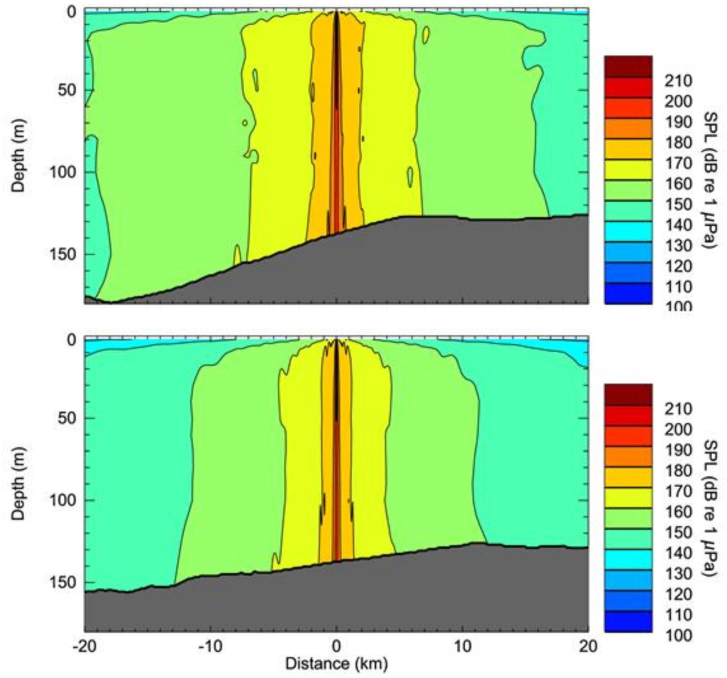

Figure 18. *Site 7, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

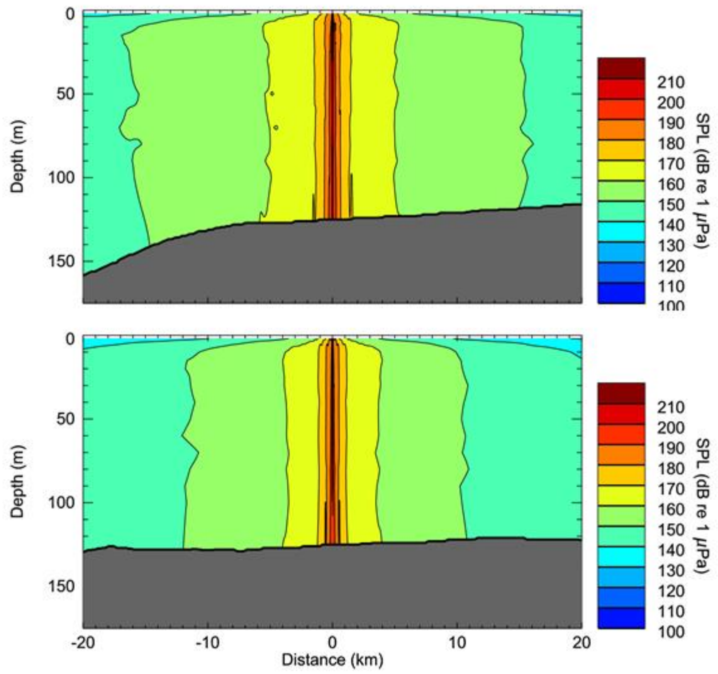

Figure 19. *Site 8, SPL*: Vertical slice of the predicted SPL for the 3260 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

5.2.2.3. Particle motion

Figures 20–22 show modelled maximum particle acceleration as a function of horizontal range in four perpendicular directions from the centre of the 3260 in^3 seismic source at the shallowest modelled site (Scenario 1, Site 1, 38 m water depth), along with sites at 84 m and 137 m water depth (Scenario 1, Site 4 and Scenario 2, Site 7). The modelling considered a resolution of 10 m, and the maximum distance to a particle acceleration of the closest value to 37.57 ms^{-2} (Section 3.3, Day et al. (2016a)) occurs at approximately 55 m (Figure 20) at Site 1 (38 m water depth), and within 5 m of the array at Site 4 (84 m water depth), while the maximum level at the seafloor at Site 7 (137 m water depth) was 26 ms^{-2}.

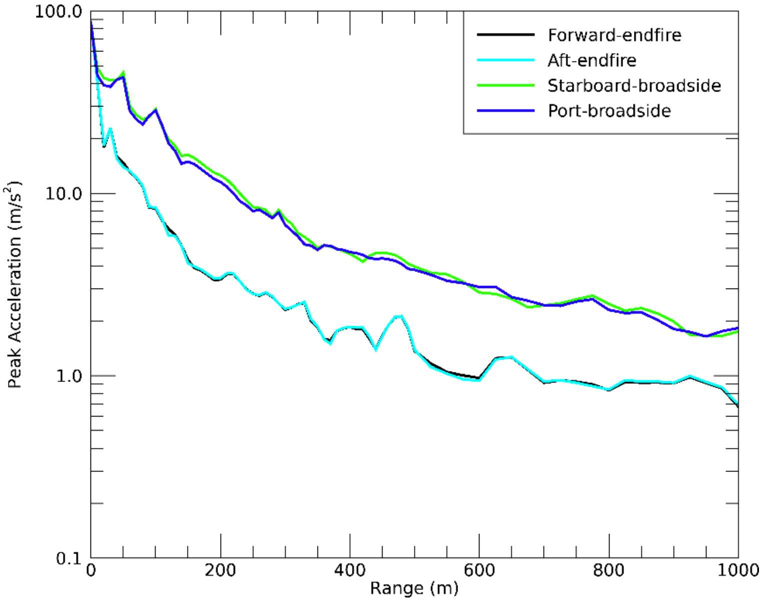

Figure 20. *Scenario 1, Site 1* (38 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3260 in^3 seismic source along four directions.

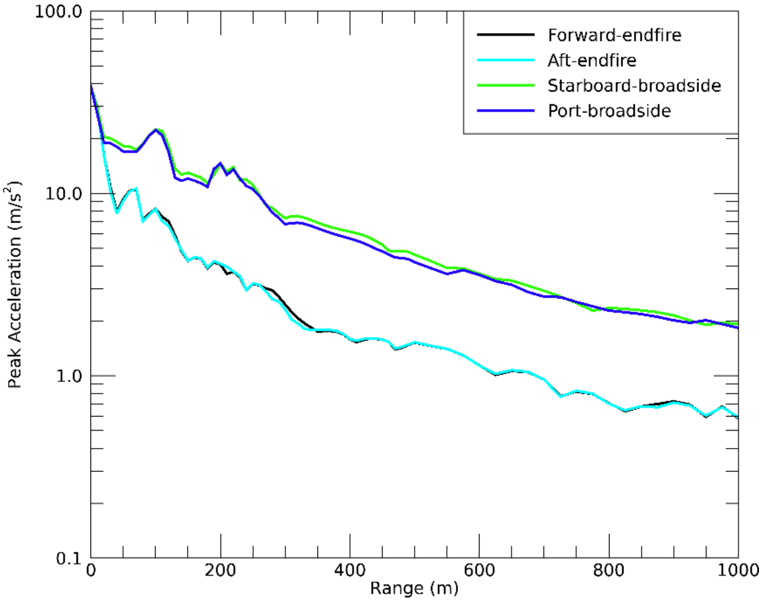

Figure 21. *Scenario 1, Site 4* (84 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3260 in^3 seismic source along four directions.

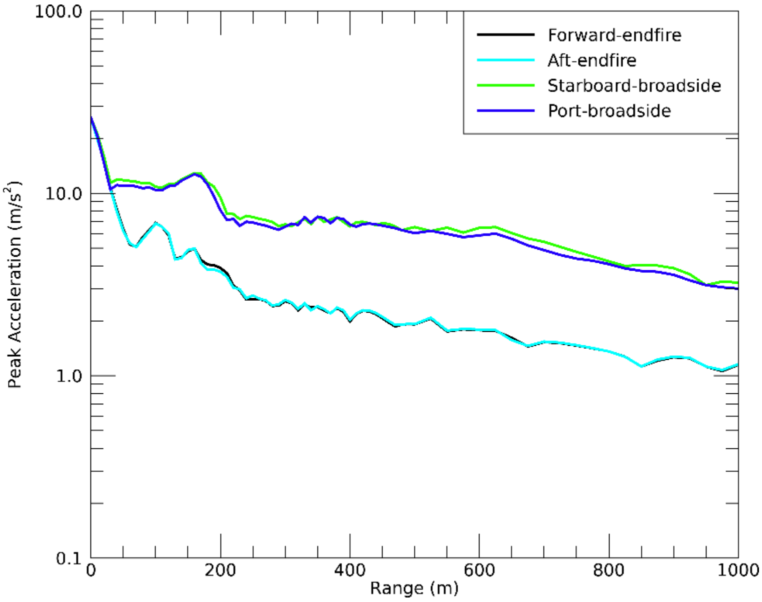

Figure 22. *Scenario 1, Site 7* (137 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3260 in^3 seismic source along four directions.

5.3. Multiple Pulse Sound Fields

The SEL_{24h} results for the proposed survey are presented for Scenario 1 and Scenario 2 within the Full Power Zone. Tables 15 and 16 show the estimated ranges to the appropriate cumulative exposure criterion contour for the various marine fauna groups considered and the corresponding ensonified areas. The ranges in this section are the perpendicular distance from the survey line to the relevant isopleth. Figures 23 and 25 show maps of the maximum-over-depth sound fields, including threshold contours relating to marine mammals and fish, while Figures 24 and 26 show estimates of the sound field at the seafloor and threshold contours relevant to fish.

5.3.1. Tabulated results

Table 15. Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2018) and turtles (Finneran et al. 2017).

Hearing group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1		Scenario 2	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS					
Low-frequency cetaceans	183	2.22	417	3.08	366
Mid-frequency cetaceans	185	—	—	0.02	0.75
High-frequency cetaceans	155	0.05	8.35	0.04	6.12
Turtles	204	0.12	17.3	0.06	8.84
TTS					
Low-frequency cetaceans	168	25.7	4768	31.1	4251
Mid-frequency cetaceans	170	0.04	1.10	0.02	0.75
High-frequency cetaceans	140	0.53	132	0.86	113
Turtles	189	1.20	293	1.34	238

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 16. Distances to SEL_{24h} based fish criteria in the water column.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth			
		Scenario 1		Scenario 2	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	0.05	6.21	0.05	4.96
II, fish eggs and fish larvae	210	0.08	12.4	0.05	7.18
III	207	0.14	26.2	0.06	12.2
Fish recoverable injury					
I	216	0.05	6.21	0.05	5.54
II, III	203	0.28	51.5	0.14	26
Fish TTS					
I, II, III	186	4.22	1020	6.32	1262

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

Table 17. Distances to SEL_{24h} based fish criteria at the seafloor.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Seafloor			
		Scenario 1		Scenario 2	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	*	*	*	*
II, fish eggs and fish larvae	210	0.08	4.25	*	*
III	207	0.13	24.5	0.04	3.93
Fish recoverable injury					
I	216	*	*	*	*
II, III	203	0.28	48	0.14	18.3
Fish TTS					
I, II, III	186	4.02	991	6.18	1252

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
An asterisk indicates that the threshold was not reached.

5.3.2. Sound field maps

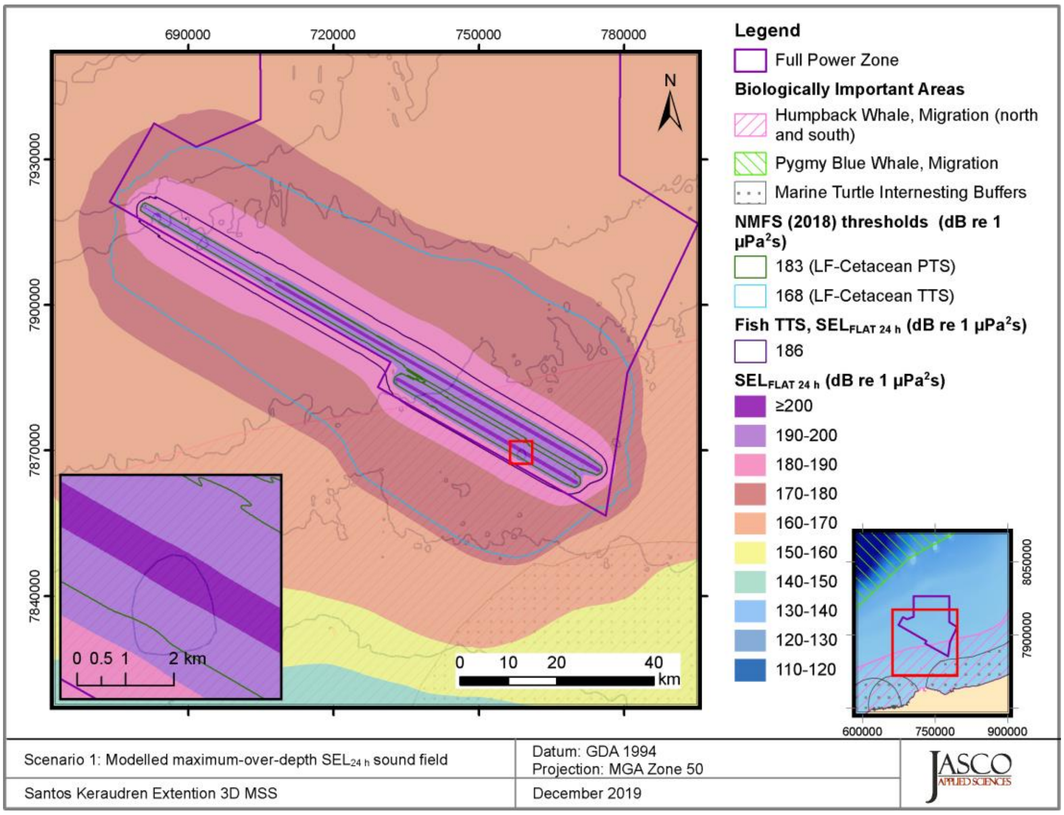

Figure 23. *Scenario 1:* Sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetaceans and fish TTS. Thresholds for mid- and high-frequency cetacean PTS were not reached.

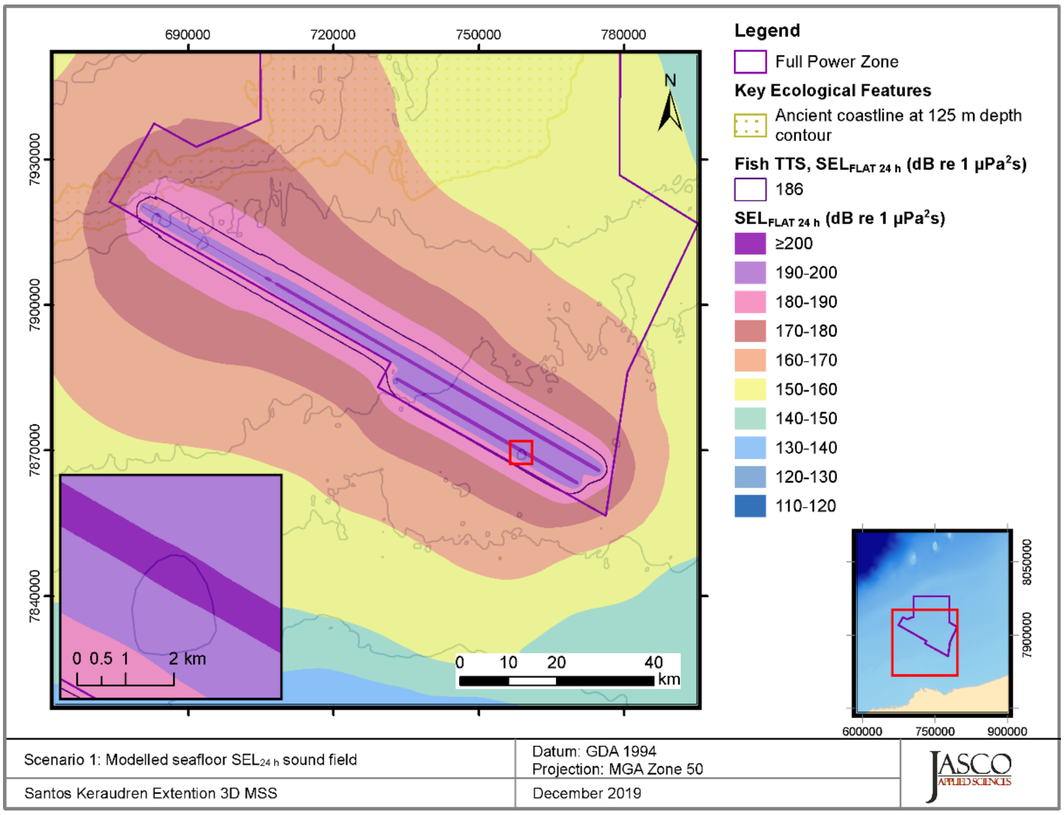

Figure 24. *Scenario 1*: Sound level contour map of unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS.

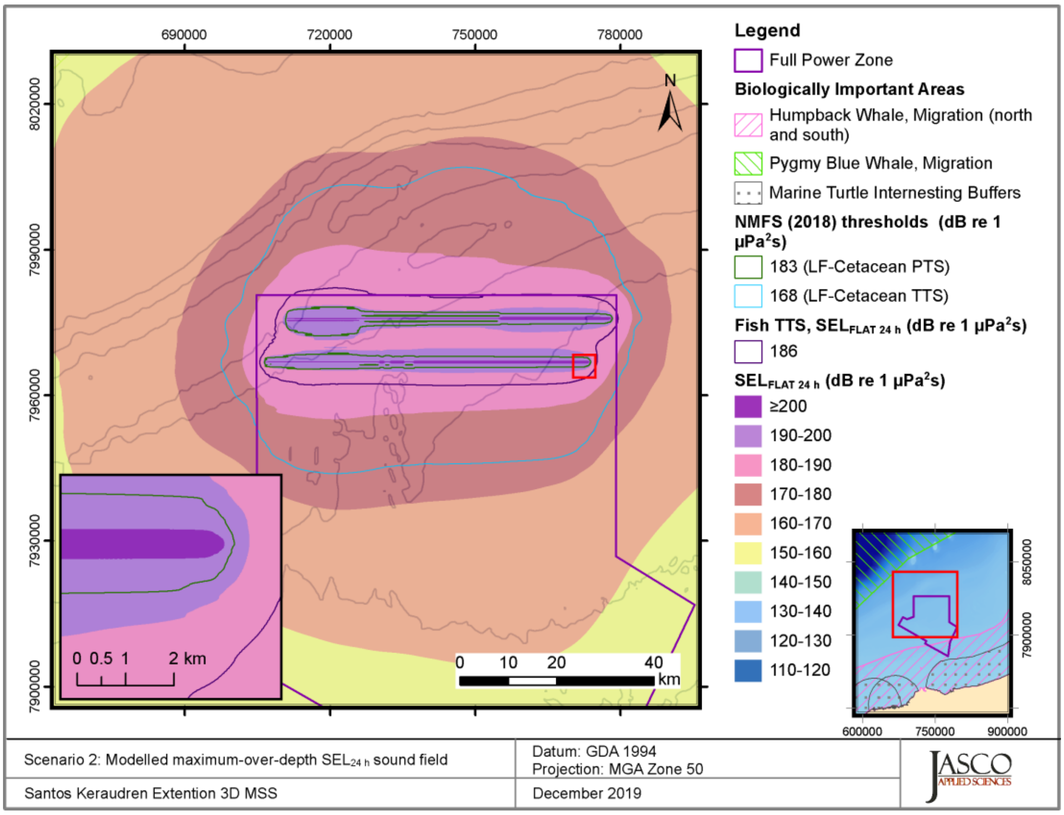

Figure 25. *Scenario 2*: Sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetaceans and fish TTS. Thresholds for mid- and high-frequency cetacean PTS were not reached.

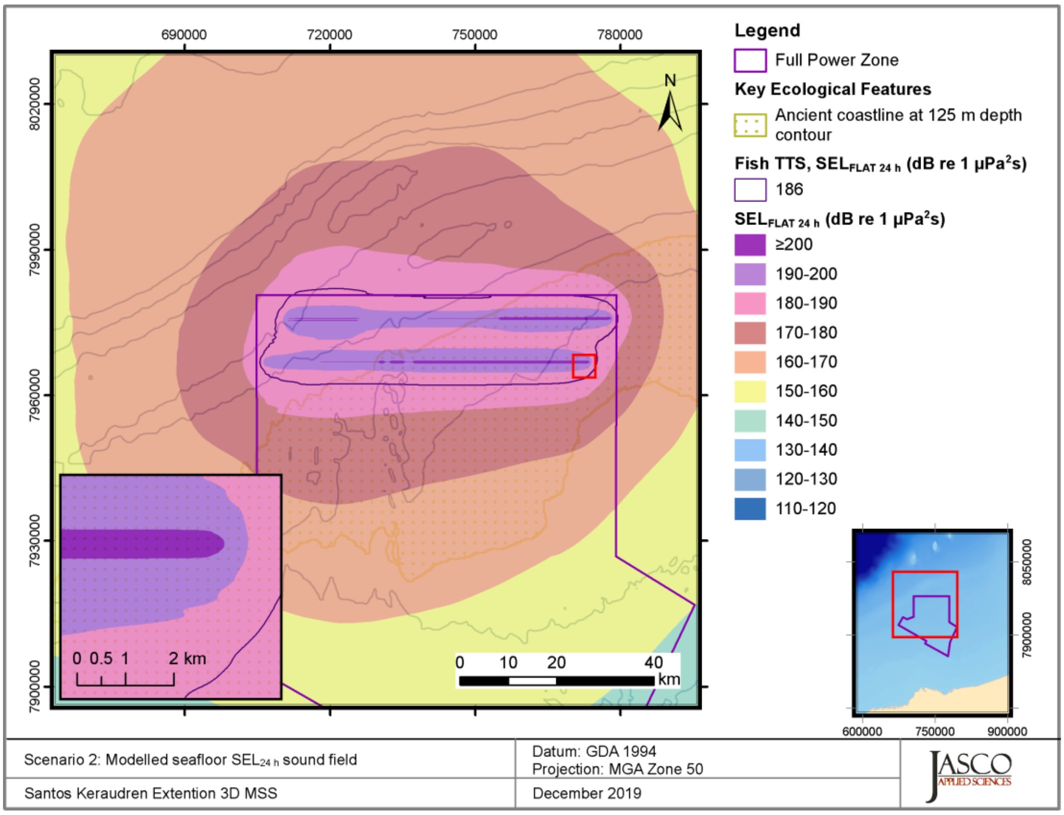

Figure 26. *Scenario 2:* Sound level contour map of unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS.

5.3.3. Accumulated levels at static receivers

Sound exposure levels were modelled at static receivers at perpendicular offsets from the closest survey line in each of the two 24-hour scenarios considered., See Figures 2 and 3 for receiver locations relative to survey lines. For plotting purposes, accumulated and per-pulse SEL were extracted at a subset of receiver distances considered.

The results are presented in Figure 27 for Scenario 1 and Figure 28 for Scenario 2. Fourteen receiver offset distances out of the seventy-one considered (0.1, 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 5.0, 8.0, 10.0, 15.0, 20.0, 25.0, and 30.0 km) were plotted as a function of time on a common graph. The notable gaps in per-pulse levels are associated the vessel turning and run-ins, during which the source was not in operation for modelling purposes.

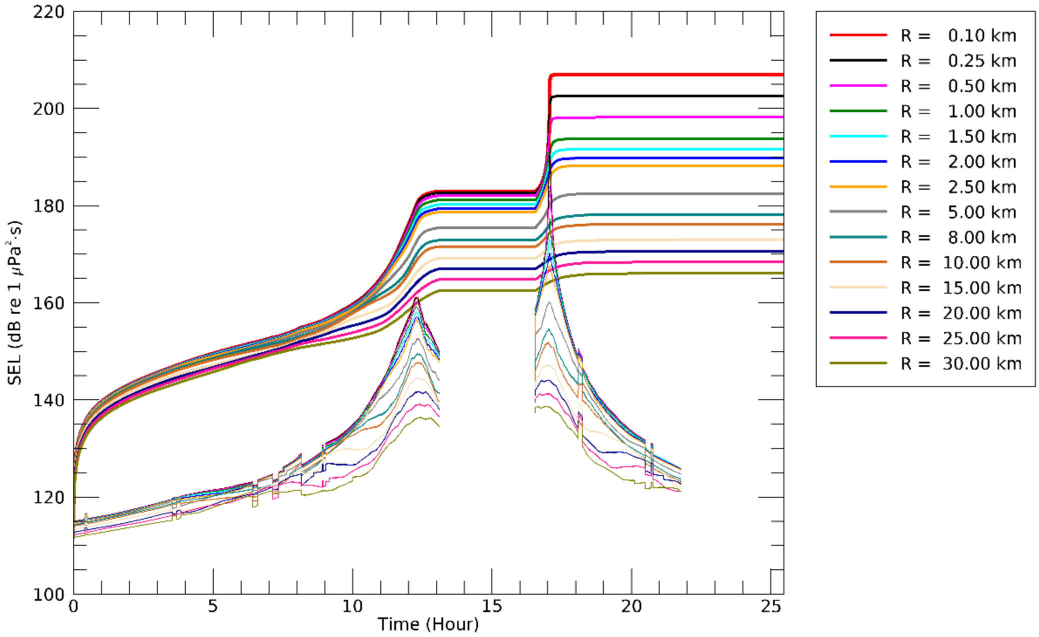

Figure 27. *Scenario 1*: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines. Gaps in the per-pulse curves correspond to vessel turns.

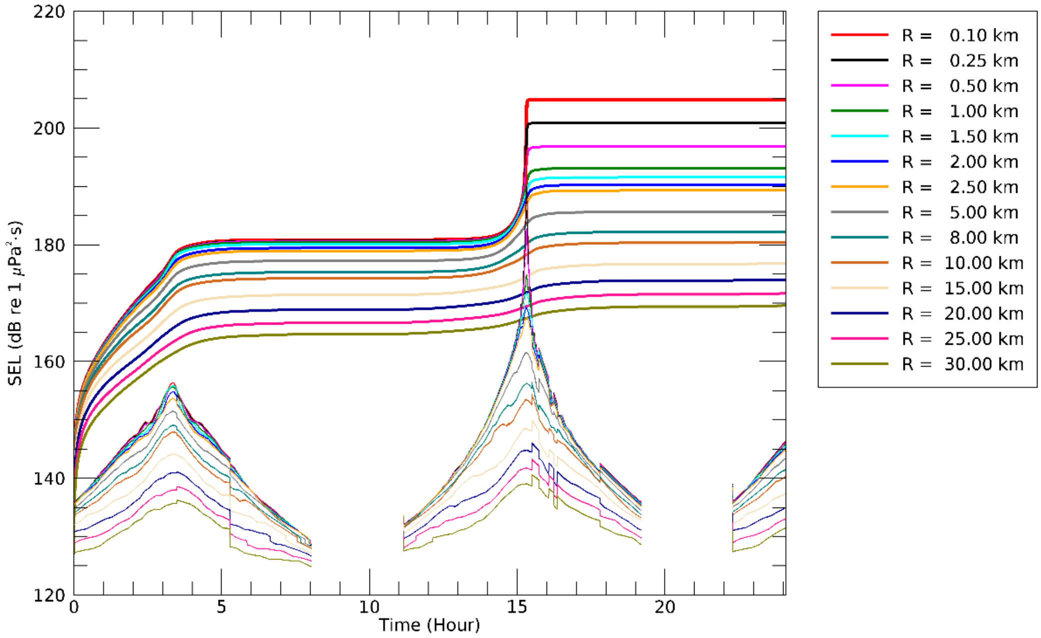

Figure 28. *Scenario 2*: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines. Gaps in the per-pulse curves correspond to vessel turns.

The accumulated SEL results are also presented for several different time windows centred around periods corresponding to CPA. Table 18 shows the estimated isopleth ranges based on the static receiver locations to the fish TTS threshold of 186 dB re 1 µPa^2·s for water column and seafloor receptors for Scenario 1 and Scenario 2. The ranges presented below were estimated by interpolating the receiver range where received levels drop below the threshold. Since all receiver locations were defined as perpendicular to survey lines, they represent an estimate of the perpendicular distance from the survey line to the relevant threshold; however, they are particular to that specific point along the line. The range for the full 24 h accumulated SEL, estimated by the same method, is also provided for comparison.

Figures 29 and 30 show the per-pulse SEL and SEL accumulated in the considered time windows around the CPA maxima as an example of the method described above.

Table 18. Distances to maximum-over-depth and seafloor static receiver SEL_{24h} based fish TTS criteria for the time windows for the considered receiver locations.

Marine fauna group	SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa^2·s)	Static Receiver	Distance (km)				
			1 h	2 h	3 h	4 h	24 h
Scenario 1							
Fish TTS I, II, III	186	Maximum-over-depth	3.0	3.1	3.1	3.1	3.3
		Seafloor	3.0	3.1	3.1	3.1	3.2
Scenario 2							
Fish TTS I, II, III	186	Maximum-over-depth	3.5	4.0	4.2	4.3	4.7
		Seafloor	3.5	4.0	4.2	4.2	4.7

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

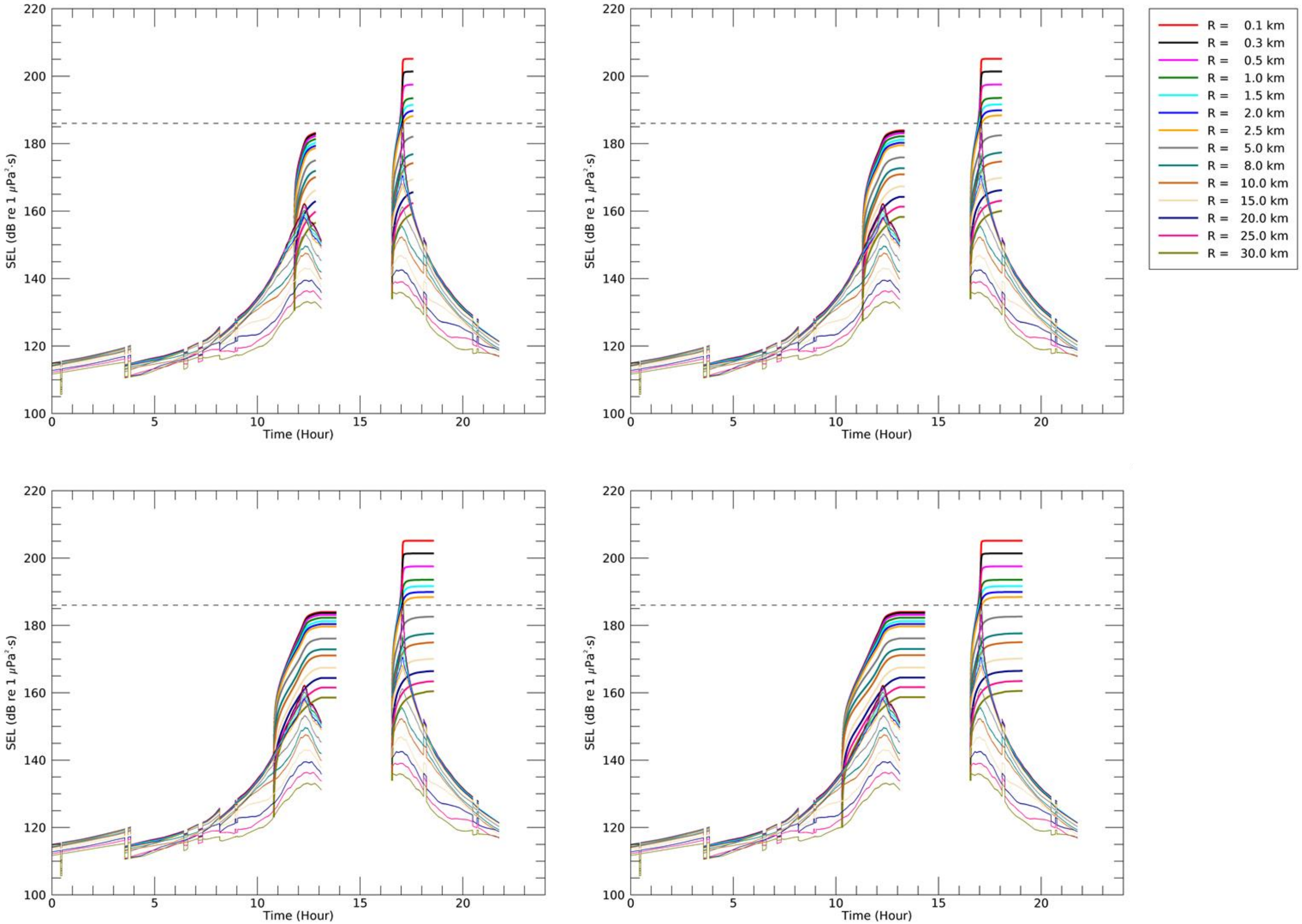

Figure 29. *Scenario 1*: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines (Figure 2). Clockwise from top-left the plots show accumulation over a 1, 2, 3, and 4 h window around the CPA, respectively. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 μPa^2·s.

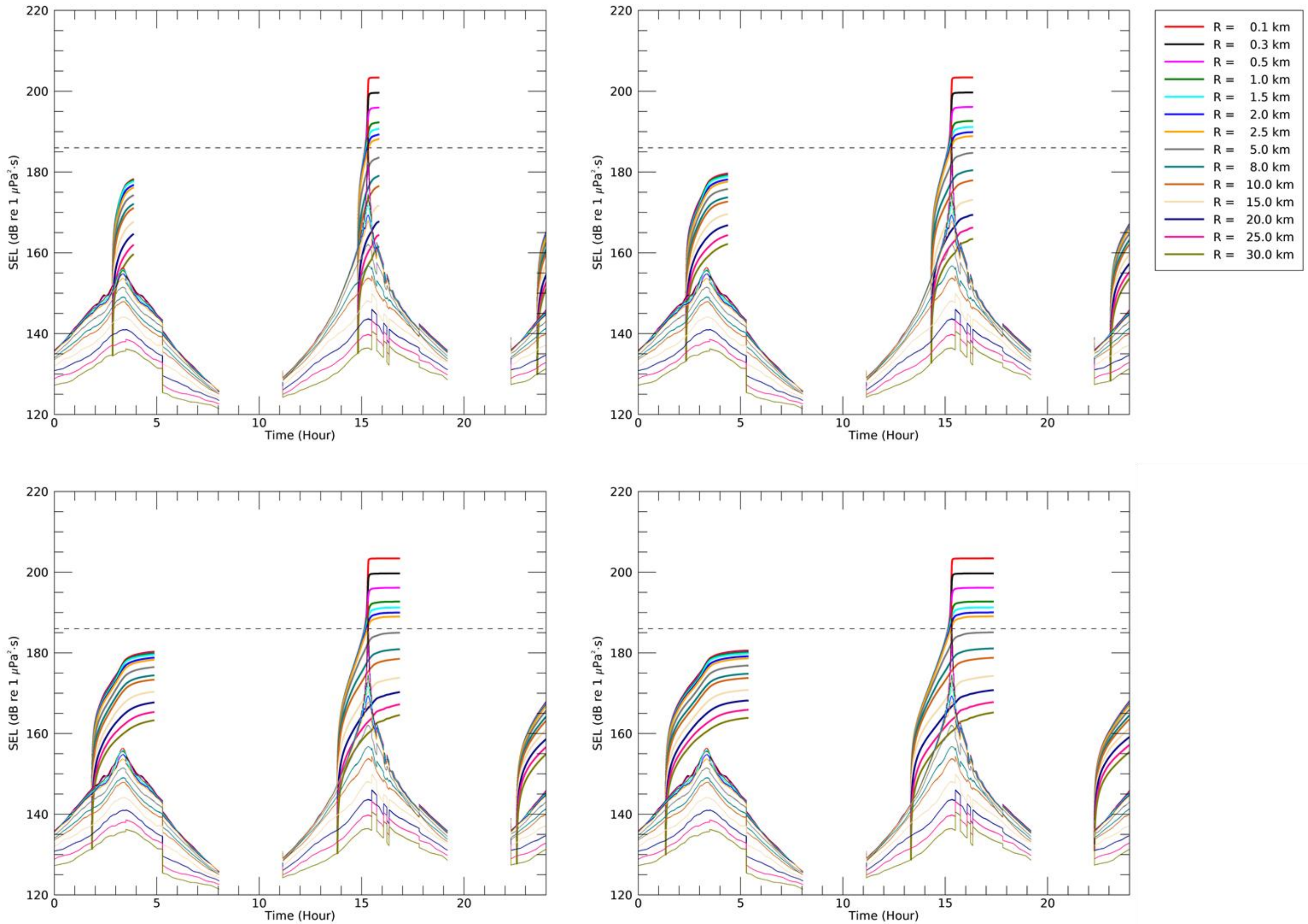

Figure 30. *Scenario 2*: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines (Figure 2). Clockwise from top-left the plots show accumulation over a 1, 2, 3, and 4 h window around the CPA, respectively. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 μPa²·s.

6. Discussion

This modelling study predicted underwater sound levels associated with the planned Keraudren Extension 3-D MSS. The underwater sound field was modelled for a 3260 in^3 seismic source (Appendix B), selected as a worst-case option based on a comparison of six seismic sources, three of which were considered for operation within the survey Operational Area (Appendix E).

An analysis of seasonal sound speed profiles, the results of which are presented in Appendix D.3.2, indicated that July was the month most conducive to sound propagation due to the presence of a upward refracting layer near the sea surface; as such it was selected to ensure a conservative estimation of distances to received sound level thresholds over the potential survey periods. Modelling also accounted for site-specific bathymetric variations (Appendix D.3.1) and local geoacoustic properties (Appendix D.3.3).

Most acoustic energy from a seismic source is output at lower frequencies, in the tens to hundreds of hertz. The modelled 3260 in^3 array had a pronounced broadside directivity for 1/3-octave-bands between ~125 to 251 Hz (Appendix B.2), which caused a noticeable axial bulge in the modelled acoustic footprints.

The overall broadband (10–25000 Hz) unweighted per-pulse SEL source level of the 3260 in^3 seismic source operating at 7 m depth was 225.0 dB 1 μPa^{2}m^{2}s in the broadside direction and 223.4 dB 1 μPa^{2}m^{2}s in the endfire direction. The peak pressure level in the same directions was 249.7 and 246.2 dB re 1 μPa m, respectively (Table 8).

6.1. Per-Pulse Sound Fields

The sound speed profile for July (Figure D-6) was primarily downward refracting apart from a slight upward refracting layer, which extended to approximately 70 m from the sea surface. The slight upward refracting layer in the sound speed profile will only effective trap frequencies above 320 Hz (Jensen et al. 2011). This layer has the potential to trap levels at higher frequencies that would otherwise dissipate more rapidly in range due to propagation, absorption, and seabed losses.

The bathymetry within survey area varied gradually between 50–150 m over a 100 km long southeast to northwest transect. This indicates that water depths generally increase to the north/northwest of the survey area as the continental shelf transitions into a deeper water slope environment. Combining low-frequency content from the seismic source with the water depths near the survey resulted in the sound field substantially interacting with the seabed. The maximum-over-depth sound footprint maps and vertical slice plots (Sections 5.2.2.1 and 5.2.2.2) assist in demonstrating the influence of the bathymetry and seabed composition on the sound field.

For the sites modelled in shallow water (less than 100 m depth, Sites 1–4) where the seabed was modelled as a thin sand layer underlain by cemented carbonate, the predicted levels were generally high near and directly below the seismic source as compared to sites in deeper water (great than 100 m depth, Sites 5–8) over the thicker layers of unconsolidated sediment. Conversely, sites over the thin sand and cemented carbonate seabed (Sites 1–4) generally displayed higher rates of loss as distance from the source increases, compared to sites located over thick layers of unconsolidated sediment. This is mainly a consequence of seabed composition and the geoacoustics for the considered modelled sites. The thin sand layer underlain by cemented carbonate seabed is more reflective at steep grazing angles (short ranges) but more absorptive at shallow grazing angle (long ranges). This resulted in smaller isopleths for lower thresholds but slightly larger isopleths for high level thresholds when compared to a more typical unconsolidated sediment dominated seabed (see single impulse isopleth radii in Table 9).

The distances to PK and PK-PK based criteria (Section 3.2 and 3.3) for fish, benthic crustaceans, and bivalves at the seafloor generally increased with increasing water depth (Tables 13 and 14). However, distances to these criteria did not always consistently change with increasing depth as any correlation between water depth and threshold distance is related to complex patterns of surface and seabed reflections that affect how sound propagates in shallow water. However, the number of modelled sites and water depths considered within the Operational Area, eight, provides a good representation of potential variability for seabed receptors.

6.2. Particle Motion

Section 5.2.2.3 discuss the relevance of particle motion (acceleration) to benthic invertebrates. Particle acceleration decays rapidly away from the source location within the distance equal to half the water depth. It is then influenced by shallow water propagation effects, such as constructive interference from sea-surface and seabed reflections. This resulted in up to 10 ms^{-2} variation in predicted levels out to two water depths, Beyond this distance, it exhibited an almost linear decay (Figures 20–22).

Particle motion traces generated during the modelling showed that vertical particle motion was larger than horizontal particle motion for receivers directly underneath or at short ranges from the array, but at longer ranges the horizontal particle motion dominated. The duration of particle motion also increased with distance as critically-reflected multipath propagation becomes important at longer ranges.

Day et al. (2016a) and Day et al. (2016b) included a regression of particle acceleration versus range for the single 150 in^3 airgun used in their study (minimum range of 6 m) and showed that acceleration at 10 and 100 m range was typically 26 and 5 ms^{-2}, respectively. Day et al. (2016a) and Day et al. (2016b) also referenced an unpublished maximum particle acceleration measurement of 6.2 ms^{-2} from a 3130 in^3 airgun array at 477 m range in 36 m of water. In our study, modelled peak acceleration at 10 m range was predicted to be between 25 and 48 ms^{-2} depending on the site; corresponding values at 100 m range are between 11 and 30 ms^{-2}. At ~477 m, our study predicts acceleration ranging between 4.8–6.2 ms^{-2} in the broadside directions. These result aligns with the measurements reported in Day et al. (2016a) and Day et al. (2016b) and thus represents what is likely to occur particularly considering the predicted broadside maximum acceleration 6.2 ms^{-2} for a 3260 in^3 array at the shallowest modelled site (Site 1) in 38 m of water.

The maximum distance to a particle acceleration of the closest value to 37.57 ms^{-2}, determined for comparing literature, (Section 3.3; Day et al. (2016a), Day et al. (2016b)) is 55 m.

6.3. Multiple Pulse Sound Fields

The accumulated SEL over 24 hours of seismic source operation was modelled considering two representative scenarios with realistic acquisition patterns for the Keraudren Extension 3-D MSS. The modelling predicted the accumulation of sound energy, considering the change in location and the azimuth of the source at each pulse point, which were used to assess possible injury in marine mammals and the SEL_{24h} based fish and marine mammal criteria. The results were presented as maps of the accumulated exposure levels and tabulated values of ranges to threshold levels and exposure areas for the given effects criteria (Section 3).

The footprints and range maxima for all accumulated SEL thresholds are influenced by the different seabed compositions across acquisition lines. Notable changes in the footprints can be observed as the seismic source transits across one seabed type to the other. The discussion above regarding ranges to isopleths also applies to the accumulated SEL calculations.

Sound exposure levels were also modelled at static receivers located at various offset distances from the closest survey line in each of the two scenarios (Figures 27 and 28). This provides a sense for the accumulation of acoustic energy as the seismic source acquires multiple lines over a 24 h period. The resulting time histories of accumulated SEL show that the single nearest pass of the seismic source(s) to a receiver will account for the majority of exposure over the 24 h period regardless of whether it occurs earlier or later, and addition passes after that one nearest exposure event will not add appreciably to the total level.

The time history of the accumulated and per-pulse SEL depends on the spatial offset between source and receiver points; as well as, the shape and extent of the isopleths for each single impulse sites, which depend on the local environmental properties. The per-pulse time histories are sensitive to the single impulse site isopleths, which can lead to local ‘jumps’ in the shape of the curves when the local environmental properties differ between adjacent impulses. This is due to the approach of using a discrete number of modelled sites to represent the 18331 or 17887 individual impulse sites within each scenario. However, for the accumulated SEL time histories, as well as the 24 h SEL assessments, larger scale sound propagation features dominated the accumulated and cumulative field as indicated by the smooth accumulated SEL time history curves.

An examination of the accumulation of sound exposure in 1–4 h windows centred around the CPA for both scenarios (Table 18 and Figures 29 and 30), expressed as percent changes in Table 19, illustrates the influence of water depth and receiver location within the water column on the results. In all cases, there was no difference between the TTS range between the 3–4 h windows around the CPA, with 90–95% of the energy accumulated over 24 h accumulated in this period. Considering how the sound exposure is accumulated as discussed above, due to the line spacing and nominal acquisition plan considering in the two modelled scenarios, the TTS threshold for fish was only exceeded at receivers when the source was active along the most proximal line. This occurred within the maximum predicted TTS range and for fish not located midway between two acquired lines in a scenario, is estimated to only occur once within the 24 h period.

Given the considerations in Popper (2018) for fish that do not move away from a surveying vessel and therefore experience TTS, accumulation of energy over longer periods than a few hours is probably inappropriate. In the scenarios considered and for the receiver locations selected, only one high-level exposure will likely occur per 24 h. For other receiver locations, for instance mid-way between lines, two mid-range exposures could occur. Regardless, considering the ranges to TTS with only a 3–4 h window is more biologically appropriate, and these distances would therefore relate only to one acquisition line. For these fish, recovery could begin a few hours after exposure (not considering the time between pulses). If these fish remained stationary, they are not predicted to experience another high-level exposure until the next proximal pass of the source.

The range to TTS considering the static receivers assessed the sound levels only on one side of a single survey line within the scenario (Figures 2 and 3) and not between the lines. The receivers were not located at a position along the line necessarily associated with the maximum range to TTS for the scenario. However, the percent change in distance, Table 19, provides context for how the distances could change.

Table 19. Percent change in distances to maximum-over-depth and seafloor static receiver SEL_{24h} based fish TTS criteria for 1–4 h time windows compared to the 24 h time window distance for the considered receiver locations.

Marine fauna group	SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Static Receiver	Distance as % of SEL_{24h} at static receiver locations				
			1 h	2 h	3 h	4 h	24 h
Scenario 1							
Fish TTS I, II, III	186	Maximum-over-depth	91%	94%	94%	94%	100%
		Seafloor	74%	85%	89%	91%	100%
Scenario 2							
Fish TTS I, II, III	186	Maximum-over-depth	94%	97%	97%	97%	100%
		Seafloor	74%	85%	89%	89%	100%

Summary

The study findings pertaining to each metric and criteria for various marine species of interest are summarised below with references to the result location.

Marine mammal injury and behaviour

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 5.66 and 8.84 km (Site 3 and Site 1), provided in Table 10.

- The results for the criteria applied for marine mammal Permanent Threshold Shift (PTS), NMFS (2018), consider both metrics within the criteria (PK and SEL_{24h}). The longest distance associated with either metric is required to be applied. Table 20 summarises the maximum distances for PTS, along with the relevant metric and the location of the results within this report; the farthest distances were associated with Scenario 2, in deeper water.
- The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding SEL_{24h} radii for low-frequency cetaceans were larger than those for peak pressure criteria, but they represent an unlikely worst-case scenario. More realistically, marine mammals (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with injury (either PTS or TTS) if it remained in that location for 24 hours.

Table 20. Summary of maximum marine mammal PTS onset distances for modelled scenarios (PK values from Table 11 and SEL_{24h} values from Table 15)

Hearing group	Scenario 1		Scenario 2	
	Metric associated with longest distance to PTS onset	R_{max} (km)	Metric associated with longest distance to PTS onset	R_{max} (km)
Low-frequency cetaceans†	SEL_{24h}	2.22	SEL_{24h}	3.08
Mid-frequency cetaceans	—	—	SEL_{24h}	0.02
High-frequency cetaceans	PK	0.43	PK	0.23

† The model does not account for shutdowns.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Turtles

- The PK turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m (horizontal modelling resolution for FWRAM) from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metric was 120 m for PTS onset and 1.34 km for TTS onset (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- Table 21 summarises the distances to where the NMFS criterion (NSF 2011) for behavioural response of turtles to the 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000b, McCauley et al. 2000a) could be exceeded.

Table 21. Summary of distances to turtle behavioural response criteria (from Table 10).

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Minimum	Maximum
175†	1.04	1.27
166‡	2.92	4.30

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b, McCauley et al. 2000a).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:

- Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- Fish with a swim bladder that do not use it for hearing
- Fish that use their swim bladders for hearing
- Fish eggs and fish larvae

- Table 22 summarises the distances to injury criteria for fish, fish eggs, and fish larvae along with the relevant metric and the location of the information within this report. This summary only presents the 24 h SEL results, rather than those considering the alternate time windows presented in Section 5.3.3 and discussed in Section 6.3.

Table 22. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios (PK values from Tables 11 and 13 and SEL_{24h} values from Tables 16 and 17).

Relevant hearing group	Effect criteria	Water column		Seafloor	
		Metric associated with longest distance to criteria	R_{max} (km)	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.07	PK	0.09
	TTS	SEL_{24h}	6.32	SEL_{24h}	6.18
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.28	SEL_{24h}	0.28
	TTS	SEL_{24h}	6.32	SEL_{24h}	6.18
Fish eggs, and larvae	Injury	PK	0.23	PK	0.16

Benthic invertebrates, Sponges, Coral, and Plankton

To assist with assessing the potential effects on these receptors, the following were determined:

- Bivalves: The distance where a particle acceleration of 37.57 ms^{-2} at the seafloor could occur was determined for comparing to results presented in Day et al. (2016a). The maximum distance to this particle acceleration level was 55 m.
- Crustaceans: The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008) was considered for seafloor sound levels; the sound level was reached at ranges between 351 and 685 m depending on the modelled site (Table 14).
- Sponges and coral: The PK sound level at the seafloor directly underneath the seismic source was estimated at all modelled sites and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); the threshold was reached within a 5 m horizontal range from the acoustic centre of the source at the shallowest modelled site, at 38 m water depths (Table 13).
- Plankton: The distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at all modelled sites through full-waveform modelling using FWRAM; the results ranged from 6.82 to 7.92 km (Table 12).

Glossary

1/3-octave
One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band
Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.

90%-energy time window
The time interval over which the cumulative energy rises from 5 to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

broadside direction
Perpendicular to the travel direction of a source. Compare with endfire direction.

cavitation
A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. See also broadside direction.

ensonified
Exposed to sound.

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for hearing high frequencies.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean
The functional cetacean hearing group that represents mysticetes (baleen whales) specialized for hearing low frequencies.

mean-square sound pressure spectral density
Distribution as a function of frequency of the mean-square sound pressure per unit bandwidth (usually 1 Hz) of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: $\mu Pa^2/Hz$.

mid-frequency (MF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for mid-frequency hearing.

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

parabolic equation method
A computationally efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

particle acceleration
The rate of change of particle velocity. Unit: meters per second squared (m/s^2). Symbol: *a*.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

peak-to-peak pressure level (PK-PK)
The difference between the maximum and minimum instantaneous pressure levels. Unit: decibel (dB).

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

received level (RL)
The sound level measured (or that would be measured) at a defined location.

rms
root-mean-square.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound exposure spectral density
Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: $\mu Pa^2 \cdot s/Hz$.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 µPa m (pressure level) or dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ (exposure level).

spectral density level
The decibel level ($10 \cdot \log_{10}$) of the spectral density of a given parameter such as SPL or SEL, for which the units are dB re 1 $\mu Pa^2/Hz$ and dB re 1 $\mu Pa^2 \cdot s/Hz$, respectively.

spectrum
An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

surface duct
The upper portion of a water column within which the sound speed profile gradient causes sound to refract upward and therefore reflect off the surface resulting in relatively long-range sound propagation with little loss.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

thermocline
The depth interval near the ocean surface that experiences temperature gradients due to warming or cooling by heat conduction from the atmosphere and by warming from solar heating.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

wavelength
Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI R2013), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,\mathrm{pk}}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure (PK-PK or $L_{p,\mathrm{pk\text{-}pk}}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure, possibly filtered in a stated frequency band, attained by an impulsive sound, $p(t)$:

$$L_{p,\mathrm{pk\text{-}pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \tag{A-2}$$

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt\Big/p_0^2\right) \tag{A-3}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,\mathrm{fast}}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,\mathrm{boxcar\ 125ms}}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa²·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \Big/ T_0 p_0^2\right) \tag{A-4}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \tag{A-5}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) \tag{A-6}$$

$$L_{p90} = L_\mathrm{E} - 10\log_{10}(T_{90}) - 0.458 \tag{A-7}$$

where the 0.458 dB factor accounts for the 10% of pulse SEL missing from the SPL(T_{90}) integration time window.

Energy equivalent SPL (L_eq; dB re 1 µPa) denotes the SPL of a stationary (constant amplitude) sound that generates the same SEL as the signal being examined, $p(t)$, over the same time period, T:

$$L_\mathrm{eq} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)\,dt \Big/ p_0^2\right) \tag{A-8}$$

The equations for SPL and the energy-equivalent SPL are numerically identical. Conceptually, the difference between the two metrics is that the SPL is typically computed over short periods (typically of one second or less) and tracks the fluctuations of a non-steady acoustic signal, whereas the L_eq reflects the average SPL of an acoustic signal over time periods typically of one minute to several hours.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,\mathrm{LF,24h}}$; see Appendix A.4) or auditory-weighted SPL ($L_{p,\mathrm{ht}}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

In the present report, audiogram-weighted, fast-averaged SPL ($L_{p,\mathrm{ht,F}}$) is defined by the exponential function from Plomp and Bouman (1959):

$$L_{p,\mathrm{ht}} = L_{E,\mathrm{ht,per\text{-}pulse}} - 10\log_{10}(d/0.9)\,,$$
$$L_{p,\mathrm{ht,F}} = L_{p,\mathrm{ht}} + 10\log_{10}\frac{1-e^{-d/\tau}}{1-e^{-T/\tau}} \tag{A-9}$$

where d is the duration in seconds, τ is the time constant of 0.125 s representing marine mammal auditory integration time, $L_{p,\mathrm{ht}}$ is the audiogram-weighted SPL over pulse duration, and T is the pulse repetition period. This metric accounts for the hearing sensitivity of specific species through frequency weighting, and results in reduced perceived loudness (i.e., sensation level) for pulses shorter than auditory integration time (τ).

A.2. Particle Acceleration and Velocity Metrics

Since sound is a mechanical wave, it can also be measured in terms of the vibratory motion of fluid particles. Particle motion can be measured in terms of three different (but related) quantities: displacement, velocity, or acceleration. Acoustic particle velocity is the time derivative of particle displacement, and likewise acceleration is the time derivative of velocity. For the present study, acoustic particle motion has been reported in terms of acceleration and velocity.

The particle velocity (v) is the physical speed of a particle in a material moving back and forth in the direction of the pressure wave. It can be derived from the pressure gradient and Euler's linearised momentum equation where ρ_0 is the density of the medium:

$$v = -\int \nabla p(t) dt / \rho_0 \qquad ()$$

The particle acceleration (a) is the rate of change of the velocity with respect to time, and it can be obtained from A-13 as

$$a = \frac{dv}{dt} = -\frac{\nabla p(t)}{\rho_0} \qquad ()$$

Unlike sound pressure, particle motion is a vector quantity, meaning that it has both magnitude and direction: at any given point in space, acoustic particle motion has three different time-varying components (x, y, and z). Given the particle velocity in the x, y, and z, directions, v_x, v_y, and v_z, the particle velocity magnitude |*v*| is computed per the Pythagorean equation:

$$|v| = \sqrt{v_x + v_y + v_z} \, . \qquad \text{(A-12)}$$

The magnitude of particle acceleration is calculated similarly from the particle acceleration in the x, y, and z directions.

A.3. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.4). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 µPa^2·s. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results obtained from MF cetacean studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 µPa^2·s.

As of 2017, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018; with the criteria defined in NMFS (2018) applied in this report.

A.4. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.4.1. Marine mammal frequency weighting functions

In 2015, a U.S. Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \qquad \text{(A-13)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016, NMFS 2018). Table A-1 lists the frequency-weighting parameters for each hearing group; Figure A-1 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by NMFS (2018).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	*K* (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
Mid-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
High-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

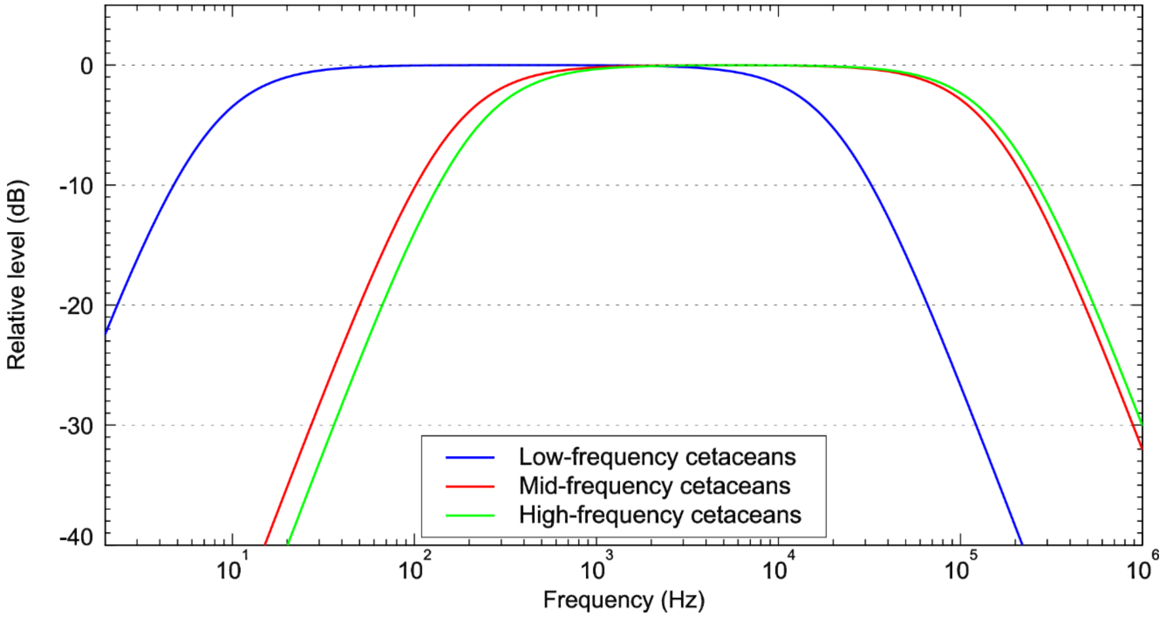

Figure A-1. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by NMFS (2018).

Appendix B. Acoustic Source Model

B.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, tow depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{\text{nf}} < \frac{l^2}{4\lambda} \tag{B-1}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, a seismic source length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

B.2. Array Source Levels and Directivity

Figure B-1 shows the broadside (perpendicular to the tow direction), endfire (parallel to the tow direction), and vertical overpressure signature and corresponding power spectrum levels for the 3260 in^3 array considered for the survey (Appendix D.4).

Horizontal 1/3-octave-band source levels are shown as a function of band centre frequency and azimuth (Figure B-2).

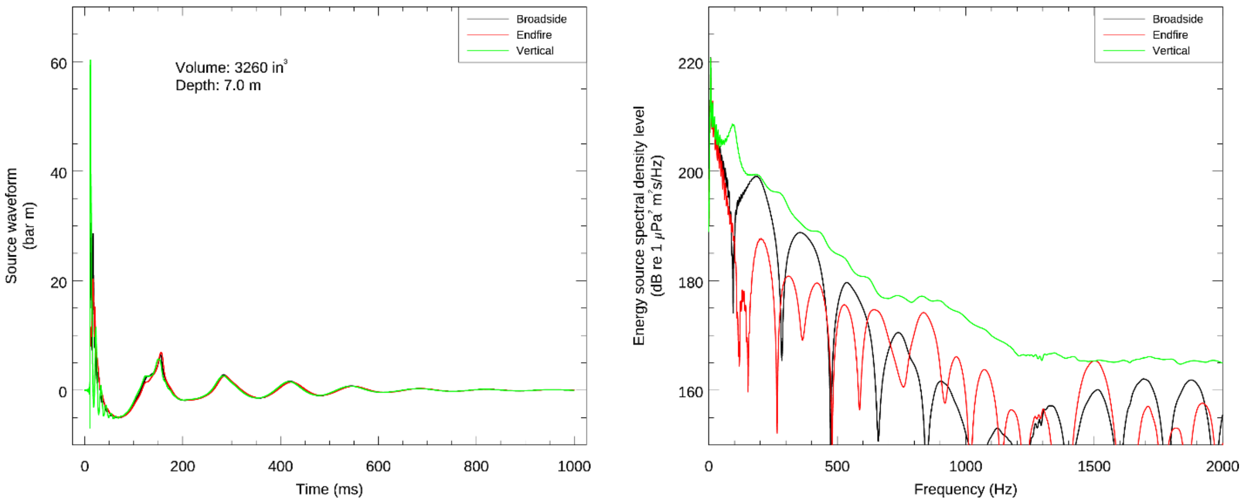

Figure B-1. Predicted source level details for the 3260 in^3 array at 7 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

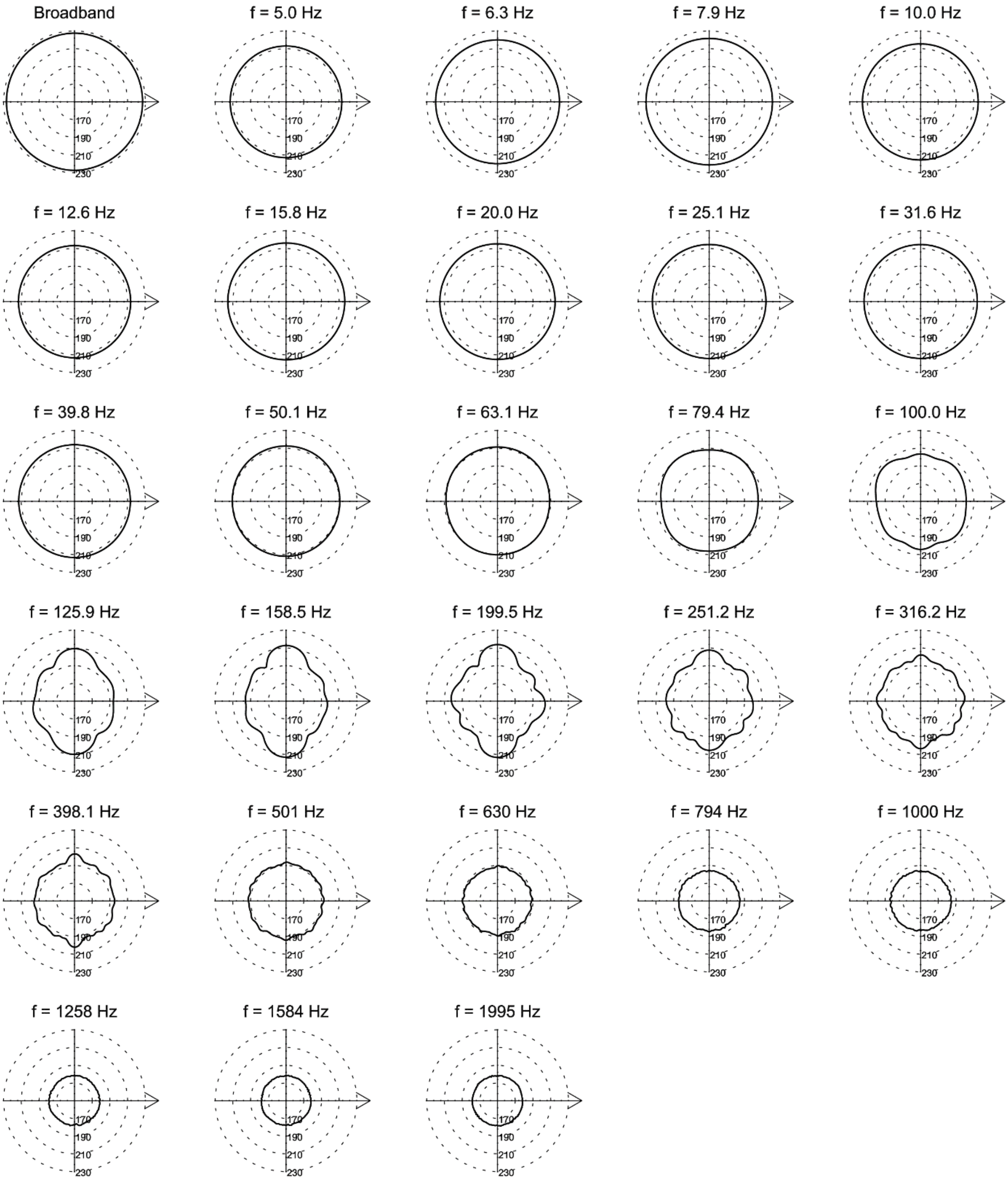

Figure B-2. Directionality of the predicted horizontal source levels for the 3260 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 µPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Tow depth is 7 m (see Figure B-1).

Appendix C. Sound Propagation Models

C.1. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). Compared to VSTACK, MONM less accurately predicts steep-angle propagation for environments with higher shear speed but is well suited for effective longer-range estimation. This model computes sound propagation at frequencies of 10 Hz to 1.25 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies > 1.25 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure C-1).

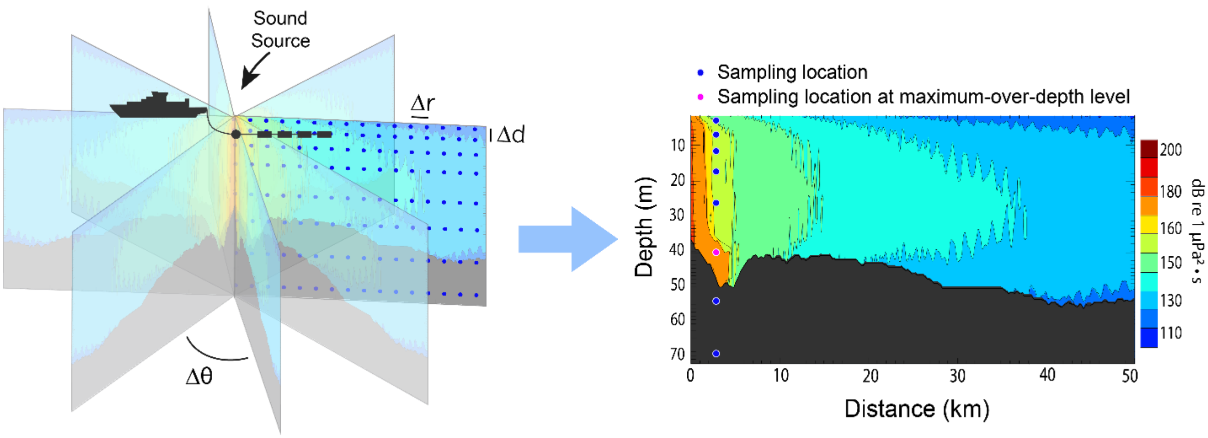

Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-pulse SEL are then computed by summing the received 1/3-octave-band levels.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SEL are presented as colour contours around the source.

An inherent variability in measured sound levels is caused by temporal variability in the environment and the variability in the signature of repeated acoustic impulses (sample sound source verification results is presented in Figure C-2). While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure C-2) upward so that the trend line encompasses 90% of all the data (dashed line, Figure C-2).

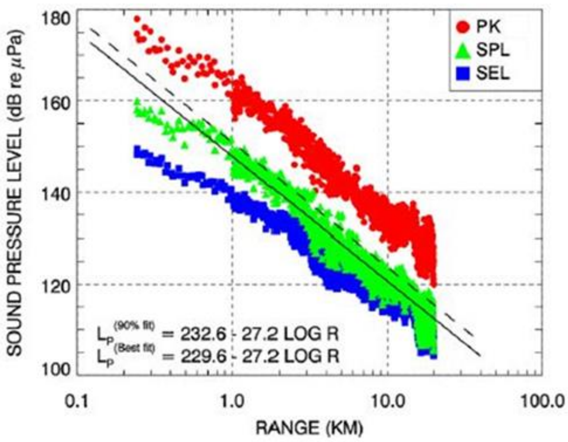

Figure C-2. PK and SPL and per-pulse SEL versus range from a 20 in^3 seismic source. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

C.2. Full Waveform Range-dependent Acoustic Model: FWRAM

For impulsive sounds from the seismic source, time-domain representations of the pressure waves generated in the water are required to calculate SPL and PK. Furthermore, the seismic source must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seafloor geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Besides providing direct calculations of the PK and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

C.3. Wavenumber Integration Model

Sound pressure levels near the seismic source were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solve the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but it is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

Appendix D. Methods and Parameters

This section describes the specifications of the seismic source that was used at all sites and the environmental parameters used in the propagation models.

D.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure D-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure D-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure D-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

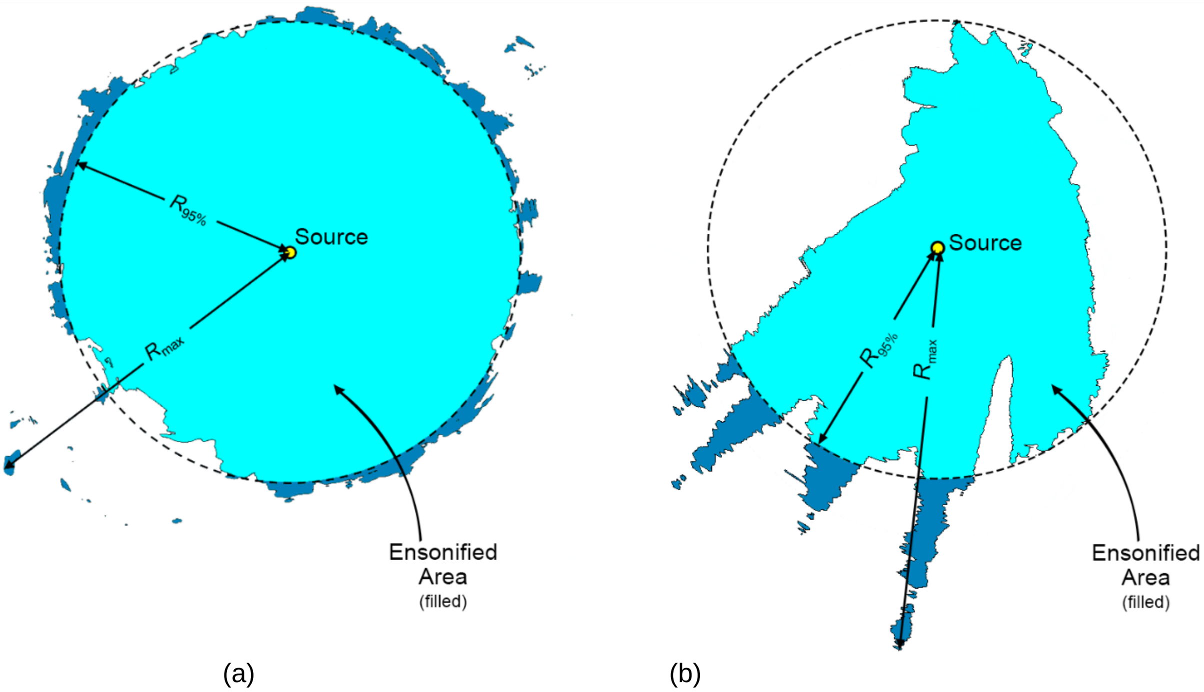

Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

D.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over a pulse's entire duration. The pulse SPL on the other hand, is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms; see Appendix A.1), as implemented in Martin et al. (2017b). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix C.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz. This was performed along all broadside and endfire radials at three sites. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL from the source can be calculated. The differences between the SEL and SPL were extracted for all ranges and depths that corresponded to those generated from the high spatial-resolution results from MONM. A 125 ms fixed time window positioned to maximize the SPL over the pulse duration was applied. The resulting SEL -to-SPL offsets were averaged in 0.02 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function for each site. The range- dependent conversion function was averaged between the two sites and applied to predicted per-pulse SEL results from MONM to model SPL values. Figure D-2 to D-4 show the conversion offsets for Sites 2,4 and 7; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source. The conversion to SPL from SEL was conducted using the considering the water depth and seabed geology at a given modelled site as compared Sites 2, 4, and 7.

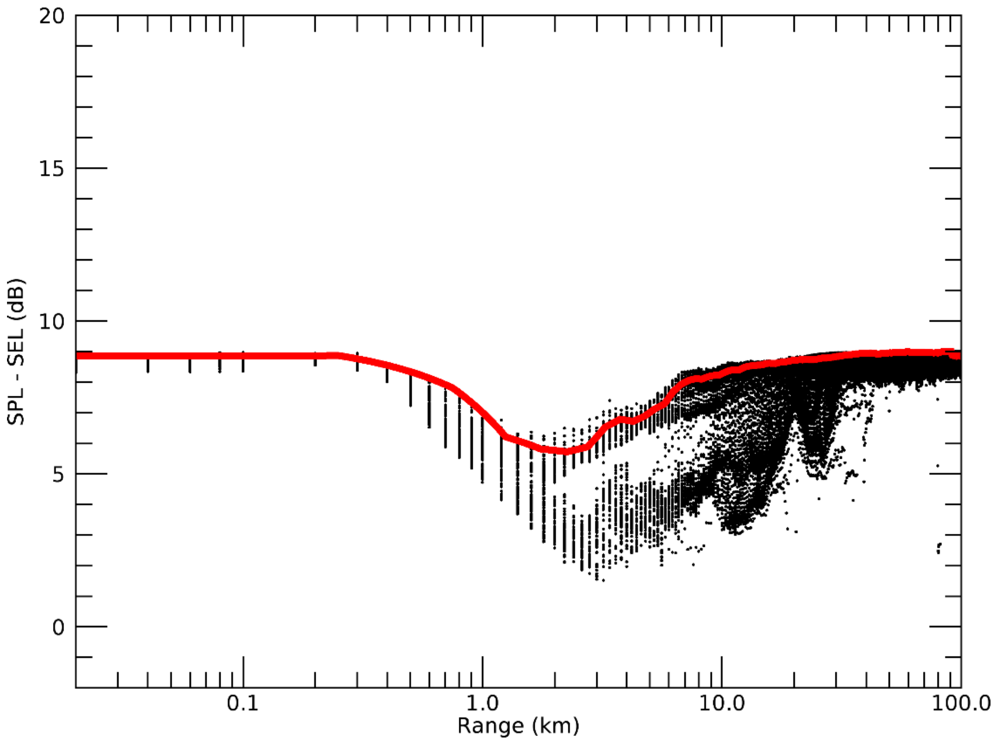

Figure D-2. *Site 2*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3260 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

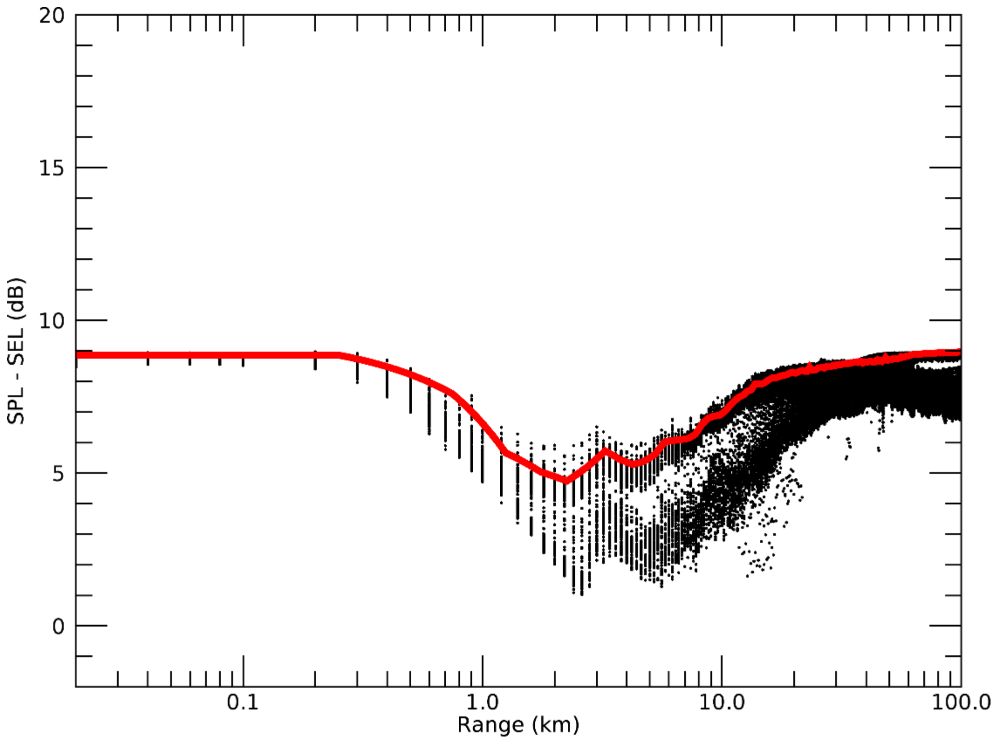

Figure D-3. *Site 4*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3260 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

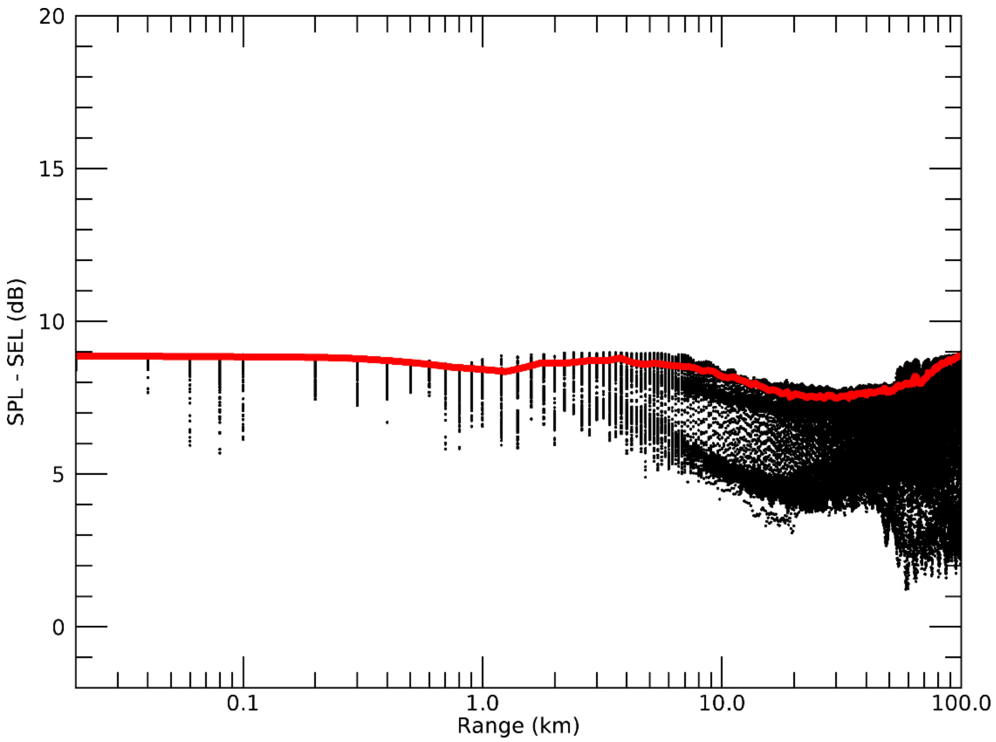

Figure D-4. *Site 7*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3260 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

D.3. Environmental Parameters

D.3.1. Bathymetry

Water depths throughout the modelled area were extracted from the Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009) for the region shown in Figure 1. Bathymetry data were extracted and re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 50) with a regular grid spacing of 200 × 200 m to generate the bathymetry in Figure D-5.

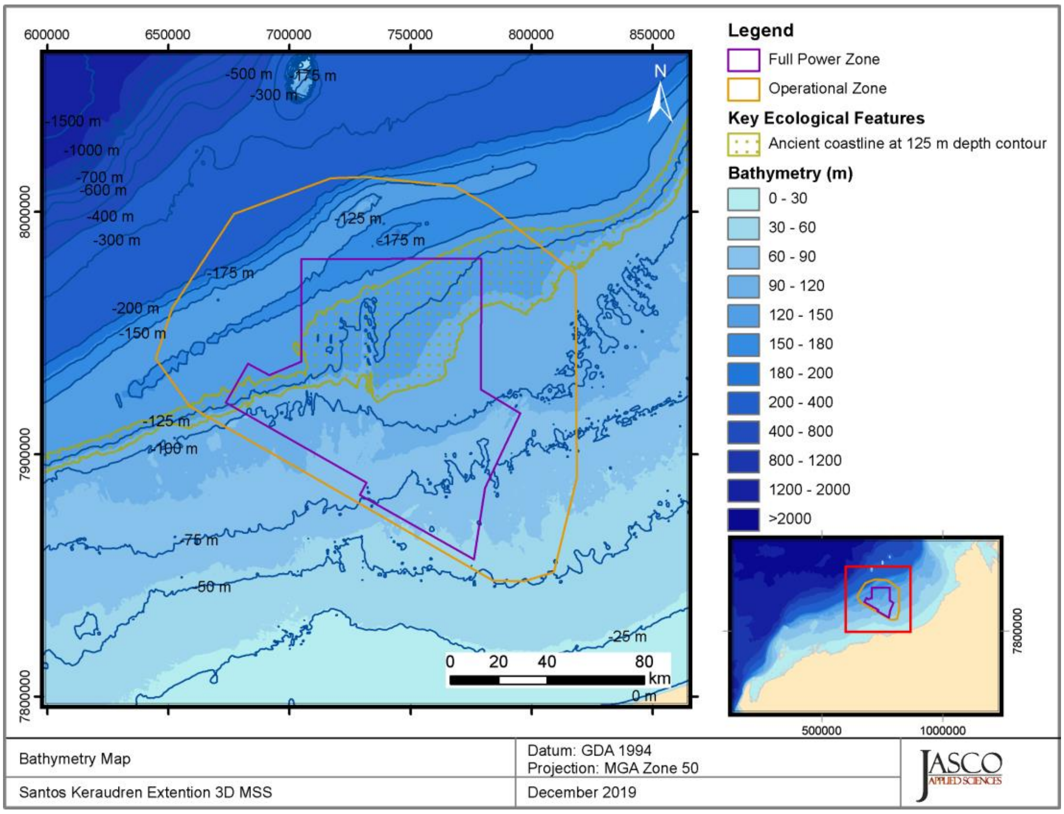

Figure D-5. Bathymetry map of the modelling area for the Keraudren Extension 3-D MSS.

D.3.2. Sound speed profile

The sound speed profiles for the modelled sites were derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles (February to July) were derived from the GDEM profiles within a 100 km box radius encompassing all modelled sites. The July sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, July was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-6 shows the resulting profile used as input to the sound propagation modelling.

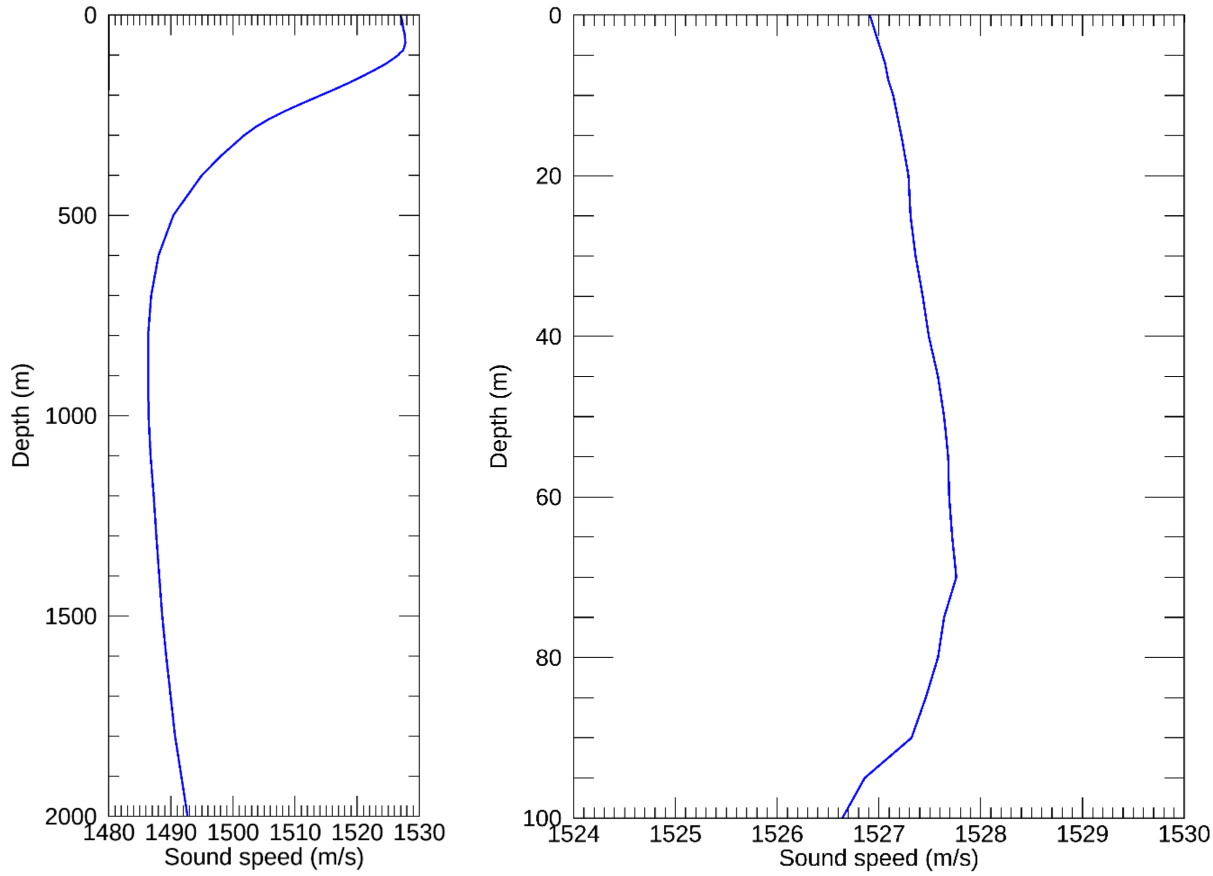

Figure D-6. The sound speed profile (July) used for the modelling showing the entire water column (left) and the top 100 m within the profile (right). Profiles are calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

D.3.3. Geoacoustics

For shallow water modelled sites (water depth < 100 m) the seabed in the area has been described as a calcarenite substrate overlain with a layer of sand (NGI 2017). This is very similar to a profile described in association with measurement data (McCauley et al. 2016), and other modelling studies in the region (AIMS 2018). The geoacoustic parameters used for modelling at Sites 1–4 and 8 (Table D-1) are based on Duncan et al. (2009).

Table D-1. Geoacoustic profile for the Sites 1–4 and 8.

Depth below seafloor (m)	Predicted lithology	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–3	Medium carbonate sand	1.8	1700	0.8	350	2.5
>3	Calcarenite	2.4	2800	0.1		

Geoacoustic parameters used for modelling at sites in deeper waters (Sites 5–7) were derived from sedimentary grain size measurements from the Australian Government's Marine Sediments (MARS) database (Heap 2009). On average, the surficial grain size indicates silty sand is present throughout the modelled area. Representative grain sizes and porosity were used in the grain-shearing model proposed by Buckingham (2005) to estimate the geoacoustic parameters required by the sound propagation models. Table D-2 lists the geoacoustic parameters used for modelling for Sites 5–7.

Table D-2. Geoacoustic profile for the Sites 5–7 each parameter varies linearly within the stated range.

Depth below seafloor (m)	Predicted lithology	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–26	Silty carbonate sand to interbedded, sandy carbonated mud and sand	1.78	1523–1674	0.05–0.67	180	0.1
26–42	Carbonated sandy silt to muddy sandy carbonate and silt/silty mud	1.80	1685–1716	0.68–0.79		
42–72	Carbonated sandy silt to muddy, sandy carbonate, silt/silty mud	1.78	1704–1745	0.77–0.91		
72–108	Silty sandy poorly cemented calcarenite	2.32–2.37	2121–2181	0.32–0.33		
108–188	Silty carbonate sand with occasional poorly cemented calcarenite layer	2.87–2.96	2781–2909	0.53–0.55		

D.4. Seismic Sources

Figure D-7 shows the layout of the 3260 in³ seismic source used for modelling in this study and considered in Appendix B. Table D-3 provides details of the airgun parameters.

The layout and airgun parameters for the 3480 in³ and 3390 in³ array considered in the preliminary array selection analysis are provided in Figures D-8 and D-9 and Tables D-4 and D-5, respectively.

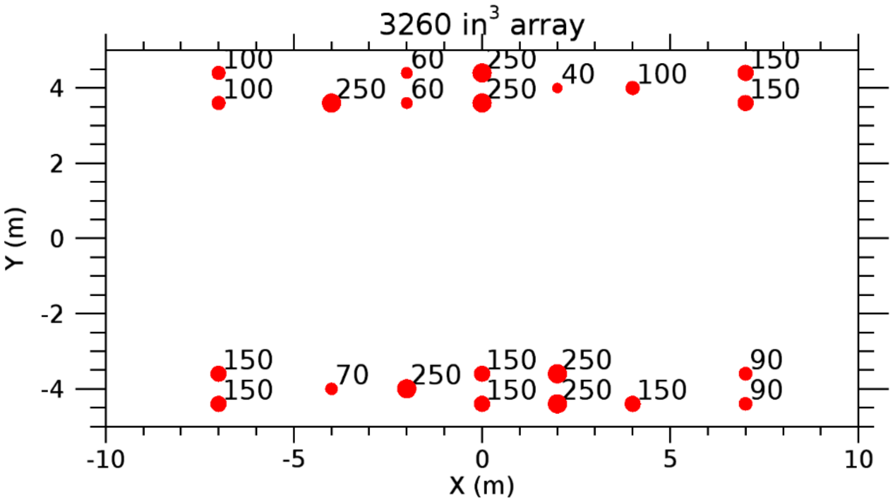

Figure D-7. Layout of the modelled 3260 in³ seismic array. Tow depth is 7 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-3.Table D-3. Layout of the modelled 3260 in³ seismic array. Tow depth is 7 m. Firing pressure for all guns is 2000 psi. Also see Figure D-7.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in³)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in³)
1	7	−4.4	7	90	13	7	3.6	7	150
2	7	−3.6	7	90	14	7	4.4	7	150
3	4	−4.4	7	150	15	4	4	7	100
5	2	−4.4	7	250	16	2	4	7	40
6	2	−3.6	7	250	17	0	3.6	7	250
7	0	−4.4	7	150	18	0	4.4	7	250
8	0	−3.6	7	150	19	−2	3.6	7	60
9	-2	−4	7	250	20	−2	4.4	7	60
10	−4	−4	7	70	21	−4	3.6	7	250
11	−7	−4.4	7	150	23	−7	3.6	7	100
12	−7	−3.6	7	150	24	−7	4.4	7	100

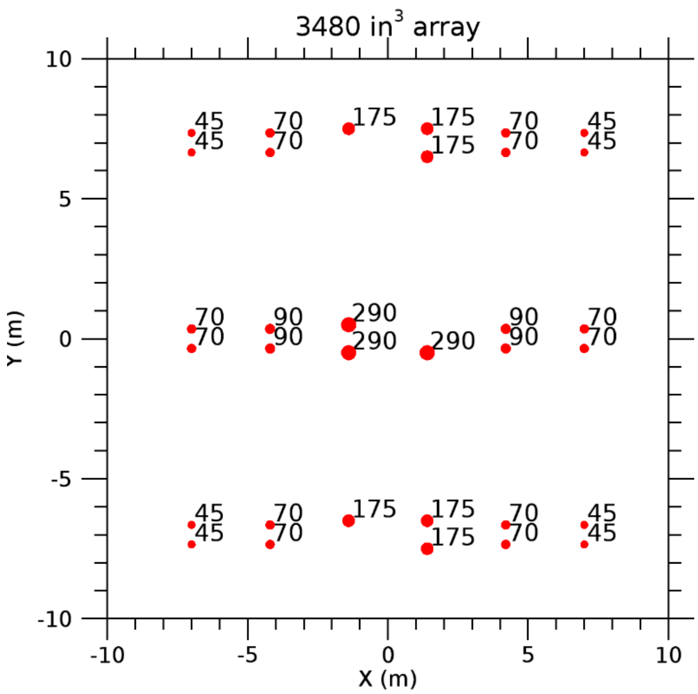

Figure D-8. Layout of the modelled 3480 in^3 seismic array. Tow depth is 7 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-4.

Table D-4. Layout of the modelled 3480 in^3 seismic array. Tow depth is 7 m. Firing pressure for all guns is 2000 psi. Also see Figure D-8.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7	−7.35	7	45	13	7	−0.35	7	70	25	7	6.65	7	45
2	7	−6.65	7	45	14	7	0.35	7	70	26	7	7.35	7	45
3	4.2	−7.35	7	70	15	4.2	−0.35	7	90	27	4.2	6.65	7	70
4	4.2	−6.65	7	70	16	4.2	0.35	7	90	28	4.2	7.35	7	70
5	1.4	−7.5	7	175	17	1.4	−0.5	7	290	29	1.4	6.5	7	175
6	1.4	−6.5	7	175	19	−1.4	−0.5	7	290	30	1.4	7.5	7	175
8	−1.4	−6.5	7	175	20	−1.4	0.5	7	290	32	−1.4	7.5	7	175
9	−4.2	−7.35	7	70	21	−4.2	−0.35	7	90	33	−4.2	6.65	7	70
10	−4.2	−6.65	7	70	22	−4.2	0.35	7	90	34	−4.2	7.35	7	70
11	−7	−7.35	7	45	23	−7	−0.35	7	70	35	−7	6.65	7	45
12	−7	−6.65	7	45	24	−7	0.35	7	70	36	−7	7.35	7	45

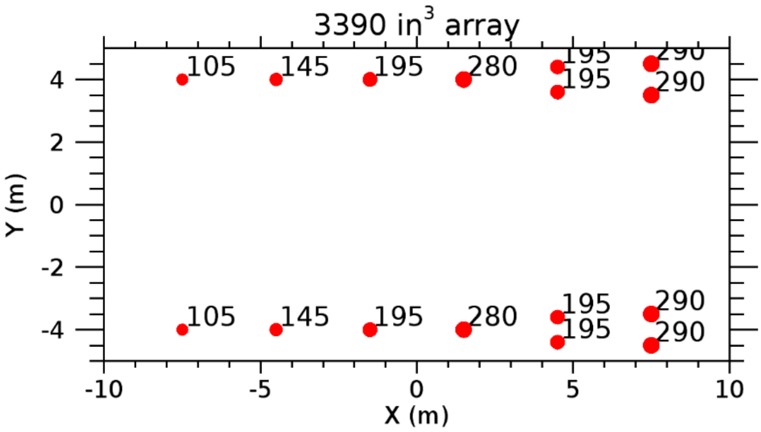

Figure D-9. Layout of the modelled 3390 in^3 seismic array. Tow depth is 7 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-5.

Table D-5. Layout of the modelled 3390 in^3 seismic array. Tow depth is 7 m. Firing pressure for all guns is 2000 psi. Also see Figure D-9.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7.5	4.5	7	290	9	7.5	−3.5	7	290
2	7.5	3.5	7	290	10	7.5	−4.5	7	290
3	4.5	4.4	7	195	11	4.5	−3.6	7	195
4	4.5	3.6	7	195	12	4.5	−4.4	7	195
5	1.5	4	7	280	13	1.5	−4	7	280
6	−1.5	4	7	195	14	−1.5	−4	7	195
7	−4.5	4	7	145	15	−4.5	−4	7	145
8	−7.5	4	7	105	16	−7.5	−4	7	105

D.5. Model Validation Information

Predictions from JASCO’s Airgun Array Source Model (AASM) and propagation models (MONM, FWRAM and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).

Appendix E. Seismic Source Comparison

E.1. Acoustic Source Levels and Directivity

Preliminary source modelling was conducted to determine the source with the highest equivalent far-field acoustic output of six comparable source arrays, which were defined as being between 2900–3500 in^3 as required to meet the technical specification and objectives of the Keraudren Extension 3-D MSS. The total volumes considered were 3150, 3260, 3090, 3480, 2965, and 3390 in^3. Table E-1 provides the results from AASM for the three loudest sources (3260, 3480, and 3390 in^3), the 3260 in^3 seismic source with a 7 m tow depth (Appendix D.4) was considered for the propagation modelling.

Table E-1. Far-field source level specifications for 3260, 3480, and 3390 in^3 sources, for a 7 m tow depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Total volume (in^3)	Direction	Peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$; dB 1 µPa²m²s)
			10–25000 Hz
3260	Broadside	249.7	225.0
3480		248.4	225.0
3390		248.7	224.8
3260	Endfire	246.2	223.4
3480		247.3	224.9
3390		246.4	224.0
3260	Vertical	255.6	228.5
3480		257.9	230.9
3390		254.4	227.9

E.2. Per-pulse Sound Field Comparison

FWRAM (Appendix C.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz at Site 4 considering a tow direction of 120°. FWRAM was used to characterise the acoustic fields in terms of SEL, SPL, and zero-to-peak sound pressure level (PK) metrics (as per Appendix A.1) for each source, which allowed for the three sources to be compared in a representative environment scenario. Modelling was performed along all broadside and endfire radials for the three the seismic sources considered (3260, 3480, and 3390 in^3; Table E-1).

Figures E-1 to E-3 present the maximum-over-depth for all radials for SEL, SPL, and PK metrics as a function of range. The 3260 in^3 and the 3480 in^3 arrays consistently produce the highest SEL and SPL. The similarity in SEL and SPL between these two arrays will result in similar isopleths for energy based assessments (i.e., the SEL_{24h} assessment) and isopleths to behavioural disturbance.

However, the 3260 in^3 array produces the highest PK levels of all the considered arrays and would therefore result in the largest radii for PK level isopleths.

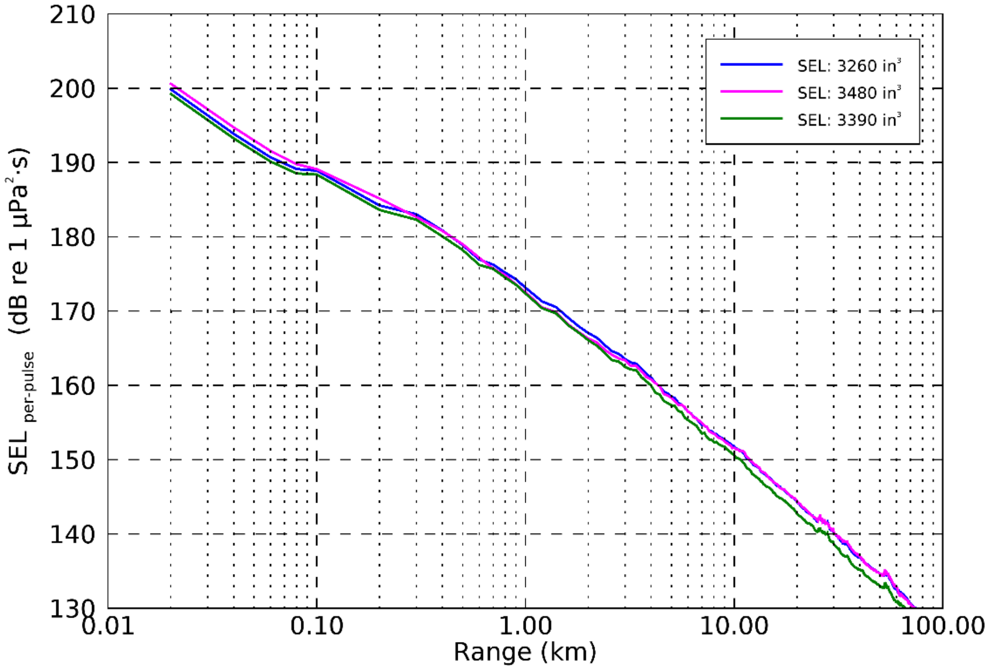

Figure E-1. *SEL*: Maximum-over-depth predicted for the 3260, 3480, and 3390 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.

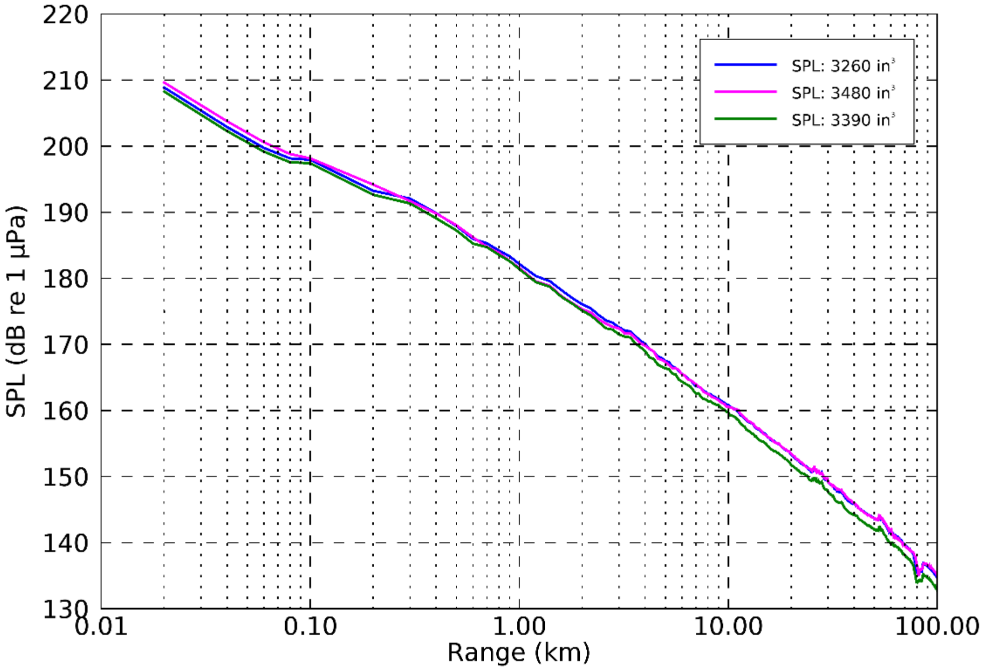

Figure E-2. *SPL*: Maximum-over-depth predicted for the 3260, 3480, and 3390 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.

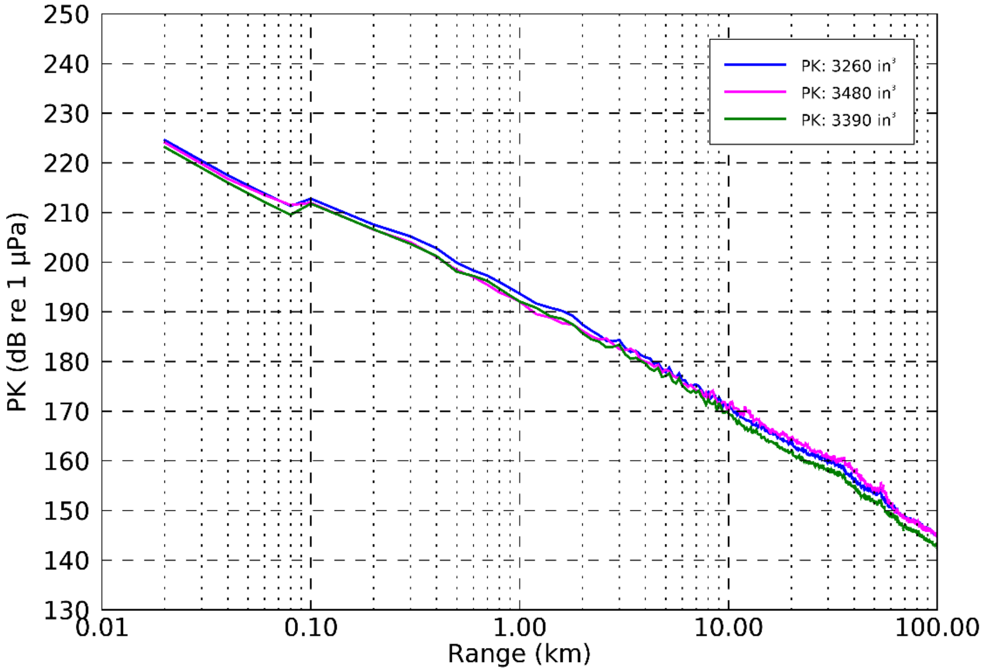

Figure E-3. *PK*: Maximum-over-depth predicted for the 3260, 3480, and 3390 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.

Santos

Appendix I – Noise Impacts Technical Appendix

Santos

Technical Appendix: Noise Impacts on Marine Fauna

PROJECT / FACILITY	Santos Keraudren Extension 3D MSS
REVIEW INTERVAL (MONTHS)	No Review Required
CONTROLLED DOCUMENT	NO

Rev	Rev Date	Author / Editor	Amendment
A	12.10.2018	Klaus Lucke	
B	20.11.2018	S Mavrick	
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1	29.11.2019	J Edgell / K Lucke	New references added on the potential sensitivity and effects of seismic sound on zooplankton, fishes, turtles, cetaceans and divers.
2	16.12.2019	S Moran	No changes, updated to a Santos template

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1 Hazard Identification

The following activities generating underwater sound are considered in this technical appendix:

+ Sound pulses from the seismic airgun array; and
+ Engine and machinery noise transmitted through the hull and propeller noise from the source and support vessels.

1.1 Seismic source

The dominant source of underwater sound during a seismic survey is generated from the operation of the seismic source (airgun array). The configuration and source characteristics of potential seismic source options for the Keraudren Extension 3D Marine Seismic Survey (MSS) are described in the sound propagation modelling report (Koessler and McPherson 2019).

The seismic source will be fired at regular intervals, producing pulses of high-intensity low-frequency sound. Seismic pulses typically have ~98% of the signal power in dominant frequencies less than 200 Hz; predominantly in the 10 to 200 Hz range (Mccauley 1994), the useful range for seismic data imaging. The airgun array comprises a series of airguns that are discharged in pre-determined order to achieve the desired sound energy and frequency of discharges with minimal interference. The underwater acoustic signatures of the array were predicted with JASCO's specialised computer model AASM, which accounts for individual airgun volumes and array geometry. Sound levels at distances from the sources were estimated using complementary underwater acoustic propagation models in conjunction with the modelled array signatures (Koessler and McPherson 2019).

1.2 Vessel-related sound sources

Sounds made by human activities at sea, whether intentional (e.g., sonar) or unintentional (shipping), can be transient or continuous, and the sounds cover varying frequency bands. The contribution of anthropogenic sound to the overall soundscape at sea has increased over the past century and is now present in almost all marine areas (Pine et al. 2012). Commercial shipping is one of the main contributing factors to the background noise in the oceans (Frisk 2012). Several studies present data recorded in various parts of the world's oceans indicating that low-frequency (<100 Hz) sound levels increased at a rate of 0.55 dB/year (~3 dB/decade) up until the 1980s (Andrew et al. 2002, Ross 2005, McDonald et al. 2006) and then slowed to 0.2 dB/year (Chapman and Price 2011). Worldwide, there are regional differences with regard to this trend (Andrew et al. 2011, Miksis-Olds and Nichols 2016), and in temperate zones, a pronounced seasonal variation in background noise is attributable to seasonal changes in human boating and recreational activities (Samuel et al. 2005).

2 Background

Sound, of all forms of energy, is transmitted underwater with the least amount of attenuation, thus sound reaches marine life over long distances. This physical characteristic is important from a biological viewpoint as it favoured, through evolution, the development of sound-producing mechanisms and sensory systems tuned to perceive sound in various marine taxa.

As in terrestrial animals, sound has also the potential to cause various effects in marine animals. The type and severity of these effects depends on the acoustic characteristics of the sound source (i.e. the emitted signal, the physical properties along path from the source to a receiver, the background noise at the receiver's position, and an animal's hearing sensitivity over frequencies included in the sound).

A sound wave can be detected underwater and classified by the pressure fluctuation it generates, as well as the particle motion associated with the propagation of the sound wave. These two components of sound, pressure and particle motion, serve as input to the sensory systems in marine animals. Different species (or taxonomic groups, taxa) developed sensors for either one of these sound components, and some are sensitive to both.

The particle motion generated by an active sound source refers to the movement of the particles that make up the media when a sound is present (Martin et al. 2016). It can be quantified in terms of particle velocity, -displacement or -acceleration; these are vector quantities having magnitude and direction.

For simple situations, such as acoustical plane-waves or spherical waves in an infinite body of water (i.e., without boundary reflections), the particle velocity can be determined from the pressure and vice-versa, as they are strongly correlated in the acoustic far-field of a sound source.

3 Noise sources and sound propagation

3.1 Impulsive sounds vs continuous sounds

Impulsive and non-impulsive sounds are primarily distinguished by their temporal pattern: Impulsive or 'pulsed' sounds can be described as discrete (single pulses) and sometimes intermittent sounds (multiple pulses) produced by sources such as airguns and pile driving. These sounds, sometimes also termed transients, are typically brief signals consisting of high peak sound pressure with rapid rise time and rapid decay (NIOSH 1998).

Non-impulsive sounds which can be intermittent or continuous produced by sound sources such as ships and pumps. Non-impulsive sounds are longer than impulsive and usually do not have the high peak sound pressure and rapid rise/decay time that impulsive sounds do (NIOSH 1998). However, especially in respect to their auditory effects, the term non-impulsive does not imply long duration signals.

3.2 Factors influencing sound propagation

It is essential to understand that a sound emitted by a source is altered along its propagation path and transformed into the signal received some distance away. A key question in the study of underwater sound is how an acoustic signal changes in nature as it propagates from its source to a receiver some distance away. This section provides a descriptive overview of key sound propagation concepts to assist with the results presented in this report. These concepts are integral to interpreting how sounds emitted by a source are transformed into those received some distance away.

The sounds are transformed by:

+ Geometric spreading: Sound levels from an omnidirectional point source in the water column are reduced with range, a process known as geometric spreading loss. As sound leaves the source, each spherical sound wave propagates outward and the sound energy is spread out over this ever-expanding sphere. The farther you are from the source, the lower the sound level you will receive. The received sound pressure levels at a recorder located a distance 'r' (in m) from the source are 20log10R dB lower than the source level (SL) referenced to a standard range of 1 m. But the sound cannot spread uniformly in all directions forever. Once the waves interact with the sea surface and seabed, the spreading becomes cylindrical rather than spherical and is limited to the cylinder formed by the surface and seabed with a lower range-dependent decay of $10*\log_{10} R$ dB. Thus, the water depth is a key factor in predicting spreading losses and received sound levels. These spherical and cylindrical spreading factors provide limits for quick approximations of expected levels from a given source. In very shallow waters, sound rapidly attenuates if the water depth is less than a quarter of a wavelength (Urick 1983).
+ Absorption, reflection, and scattering at the sea surface and seabed: If geometric spreading were the only factor governing sound attenuation in water, then at a given distance from a source, sound levels in shallow waters would almost always be higher than those in deep waters. In shallow water, however, the sound interacts more often with the seabed and sea surface than sound travelling in deep waters, and these interactions reflect, absorb, and scatter the sound. The sea surface behaves approximately as a pressure release boundary, where incident sound is almost completely reflected with opposite phase. As a result, the sum of the incident and reflected sounds at the sea-surface is zero. At the seabed many types of interactions can occur depending on the composition

of the bottom. Soft silt and clay bottoms absorb sound, sand and gravel bottoms tend to reflect sound like a partially reflective mirror, and some hard yet elastic bottoms, such as limestone, reflect some of the sound while absorbing some of the energy by converting the compressional waves to elastic shear waves.

+ Refraction due to sound speed changes: The speed of sound in water depends on the water's temperature, salinity, and pressure (i.e., water depth). Colder and fresher water has a lower sound speed, while warmer and saltier water has a higher sound speed. As the water depth increases, the pressure increases the water density slightly, which increases the sound speed (Jensen et al. 2011). These effects combine with environmental forces, such as solar heating, wind mixing, and currents, to constantly affect the sound speed in the upper 500 m of the water column, which thus has daily variations around typical seasonal means. When the sound speed changes with depth, which it always does, the sound refracts toward the depth with the lowest sound speed. This often results in sound being trapped in a 'duct' and travelling long distances with little attenuation. Conversely, in conditions where the sound speed decreases with depth, sound is refracted toward the seabed. The ability of a minimum in the sound speed profile to 'duct' sound depends on the magnitude of the sound speed change at the minimum, the vertical height of the minimum, and the sound's wavelength. Ducts must be several times larger than the wavelength to effectively trap sound (Etter 1996). A corollary of this effect is that higher frequencies are refracted more readily by sound speed changes than lower frequencies, which have longer wavelengths.
+ Absorption by sea water: As sound travels through the ocean, some of the energy is absorbed by the ionic relaxation of boric acid and magnesium sulphate, which turns the acoustic energy into heat. The amount of absorption that occurs is quantified by an attenuation coefficient, expressed in units of decibels per kilometre (dB/km). This absorption coefficient depends on the temperature, salinity, pH, and pressure of the water, as well as the sound frequency. In general, the absorption coefficient increases with the square of the frequency, so low frequencies are less affected. The absorption of acoustic wave energy has a noticeable effect (>0.05 dB/km) at frequencies above 1 kHz. For example, at 10 kHz the absorption loss over 10 km distance can exceed 10 dB, as computed according to the formulae of François and Garrison (1982b, 1982a).

Each of these aspects results in substantial changes to acoustic characteristics of the emitted signal and its propagation from the sound source to the received individual. A key question in the study of underwater sound is how a sound signal changes in nature as it propagates from its source to a receiver some distance away. At the other extreme, sounds from fin whales (20 Hz) and low-frequency energy from seismic airguns (5–100 Hz) can be detected thousands of kilometres away under the right conditions (Nieukirk et al. 2012).

3.3 Metrics

The publication of ISO 18405 Underwater Acoustics – Terminology (ISO 2017) (**Table 3-1**) provided a dictionary of underwater bioacoustics. For future reference, the terminology defined in this standard should be used to avoid ambiguity in reported sound levels. However, most of the relevant studies on noise effects in marine fauna are not compliant as they were published before the new standards were released.

Table 3-1: Metrics used to describe underwater sound

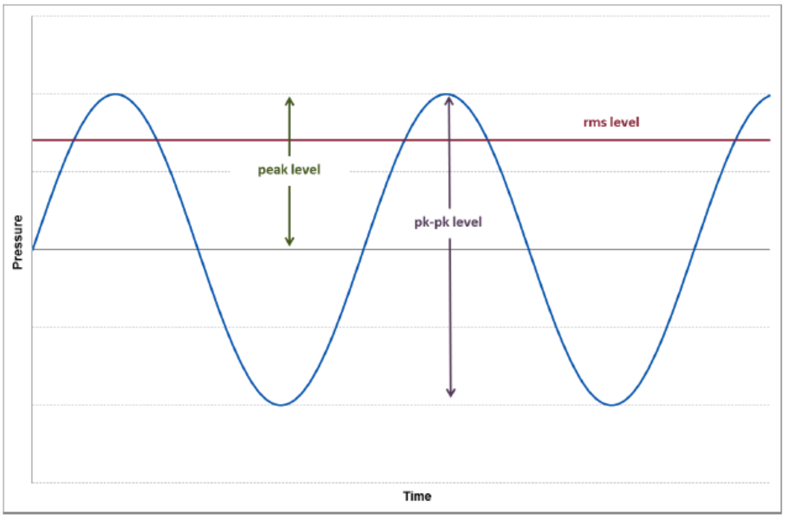
Metric	Commonly used (before 2017)	ISO (2017) / NMFS (2018)	
		Main text	Tables/equations
Sound Pressure Level	SPL_{rms}, SPL_{RMS}	SPL	SPL (L_p)
Peak Pressure	SPL_{pk}	PK	PK (L_{pk})
Sound Exposure Level	SEL_{cum}	SEL_{24h}	SEL_{24h} ($L_{E,24h}$)

The Sound Exposure Level metric (SEL_{24h}) describes the sound energy received by a receptor over a period of 24 hours.

3.3.1.1 Sound metric terminology

Given the multiple measures commonly used to express sound metrics, it's important to ensure any comparisons between specific sound level values are made using the same measures. These sound level metrics are summarised in **Table 3-2.**

Table 3-2: Sound Level Metrics Definitions

Source level	Source level (SL): The sound pressure level or sound exposure level measured 1 metre from a theoretical point source that radiates the same total sound power as the actual source. It is a theoretical value for a seismic source, because a seismic source is not a point source, but rather is made up of individual elements covering a defined area. Source level can be expressed as an SPL, SEL or PK. Unit: dB re 1 $\mu Pa^2 m^2$ or dB 1 $\mu Pa^2 m^2 s$.
Impulse / Pulse	The terms used to refer to the discharge of a seismic source are impulse and pulse, therefore the terms used to describe a single discharge are per-impulse or per-pulse.
Peak pressure (PK) Impulsive sounds	Zero-to-peak sound pressure (PK), the greatest magnitude of the sound pressure during a specified time interval, unit: dB re 1 µPa. PK levels are modelled to assess mortality and potential mortal injury to fish, turtles, fish eggs and larvae. Refer to the below for graphical representation of PK. 
Peak-to-peak pressure (PK-PK) Impulsive sounds	Peak-to-peak sound pressure (PK-PK), is the sum of the peak compressional pressure (highest pressure variation) and the peak rarefactional (pressure lowest pressure variation) during a specified time interval, unit: dB re 1 µPa. PK-PK is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound. Refer to the above for graphical representation of PK-PK.
Sound exposure level (SEL) Non-impulsive sounds	Sound exposure level (SEL), a measure related to the sound energy in one or more pulses, or the ratio of the time-integrated squared sound pressure to the specified reference value, unit: dB re 1 $\mu Pa^2 \cdot s$, and can be considered as a dose-type measurement. This measure recognises that the effects of sound are a function of exposure duration as well as maximum instantaneous peak pressure. The SEL metric integrates noise intensity over some period of exposure and is used as it allows exposure duration and the effect of exposure to multiple events to be taken into account. SEL is specified in terms of either per-impulse (per-pulse) or a defined accumulation period. The metrics determined for the defined accumulation period assume that a receptor remains stationary for the period. The

	accumulation period applied for this assessment is 24 hours, and therefore the SEL is referred to as either per-impulse SEL or SEL24h.
Particle motion metrics	Acoustic particle motion is defined as that motion caused by a sound wave of a given infinitesimal part of the medium relative to the medium as a whole, and it is an integral part of any sound field. Unlike pressure, particle motion is directional in nature and is typically described using three-dimensional vector notation. Particle motion levels can be expressed in a variety of units related to displacement, velocity, or acceleration. Acoustic particle velocity is the time derivative of particle displacement, and likewise acceleration is the time derivative of velocity. The particle velocity (v) is the physical speed of a particle in a material moving back and forth in the direction of the pressure wave. The particle acceleration (a) is the rate of change of the velocity with respect to time. Bivalves are sensitive to particle velocity or acceleration rather than pressure, and therefore modelled particle motion values have been referenced for the impact assessment. Many types of marine fishes are also primarily sensitive to particle motion, although limited information is currently available on the levels that may result in impacts.

3.3.1.2 Noise effect criteria

During a seismic survey, new sound energy of finite duration is introduced into the environment with each pulse from the seismic source. For this assessment, the sound levels emitted into the marine environment have been modelled and are expressed using the abovementioned sound metrics (i.e. SL, PK, SEL, etc.).

Whether the received noise levels injure or disturb marine fauna (i.e. have an effect) is an active research topic. The noise thresholds (i.e. the level that must be exceeded for an effect to occur) for sound-induced effects on marine fauna are described in the following sections of this document.

Noise thresholds have been defined for both the per-pulse sound energy released, as well as the total sound energy (accumulated) that marine fauna is subjected to over a defined period of time. For recent regulatory assessments of seismic surveys, the period of total sound energy integration (i.e. accumulation) has been typically defined as 24 hours; hence, was the period used for modelling and in this assessment. For fish this period is based on available research (Popper et al. 2014) which found fish experiencing a temporary threshold shift (TTS) in hearing recovered to normal hearing levels within 18 to 24 hours, and for marine mammals the period is required to be either 24 hours or the length of the activity, whichever is shorter (NMFS 2018).

Importantly, the 24-hour accumulated sound metric reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. More realistically, marine mammals and many fish (pelagic and some demersal) would not stay in the same location or at the same range for 24 hours. Popper et al. (2014) discuss the complications in determining a relevant sound exposure period of mobile seismic surveys, as the levels received by the receptor change between impulses due to the mobile source. For marine mammals and many fish, sound exposures at the closest point to the seismic source are the primary exposures contributing to a receptor accumulated level (Gedamke et al. 2011). Hence, thresholds based on a 24-hour exposure period are a conservative measure of potential effect.

4 Sound perception

4.1 Hearing sensitivity

Marine animals will only respond to acoustic signals they can detect. The sensitivity of a subject's auditory (i.e., hearing) system is described as a function of sound frequency. The lowest intensity of a sound at a particular frequency that an individual can hear describes its hearing threshold. The graphical representation of these thresholds over the range of frequencies that are audible to the individual is called its hearing curve or audiogram. Only a few individuals in a selected number of marine species have been tested in all taxonomic groups of marine animals.

4.2 Weighting functions

The potential for anthropogenic sounds to impact marine mammals is largely dependent on whether the sound occurs at frequencies that an animal can hear well, unless the sound pressure level is so high that it can cause physical tissue damage regardless of frequency. Auditory weighting functions reflect an animal's ability to hear a sound. Sound spectra are weighted at particular frequencies in a manner that reflects an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Auditory weighting functions have been proposed for marine mammals acoustic thresholds expressed in metrics that consider what is known about marine mammal hearing (e.g., SEL_{24h}, L_E) (Southall et al. 2007, Erbe et al. 2016, Finneran 2016). Marine mammal auditory weighting functions published by Finneran (2016) are included in the National marine Fisheries Service, NMFS (2018) Technical Guidance for use in conjunction with corresponding onset acoustic criteria for PTS (auditory injury) (**Table 6-1**).

Applying marine mammal auditory weighting functions emphasizes the importance of making measurements and characterizing sound sources in terms of their overlap with biologically-important frequencies (e.g., frequencies used for environmental awareness, communication, or the detection of predators or prey), and not only the frequencies of interest or concern for completing the sound-producing activity (NMFS 2018).

4.3 Noise criteria, rationale

To assess the potential impacts of the proposed survey, exposure criteria must first be established for which sound levels may be expected to negatively impact animals.

For marine mammals, NOAA issued a Technical Guidance document that provides acoustic thresholds for onset of temporary and permanent threshold shift (TTS and PTS, respectively) in marine mammal hearing for all sound sources (NMFS 2018). NOAA also provided guidance on the use of weighting functions when applying injury criteria. The NOAA Guidance recommends the use of a dual criteria for assessing injurious exposures, including an unweighted (flat) peak sound pressure level metric PK (L_{pk}) and a sound exposure level SEL_{cum} ($L_{E,24h}$) metric with frequency weighting. Both acoustic criteria and weighting function application are different for the marine mammal functional hearing groups.

Southall et al. (2019) published an updated set of criteria for onset of TTS and PTS in marine mammals. While the authors propose a new nomenclature and classification for the marine mammal functional hearing groups, the proposed thresholds and weighting functions for exposure to underwater sound do not differ in effect from those proposed by NOAA (2018). The new hearing groups proposed by Southall et al. (2019) have not yet been adopted by NOAA.

Popper et al. (2014) developed a set of criteria for fishes that are based on onset levels for barotrauma injury. These criteria are supported by data by Casper et al. (2013), who showed that less acoustic energy is required for the onset of barotrauma in fishes than for the onset of hair cell damage (the 'typical' cause for hearing injury in mammals). Injuries include direct mortality, non-recoverable injury including disorientation, and recoverable injury including TTS (Hawkins and Popper 2017). Criteria were chosen for all types of acoustic signals based on results from exposures to impulsive pile driving. This represents a conservative approach, as impulsive noise has a higher potential to cause deleterious effects than continuous sounds. The guidelines suggested by Popper et al. (2014) then separated marine fishes into four classes according to available data on hearing sensitivity and onset of injury in relation to the presence of morphological adaptations to their hearing system. The logic for choosing this indicator (injury), the baseline data (pile driving) and classification (animal groups) is reasonable and supported by the best available knowledge.

5 Potential noise effects

Marine fauna use sound in a variety of functions, including social interactions, foraging, orientation, and responding to predators. Underwater noise can affect marine fauna in three main ways:

+ Injury to hearing or other organs. Hearing loss may be temporary (temporary threshold shift (TTS)) or permanent (permanent threshold shift (PTS));
+ Disturbance leading to behavioural changes or displacement of fauna. The occurrence and intensity of disturbance is highly variable and depends on a range of factors relating to the animal and situation; and
+ Masking or interfering with other biologically important sounds (including vocal communication, echolocation, signals and sounds produced by predators or prey).

5.1 Stress

Stress is an integral, necessary part of the body's homeostasis, and certain stress levels are tolerable. At higher levels, if repeated too often, or continued over long durations stress can, however, become deleterious by creating an allostatic load to the body. This is expressed and can be measured as imbalances in the autonomic nervous system, central nervous system, neuroendocrine, and immune systems and/or result in changes in growth rate, disruption of diurnal rhythms and behavioural changes. Animals may not show overt signs of responding to an increase in noise but may nonetheless show physiological changes (e.g., Slabbekoorn et al. 2010, Kight and Swaddle 2011). Symptomatic stress responses include changes in respiration rate, oxygen consumption, excretion, or food consumption rates or in chronic effects such as immune suppression. The effects of increased stress levels (acute or chronic) can be expressed through a variety of metabolic and/or physiological factors. The imbalance caused by stress in these factors can lead to immune suppression and/or result in changes in growth rate, disruption of diurnal rhythms, and behavioural changes. This cascade of effects may reduce the individual's fitness through alterations in reproduction (e.g.,Sierra-Flores et al. 2015) and, ultimately, survival (see review by Slabbekoorn et al. 2010).

5.2 Behaviour

The intensity of behavioural responses of marine mammals to sound exposure ranges from subtle responses, which may be difficult to observe and have little implications for the affected animal, to obvious responses, such as avoidance or panic reactions. The context in which the sound is received by an animal affects the nature and extent of responses to a stimulus. The threshold for elicitation of behavioural responses depends on received sound level, as well as multiple contextual factors such as the activity state of animals exposed to different sounds, the nature and novelty of a sound, spatial relations between a sound source and receiving animals, and the gender, age, and reproductive status of the receiving animal.

5.3 Masking

Masking is the process by which the threshold of hearing for one sound is raised by the presence of another (masking) sound (Erbe and Farmer 1998, Erbe 2008, Erbe et al. 2016). This describes the reduction in audibility for one sound (termed 'signal') caused by the simultaneous presence of another sound (termed 'noise'). For this to occur, the sound must be loud enough, have similar frequency content to the signal, and must happen at the same time. Masking depends on the spectral and temporal characteristics of signal and noise and is reduced if the signal and noise are separated in time, frequency, or direction (space); it can occur if the noise happens shortly before or after the signal (forward and backward masking). The zone of masking can maximally be as large as the zone of audibility, as a faint noise might mask a faint signal. The masking effect can be reduced or remedied by various active or passive mechanisms for masking-release, such as spatial or temporal release from masking, the Lombard effect, or comodulation masking release.

Auditory masking can lead to disruption of a behaviour, lack of appropriate behavioural reactions, increased vulnerability to predators, reduced access to prey, reduced communication, changes in vocal behaviour, disruption of spawning activities, and stress. The biological significance of acoustic masking is directly linked to the duration of the masking sound. While masking can be detrimental to the fitness, reproduction, and survival of individuals, it ends immediately after the masking sound ceases. Both anthropogenic and natural marine sound can affect hearing and partially or completely reduce an individual's ability to effectively communicate; detect important predator, prey, and/or conspecific signals; and detect important environmental features associated with spatial orientation (Clark et al. 2009). This is true for all marine fauna; however, masking is most frequently associated with marine mammals. Masking in fishes has not been studied in detail.

5.4 Noise-induced threshold shift

Exposure to sufficiently intense sound may lead to an increased hearing threshold in any living animal capable of perceiving acoustic stimuli. If this shift is reversed and the hearing threshold returns to normal, the effect is called a temporary threshold shift. The onset of TTS is often defined as threshold shift of 6 dB above the normal hearing threshold (e.g., Southall et al. 2007). If the threshold shift does not return to normal, the residual shift is called a permanent threshold shift (PTS). Threshold shifts can be caused by acoustic trauma from a very intense sound of short duration, as well as from exposure to lower level sounds over longer time periods (Houser et al. 2017). Injury to the hearing apparatus of a marine animal may result from a fatiguing stimulus measured in terms of sound exposure level (SEL), which considers the sound level and duration of the exposure signal. Intense sounds may also damage the hearing apparatus independent of duration, so an additional metric of peak pressure (PK) is needed to assess acoustic exposure injury risk.

5.5 Mortality

In extreme cases, exposure to intense underwater sound may lead to mortality of an exposed animal. Mortality is either a direct effect of the exposure (in case of severe injury) or indirect if an animal is moderately injured. Data on sound-induced mortality in marine animals are scarce.

6 Species

The range of species considered in this technical appendix is based on the species listed in the *Keraudren Extension 3D Marine Seismic Survey Environment Plan, SO-91-BI-20006.01*. Species-information is often lacking, and taxonomic groups have been collectively considered instead.

6.1 Marine Invertebrates

Exposure to anthropogenic sound sources could have a direct consequence on the functionality and sensitivity of the sensory systems of marine invertebrates. The sensory organs involved in receiving underwater sound in this taxonomic group can be classified into three groups (Budelmann 1992b):

1. Superficial receptor systems on the body surface are receptors sensitive to water displacements, therefore mainly encoding hydrodynamic cues;
2. Internal statocyst receptor systems are found in a wide range of aquatic invertebrates. These are inertial gravity receptor systems that may function as acoustic particle motion detectors and thus play a role in underwater hearing (Budelmann 1992b) or substrate-borne vibrations (Cohen et al. 1953, Cohen 1955);
3. Chordotonal organs are proprioceptive receptors that monitor joint movement, the direction of movement, and static position. These organs are sensitive to oscillation of the water column surrounding it (Budelmann 1992a).

Numerous studies have investigated the effect of sound on marine invertebrates but have been conducted in confined environments that make it difficult to control and assess the acoustic conditions.

Moreover, by measuring and reporting only the pressure component of sound, the results are of reduced relevance for assessing any observed effects.

6.1.1 Plankton

Parry et al. (2002) studied the abundance of plankton after exposure to airgun sounds but found no evidence of mortality or changes in catch-rate on a population-level.

The effects of impulsive sound on fish eggs and larvae were investigated in the context of offshore pile driving. Bolle *et al*. (2012) investigated the risk of mortality in common sole larvae by exposing them to impulsive stimuli in an acoustically well-controlled study. Even at the highest exposure level tested, at an SEL of 206 dB re 1 μPa²·s (corresponding to 100 strikes at a distance of 100 m) no statistically significant differences in mortality was found between exposure and control groups.

Contrary to other studies, McCauley et al. (2017) found that after exposure to airgun sounds generated with a single airgun (150 in³) zooplankton abundance decreased and mortality in adult and larval zooplankton increased two- to threefold when compared with controls. In this first large-scale field experiment on the impact of seismic activity on zooplankton, they used a sonar and net tows to measure the effects on plankton. They determined a maximum effect-range of horizontal 1.2 km. Their findings contradicted the conventional idea of limited and very localised impact of intense sound in general, and seismic airgun signals in particular, on zooplankton. Their results indicated that there may be noise-induced effects on these taxa and that these effects may even be negatively affecting ocean ecosystem function and productivity. The study was compromised by methodological design of the study (small sample sizes, large daily variability in the baseline and experimental data) and the statistical robustness of the data and conclusions (large number of speculative conclusions that appear inconsistent with the data collected over a two-day period). The lead author stressed that even though their conclusions were based on numerous assumptions, the combined likelihood of all measured parameters occurring without being correlated to the airgun survey is extremely low (McCauley, pers. comm.).

CSIRO (Richardson *et al*. 2017) simulated the large-scale impact of a seismic survey on zooplankton using the mortality rate found by McCauley *et al*. (2017). The aim of the CSIRO study was to estimate the spatial and temporal impact of seismic activity on zooplankton on the Northwest Shelf of Western Australian. The major findings of the CSIRO study were that there was substantial impact of seismic activity on zooplankton populations on a local scale within or close to the survey area, however, on a regional scale the impacts were minimal and were not discernible over the entire Northwest Shelf Bioregion. The study found that the time for the zooplankton biomass to recover to pre-seismic levels inside the survey area, and within 15 km of the area, was only three days following the completion of the survey. This relatively quick recovery was due to the fast growth rates of zooplankton, and the dispersal and mixing of zooplankton from both inside and outside of the impacted region (Richardson *et al.* 2017). Though the CSIRO model was based on a hypothetical 3D survey of 2,900 km² in size and over a 35-day period it is seen as being applicable for this impact assessment based on the following:

+ The CSIRO model was designed to model potential impacts to plankton on the Northwest Shelf where the Keraudren seismic survey will take place;
+ Richardson *et al.* (2017) showed that zooplankton communities can begin to recover during the seismic survey, during periods of good oceanic circulation, or “bottom out” at a maximum impact level (presumably where growth rates and/or zooplankton entering the survey area roughly approximate mortality rates) after 23 - 30 days of commencement of survey operations.

Popper *et al*. (2014) has published exposure guidelines for fish eggs and larvae which are based on pile driving data. Based on the available data, Popper *et al*. (2014) proposed a precautionary threshold for mortality of fish eggs and larvae of >207 dB re 1 μPa PK, which the authors note is likely to be conservative.

Fields et al. (2019) exposed zooplankton (copepods) to seismic pulses at various distances up to 25 m from a seismic source. The source levels produced were estimated to be 221 dB re 1 μPa².s, comparable to the far-field source levels associated with some commercial scale seismic surveys. The study observed an increase in immediate mortality rates of up to 30% of copepods in samples compared to controls at distances of 5 m or less from the airguns. Mortality one week after exposure was significantly higher by 9% relative to controls in the copepods placed 10 m from the airguns. Fields *et al*. (2019) also reported that no sublethal effects occurred at any distance greater than 5 m from the seismic source. The findings of the study indicate that the potential effects of seismic pulses to zooplankton are limited to within approximately 10 m from the seismic source. Fields *et al*. (2019) also note that the findings of the McCauley *et al*. (2017) study are difficult to reconcile with the body of other available research and may, therefore, provide an overly conservative estimate of the potential effects of seismic pulses to zooplankton.

6.1.2 Bivalves and decapods

There are indications that New Zealand scallop (*Pecten novaezelandiae*) larvae exposed to extended periods of airgun signals during their ontogeny may be negatively affected as reported by Aguilar de Soto et al. (2013). The authors found an increase in abnormality and mortality rates in scallop larvae after continued exposure to playbacks of intense airgun signals in a laboratory experiment. These results indicated that there may be species-specific differences in sensitivity of early life stages to sound exposure.

In a laboratory study, Przeslawski et al. (2016) focused on potential short-term impacts of marine seismic surveys on scallops in the Gippsland Basin. Commercial scallops (*Pecten fumatus*) were not abundant in the study area, and there was no evidence of mortality or change in the condition of scallops two months after a marine seismic survey ended. Analysis of images and samples revealed site-specific variance in scallop abundance, size, condition, and assemblages were higher than the observed effects from exposure. The analysis of the acoustic parameters, however, is likely compromised by the erroneous use of acoustic modelling methods.

Day et al. (2016) conducted a study on the effects of exposures of southern rock lobster (*Jasus edwardsii*) and scallop to impulsive noise produced by an airgun. Their study used field and laboratory experimental approaches to investigate potential impacts of marine seismic surveys on these species. Their field study used a real airgun and had better control over the relevant experimental parameters than other reported studies. Accordingly, their results are more relevant than those obtained under laboratory conditions with animals exposed to simulated signals.

It is likely that particle motion and interface waves are the more relevant stimulus. Day et al. (2016) provide a regression of particle acceleration versus range for the single 150 in^3 airgun used in the study and showed that acceleration at the 10 and 100 m ranges were typically 26 and 5 ms^{-2}, respectively. The study also references an unpublished maximum particle acceleration measurement of 6.2 ms^{-2} from a 3130 in^3 airgun array at 477 m range in 36 m of water.

Consistent with other studies of high-intensity, low-frequency sound exposure of crustaceans and molluscs (reviewed by Edmonds et al. 2016, Carroll et al. 2017), the study found no evidence of mass mortality directly following airgun exposure. Consequently, the authors rejected the hypothesis that exposure to seismic airguns causes immediate mass mortality.

Unlike other studies, this study uncovered a few issues concerning long-term health and ecology. Two reflex behaviours, tail tonicity or extension and righting behaviour, were assessed. These reflexes have been used in lobster fishery industries in grading animals for their likelihood of survival. While results for tail tonicity were inconclusive, there was a significant response to exposure in the righting response, which is a more complex reflex requiring neurological control and muscle coordination.

No specific studies have focussed on the effects of seismic sources on pearl oysters (*Pecten maxima)*, however, studies on the impacts of underwater explosions on several species of bivalve, including two pearl oyster species, indicated strong resilience to the shock waves created by the detonation of explosives underwater. LeProvost *et al*. (1986) found that no mortality occurred in the exposed animals over a 13-week period and at a minimum exposure range of 1 m from the blast centre. Extrapolating this finding to seismic sources would suggest even less impact on bivalves than explosives, that is, it is likely that bivalves would have to be within a very close range of a seismic source to experience pathological damage or mortality – available evidence would suggest ~1 to 2 m. These studies do not offer any insights as to the distances at which sub-lethal effects (such as morphological, biochemical and physiological changes being indicators of some level of stress in an animal) could occur.

6.1.3 Squid

André et al. (2011) and Solé et al. (2013) provide evidence of acoustic trauma in four cephalopod species (*Sepia officinalis, Octopus vulgaris, Loligo vulgaris*, and *Illex condietii*), which they exposed (under water) for 2 h to low-frequency sweeps between 50–400 Hz (1 s duration) generated by an in-air speaker. The received level at the animals' position was 157 dB re 1 µPa with peak levels (unspecified) up to 175 dB re 1 µPa. Both studies reported permanent and substantial morphological and structural alterations of the sensory hair cells of the statocysts following noise exposure, with no indication of recovery. In a recent experiment, Solé et al. (2017) exposed common cuttlefish (*Sepia officinalis*) to tonal sweeps between 100–400 Hz in a controlled exposure experiment in open water. Their results showed a clear statistical relationship between the cellular damage detected in the sensory cells of the individuals exposed to the sound sweeps and their distance from the sound source. The authors measured the particle motion and pressure of the signals received by the animals, but due to the signal type (frequency sweep), they only provided the maximum received levels or an estimate thereof, respectively; the maximal particle motion level was 0.7 ms^{-2} observed at 1 m depth, the pressure reached levels of 139–142 dB re 1 μPa^2. The reported sound pressure levels were only slightly higher than the hearing threshold determined for longfin squid (*Loligo pealeii*) measured by Mooney et al. (2010). The maximum particle motion (reported in terms of particle acceleration) reported by Solé et al. (2017) is in the same order of magnitude as the behaviourally thresholds measured at 100 Hz by Packard et al. (1990) using a standing wave acoustic tube.

6.1.4 Benthic species

Many marine invertebrates are permanently in contact with bottom sediment. The sediment, however, does not follow exactly, or at all, the movement of the surrounding water. Therefore, exposure to underwater sound will result is in a relative movement between the body of these animals and the oscillating water column. Accordingly, it is important to also consider the propagation of vibration through the ground. For benthic organisms, this type of vibration is likely of similar or greater importance than the water-borne vibration or even the compressional component of a sound (Roberts and Elliott 2017). The published scientific information on vibration sensitivity in marine invertebrates is extremely scarce (Roberts et al. 2015, Roberts et al. 2016). Only a small number of studies have indicated reception of vibration and behavioural responses in bivalves, which include the closure of the syphons and, in more active molluscs, movement away from the substrate (Mosher 1972, Ellers 1995, Kastelein et al. 2008). To date, there is no convincing evidence for any significant effects induced by non-impulsive noise in benthic invertebrates. Moreover, given the rapid attenuation of vibrational signals beyond the near-field of a sound source (Morley et al. 2014), it is unlikely that these stimuli are causing more than behavioural effects (e.g., flight or retraction) or physiological (e.g., stress) responses.

From 2013–2015, a long-term study evaluated the acoustic impacts from seismic exposure on scallops in Australia (Day *et al*. 2016b, 2017). The experimental field research maintained the scallops in mesh enclosures while a vessel with the acoustic source passed close to the animals. Seismic sound exposure did not cause mass mortality of scallops during the experiment; however, repeated exposure (i.e. more than one pass of the airgun) where maximum exposure levels were in the range of 181 to 188 dB re 1μPa^2.s SEL (191 to 213 dB re 1µPa peak-peak SPL) was considered to possibly increase the risk of mortality (Day *et al*. 2016a, 2016b).

Though Day *et al*. (2016b) recorded increased mortality with repeated exposure to a seismic source, it has not been established as to whether this was due to the seismic source exposure or other mechanism related to the study design (Przeslawski *et al*. 2016). Using a precautionary approach, if the increased mortality was due to the seismic source then the increased mortality identified translates to an annual increase of between 9.4% and 20%. These fall towards the low end of what might be expected when compared with natural mortality rates in wild scallop populations, which range from 11-51% with a six year mean of 38% (Day *et al*. 2016b).

Scallops exposed to repeated seismic sound suffered physiological damage with no signs of recovery over the four-month period; suggesting potentially reduced tolerance to subsequent stressors. In addition, changes in behaviour and reflexes during and following seismic exposure were observed. Day *et al*. (2016a, 2016b) however cautioned that it was unclear from the study whether the observed physiological (and behavioural) impairments would result in mortality beyond the timeframes considered in their study.

Przeslawski et al. (2018) concluded that there was no evidence of increased scallop mortality, or effects on scallop shell size, adductor muscle diameter, gonad size, or gonad stage due to the seismic sound from an actual seismic survey. The authors concluded that the study provided no clear evidence of adverse effects on scallops, fish, or commercial catch rates due to the 2015 seismic survey undertaken in the Gippsland Basin. Przeslawski et al. (2018) further concluded that the study provided a robust and evidence-based assessment of the potential effects of a seismic survey on some fish and scallops.

There is limited published literature on the potential impacts of seismic noise on hard and soft corals, and unlike other faunal groups, currently there are no peer-reviewed criteria against which potential noise impacts to coral can be assessed.

Heyward *et al.*, 2018 monitored scleractinian corals, primarily plate corals in families Agaracidae and Acroporidae, and soft corals *in situ* before, during and after a 3D seismic survey. There were no detectable impacts on scleractinian coral mortality, skeletal damage or visible signs of stress immediately after and up to four months following the 3D marine seismic survey. Similarily, there was no evidence of a behavioural response, such as polyp withdrawal or flaccidity in soft corals such as *Lobophytum* spp.

6.2 Fishes

Although hearing ranges and sensitivities vary substantially between species (e.g., Ladich and Fay 2013), all fish species tested to date can hear (Dale et al. 2015). Fishes have developed two sensory mechanisms for detecting, localising, and interpreting underwater sounds and vibrations: the inner ear, which is tuned to sound detection, and the lateral line system, which allows a fish to detect vibration and water flow. Inter-specific variations in hearing range and sensitivity result from the different adaptations in these systems for perceiving sound pressure and particle motion information (Popper and Fay 2011).

Sensitivity to sound pressure seems to be functionally correlated in fishes to the presence and absence of gas-filled chambers in the sound transduction system. These enable fishes to detect sound pressure and extend their hearing abilities to lower sound levels and higher frequencies (Ladich and Popper 2004, Braun and Grande 2008). Based on their morphology, Popper et al. (2014) classified fishes into three animal groups comprising (1) fishes with swim bladders whose hearing does not involve the swim bladder or other gas volumes (e.g., some species of tuna, *Thunnus sp.*, or Atlantic salmon, *Salmo salar*); (2) fishes whose hearing does involve a swim bladder or other gas volume (e.g., Atlantic cod, *Gadus morhua*, or herring, *Clupea harengus*); and (3) fishes without a swim bladder (e.g., sharks) that can sink and settle on the substrate when inactive (Popper et al. 2014, Carroll et al. 2017).

Based on their morphology, the Popper *et al*. (2014) classifications can be assigned to the following families or species of fish, common in Australian waters:

+ Fishes with swim bladders or other gas volumes, but whose hearing does not directly involve the swim bladder, e.g., snappers, emperors, groupers and rock cods (Lutjanids and Lethrinids such as *Pristipomoides* spp., *Lethrinus* spp., *Lutjanus* spp., and family Serranidae), and some species of tuna (*Thunnus* sp.) (Tavolga and Wodinsky 1963, Bertrand and Josse 2000, Higgs et al. 2006, Song et al. 2006, [DoN] Department of the Navy (U.S.) 2008, Braun and Grande 2008, Engineering-Environmental Management 2008, Caiger et al. 2012);
+ Fishes whose hearing does directly involve a swim bladder or other gas volume e.g., family Clupeidae (herrings, sardines, pilchards and shads), family Gadidae (true cods such as whiting), and potentially some nearshore / reef species relevant to tropical Australia, including some Pomacentridae (damsel fishes and clown fishes), some Holocentridae (soldierfishes and

squirrelfishes) and some Haemulidae (grunters and sweetlips) (Nedwell et al. 2004, Braun and Grande 2008, Popper et al. 2014); and

+ Fishes without a swim bladder (e.g., mackerel, *Scomberomorus* spp., some species of tuna, *Thunnus* sp, and sharks, including whale sharks, *Rhincodon typus*) (Casper *et al*. 2012, Popper *et al*. 2014, Carroll *et al.* 2017).

Most fishes are primarily sensitive to particle motion effects, while fishes with hearing that involves the swim bladder are also sensitive to sound pressure (Popper and Hawkins 2019, Popper et al. 2019). The most relevant metric for perceiving underwater sound for most fish species is, therefore, particle motion but, with the exception of few species (Popper and Fay 2011; Popper *et al*. 2014), there is an almost complete lack of relevant data on particle motion sensitivity in fishes (Popper and Hawkins 2018).

The majority of fish species detect sounds from below 50 Hz up to 500-1500 Hz. A smaller number of species can detect sounds to over 3 kHz, while a very few species can detect sounds to well over 100 kHz. The critical issue for understanding whether an anthropogenic sound affects hearing is whether it is within the hearing frequency range of a fish and loud enough to be detectable above threshold. For the sake of this impact assessment, it is assumed that all fishes can detect signals below 500 Hz and so can 'hear' the seismic source.

The Working Group on the Effects of Sound on Fish and Turtles undertook a review of experimental findings of sound on fishes. In their American National Standards Institute (ANSI) accredited report (Popper *et al*. 2014) they presented sound exposure guidelines for different levels of effects for different groups of species), for three types of immediate effects:

+ Mortality, including injury leading to death;

+ Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma; and

+ Temporary threshold shift (TTS).

In the absence of any qualitative scientific information, acoustic masking of signals and behavioural effects caused by the reception of seismic sounds are assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds.

6.2.1 Behaviour

The sound-related factors influencing behavioural reactions in fishes can include its frequency content, intensity above background noise and temporal sound characteristics. If exposed to the same stimulus over a prolonged period, an initial behavioural reaction might fade as the fish's habituate to the sound. Behavioural reactions that are usually observed in fishes in response to sound are dispersion, directed movements away from the sound source (leaving the area of the noise source, aggregation and descending closer to the bottom), startle response (fast start escapes, C-start response) at sound onset (Akamatsu *et al*. 1996; Wardle *et al*. 2001; Slotte *et al*. 2004; Woodside 2007). Effects can be acute (such as acoustic masking), or chronic (including altered distribution), lasting from the immediate duration of sound exposure to several days or weeks if fishes are displaced from their preferred areas during a survey (Engås *et al*. 1996; Slotte *et al*. 2004; Løkkeborg *et al*. 2012a,b; Streever *et al*. 2016).

The onset level of behavioural responses in fishes varies greatly between and within species, including between fishes of different ages and sizes, the behavioural and social context, and the motivation of the fishes. Existing data on behavioural responses do not provide a clear dose-response relationship and, consequently, it is currently impossible to determine single value thresholds for the onset of behavioural reactions. Instead, broad response and effect categories such as those proposed by Popper et al. (2014) seem most reasonable and may guide regulatory decisions in this context.

Strong 'startle' responses have been observed in some fish species at received sound levels of 200-205 dB re 1 µPa, indicating that sounds at or above this level may cause more severe behavioural reaction such as avoidance. Sound levels of this intensity are likely to occur 100 to 300 m from an acoustic array. Based on this, an approximate range of 200 m was estimated as the minimum distance at which fish may start avoiding the approaching seismic source (McCauley 1994). Wardle *et al*. (2001) documented that schooling reef fish swam past a seismic source array at received levels that would be received at about 20 m below a survey array consisting of 30 airguns.

Pearson *et al*. (1992) showed that that exposure to airgun sound can cause changes in schooling patterns and distribution. Løkkeborg *et al*. (2012a, b) found changes in catch rates of fish species in Norwegian waters, indicating that these species all responded to airgun sounds. However, they also showed that gillnet catches were doubled for some fish species during seismic surveying and only longline catch rates fell slightly. Except for one species, they did not find any changes in abundance or displacement from fishing grounds. Hawkins *et al*. (2014) used synthetic impulsive signals in a behavioural response study; they documented that sprat and mackerel reacted to the impulsive sound exposure generally by dispersal and depth changes (which would make it difficult to detect the true scope of effects in a study relying on fisheries technology).

Santulli *et al.* (1999) exposed caged European sea bass (a demersal species) to a 2,500 cubic inch seismic source. Limited response was observed at 2.5 km distance, a startle response was observed when the array was at a distance of approximately 800 m, but after passing within 180 m, fish behaviour appeared to return to normal within one hour. Increased biochemical stress levels were measured in some fish following exposure, returning to normal levels within 72 hours of exposure. It is noted that exposures of fish in the wild would likely result in avoidance of high sound levels prior to the seismic source approaching to as close a range and to as high sound levels as the captive fish in the experiment were exposed to.

The most recent relevant study on how the behaviour of fishes exposed to seismic signals changed is Woodside's Maxima 3D survey at Scott Reef (Woodside 2011a, 2011b; Miller and Cripps 2013). The behavioural observations of free-swimming fish conducted in these studies show that seismic airgun emissions did not cause lethal or sub-lethal effects on fish near the operating array. At close range, the vessel approach caused fishes to cease their behaviours and move towards the seabed, but the effect was short-lived, and fishes began to feed and behave normally again within 20 minutes after the passage of the seismic survey vessel. Caged fishes displayed startle responses too infrequently to analyse. However, agitation levels increased with increasing received sound exposure level for the three holocentrid species (squirrelfishes and soldierfishes, *Holocentroidei*) but were not detectable for the blue-stripe sea perch (*Lutjanus kasmira*). Sonar observations of free-swimming fishes indicated that individual animals tended to move towards the seabed on approach of the operating airgun array, consistently out to 400 m either side of the survey test line. Schools of fishes moved towards the seabed within 200 m of the survey test line in response to the passage of the operating seismic source and stayed significantly closer to the seabed up to 63 minutes post-exposure. The vocal behaviour of fishes was unaffected from the seismic activity; fish choruses remained unchanged with regards to timing and chorus level (at daily, lunar and seasonal scales); these findings suggest that in the long term the survey had little effect on the fish that produced the choruses. Visual census revealed that diversity and abundance of both Pomacentridae (damselfishes and clownfishes) and non-Pomacentridae fish species (inhabtiting shallow-slope regions) showed no significant changes after the seismic survey compared to the long-term temporal trend before the survey. Analysis of recordings from baited remote underwater video stations showed no detectable effects of the seismic survey on the diversity and abundance of deeper water fish communities at the spatial and temporal scales examined. Also, there were no signs of loss of individuals or of systematic re-distribution of individuals and species at any of the time scales examined.

The findings from the research at Scott Reef support those by Wardle *et al*. (2001), who exposed free ranging marine fish inhabiting an inshore reef to sounds from a seismic source (maximum received levels (RL) of 195-218 dB re 1 μPa PK). The study found that fishes exhibited a startle response to all received levels, but no avoidance behaviour were observed, they showed no signs of moving away from the reef and exposure to the seismic noise did not interrupt a diurnal rhythm of fish gathering at dusk. Slight changes were recorded to the long-term day-to-night movements of two tagged pollack (*Pollachius sp.*), particularly when positioned within 10 m of their normal living positions. However, the seismic sound had little effect on the day-to-day behaviour of the resident fishes and invertebrates.

Fewtrell and McCauley (2012) showed that fishes tended to remain lower in the water column and/or swim faster and form tighter schools during periods of close air-gun emissions.

Fish populations can be further impacted if behavioural responses result in deflection from migration paths, feeding grounds or disturbance of spawning, thereby affecting recruitment of fish stocks. Available evidence suggested that behavioural changes for some fish species are insignificant and short-lived; the duration of effect is less than or equal to the duration of exposure and is expected to vary between species and individuals and be dependent on the properties of received sound (DFO 2004). Such a temporary, short range displacement of pelagic or migratory fish populations would have insignificant repercussions at a population level (McCauley 1994); and for site-attached reef fish, spatial patterns of species richness, abundance and diversity does not change after airgun noise emissions (Woodside 2007; Miller and Cripps 2013). The ecological significance of such effects is expected to be low, except where they may influence reproductive activity. However, researchers have observed that once acoustic disturbances are removed, fish return to normal behaviour within about an hour (McCauley *et al*. 2000; Pearson *et al*. 1992; Wardle *et al*. 2001). In conclusion, it is evident that behavioural reactions can occur to seismic airguns, but at this point there are no data that can be applied to develop guidelines.

6.2.2 Acoustic Masking

Masking impairs an animal's hearing impairment with respect to the relevant biological sounds normally detected within the environment and can have long lasting effects on survival, reproduction and population dynamics of fishes. The consequences of masking for fishes, however, have not been sufficiently examined to allow a thorough assessment of effects caused in the context of this survey. Popper *et al*. (2014) surmised that "*It is likely that increments in background sound within the hearing bandwidth of fishes and sea turtles may render the weakest sounds undetectable, render some sounds less detectable, and reduce the distance at which sound sources can be detected. Energetic and informational masking may increase as sound levels increase, so that the higher the sound level of the masker, the greater the masking*." If impulsive sounds are generated repeatedly by many sources over a wide geographic area there is a possibility that the separate sounds might merge and that the overall background noise be raised (Nieukirk *et al*. 2004). However, acoustic masking only occurs while the interfering sound is present, and therefore, masking resulting from a single pulse of sound (such as an airgun impulses) or widely separated pulses would be infrequent and not likely affect an individual's overall fitness and survival.

Temporary Threshold Shift (TTS)

The following is sourced from Popper *et al*. (2014):

> *"Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS has been demonstrated in some fishes, and its extent is of variable duration and magnitude. TTS results from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves innervating the ear (Smith et al. 2006; Liberman 2015). However, sensory hair cells are constantly added in fishes (e.g., Corwin 1981, 1983; Popper and Hoxter 1984; Lombarte and Popper 1994) and also replaced when damaged (Lombarte et al. 1993; Smith et al. 2006; Schuck and Smith 2009), unlike in the auditory receptors of mammals. When sound-induced hair cell death occurs in fishes, its effects may be mitigated over time by the addition of new hair cells (Smith et al. 2006, 2011; Smith 2012, 2015).*
>
> *After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure (e.g., Popper and Clarke 1976; Scholik and Yan2001, 2002a, b; Amoser and Ladich 2003; Smith et al. 2004a, b, 2006, 2011; Popper et al. 2005, 2007). While experiencing TTS, fishes may have a decrease in fitness in terms of communication, detecting predators or prey, and/or assessing their environment."*

McCauley *et al*. (2003) demonstrated that exposure to repeated emissions of a single airgun (SL (source level) of 222.6 dB re 1µPa PK-PK) from 5 to 15 m at the closest approach caused extensive damage to the sensory hair cells in the inner ear of caged pink snapper (*Pagrus auratus*). Although no mortality was observed, the damage was severe with no evidence of repair or replacement of damaged sensory cells up to 58 days post-exposure. However, the study did not investigate the effects on fish hearing. The study acknowledged that the fish were caged and therefore not able to swim away from sound source, and that the monitoring video suggested the fish would have fled the sound source if possible. The authors of the study also acknowledged that the impact of exposure on ultimate survival of the fish was not clear.

As part of Woodside's Maxima 3D MSS, an extensive field study was undertaken at Scott Reef. A component of this study investigated the potential physical, physiological and behavioural noise-induced effects on fish assemblages. The results showed statistically more damage to the hearing in blue-stripe sea perch (*Lutjanus kasmira*) exposed to the seismic impulses than in control fishes. However, the damage found in these fishes was marginal, and—assuming a direct relationship between hair cell density and hearing capability—a negligible effect on the fishes' hearing capability. The damage was monitored through time out to 58 days post seismic exposure and did not increase significantly through time, with almost zero damage detected by 58 days (McCauley 2008).

A study of auditory sensitivity in four species of tropical reef fishes following exposure to emissions from the 2,055 in^3 array showed that none of the four species, including the pinecone soldierfish (a species with expected to have good hearing sensitivity) experienced any hearing sensitivity loss (i.e. TTS) following exposure to SEL_{cum} up to 190 dB re 1 $\mu Pa^2 \cdot s$ (Hastings *et al*. 2008; Hastings and Miksis-Olds 2012). No detectable gross physiological damage was found in individuals from any of the seven species (McCauley and Kent 2012). The results of the hearing tests are consistent with the sound exposure guidelines proposed in Popper *et al*. (2014), which indicated that TTS may occur at SEL_{cum} levels >186 dB re 1 $\mu Pa^2 \cdot s$ while other studies (Popper and Hastings 2009; Song *et al*. 2008) indicate that TTS may occur at levels as high as SPL 205-210 dB re 1μPa (PK).

Mortality/potential mortal injury

With regard to seismic noise induced mortality in fishes Carroll et al. (2017) conclude that "For fish, there are few data on the physical effects of seismic airguns (e.g. mortality, barotrauma), and of these none have shown mortality." Fishes in open water can move away from an approaching seismic source which reduces the potential for mortality or mortal injury. Bottom-dwelling fish that show greater site attachment may be less inclined to flee from a seismic sound source and experience greater effects.

Other than physiological stress responses or hearing loss, no other physical damage to adult fish or invertebrates have been directly attributed to exposure to airgun discharges, even at close proximity (NSW DPI 2014). It should be noted that some reports of physical damage arise from studies undertaken using explosions and other high-pressure sound waves, and not from air-gun emissions that generate a lower maximum pressure and pressure change (Popper and Hastings 2009).

Bony fish apparently have the ability to regenerate the sensory cells in their hearing system to a fully functional state within weeks after a detrimental exposure. The processes involved in the recovery are not fully understood, and there is conflicting evidence from sound exposure studies, such as McCauley et al. (2003). These findings could also suggest that the process of sensory hair cell death and regeneration is species-specific.

Recovery processes take a few days to a few weeks (Scholik and Yan 2001, Mackenzie and Raible 2012), and the time course for recovering from hearing loss likely depends on the species, its normal hearing sensitivity, the sound exposure intensity and duration, and the amount of sensory epithelial damage (Smith and Monroe 2016). Noise-induced PTS has not been reported for fishes yet, which may be explained by their apparent ability to recover hair cells.

Exposure to excessive levels of any type of underwater sound can kill and injure fishes (Carlson and Johnson 2009). Impulsive sounds, with rapid changes in pressure, are more damaging to tissues than gradual changes (Popper et al. 2014).

Injurious effects caused by rapid pressure changes within the body are called 'barotrauma' (Stephenson et al. 2010, Halvorsen et al. 2011, Halvorsen et al. 2012b). The range of barotrauma effects in fishes mostly depends on the temporal pattern of the pressure changes and the physiological state of the exposed fishes (Stephenson et al. 2010, Halvorsen et al. 2012a, Halvorsen et al. 2012b); they range in severity from damages with full recovery to lethal injury (McKinstry et al. 2007).

Casper et al. (2012) showed that fishes can recover from less severe injuries under laboratory conditions, suggesting that minor injuries not inevitably lead to mortality. Nevertheless, in open waters, they have the potential to reduce the animal's fitness to the extent that its ability to find food decreases and its risk of being predated increases (Halvorsen et al. 2011, Halvorsen et al. 2012b).

Mortality is either a direct effect of barotrauma (in the case of severe injury) or indirect if an animal is moderately injured. Data on sound-induced mortality in fishes are scarce and mainly related to underwater explosions (see review by Popper and Hastings 2009). California Department of Transportation (2001) documented fish mortality near underwater pile driving. There is no evidence for fish mortality caused by exposure to other sound sources such seismic airguns, dredging, or vessel noise (Normandeau Associates Inc 2012).

Whale sharks have not been tested for their auditory sensitivity or susceptibility to noise-induced effects. Like all elasmobranchs, they are lacking a swim bladder and have no air-filled chambers or accessory morphological structures to their hearing system that could serve as hearing specialisations. Accordinlgy, similar to other shark species, they can be considered to have relatively insensitive hearing and less likely to be negatively affected by intense underwater sound.

6.3 Fishing

Scientific evidence of acoustic impacts on fish catches are somewhat equivocal because of the lack of determination between natural movements and changes in fish abundance. One comprehensive study (Engås *et al.* 1996) observed cod and haddock moving back within an area 3-5 days after seismic survey exposure. Similarly, Slotte *et al.* (2004) observed westward movement of large masses of blue whiting and herring towards and into the survey area 3-4 days after seismic shooting, indicating that migrations proceeded as normal soon after a seismic survey. Therefore, any disruptions would likely be short-term and during the survey, with conditions returning to 'normal' levels soon after.

Studies undertaken by Lokkeborg *et al.* (2012a, b) demonstrated that gillnet catches increased substantially for redfish (86% increase) and Greenland halibut (132% increase) during seismic shooting on a Norwegian fishing ground. However, longline catch rates fell (16% for Greenland halibut, 25% for haddock). These contrary results were explained by greater swimming activity versus lowered food search behaviour in fish exposed to air-gun sound emissions. Although catch rates changed in all species studied (including saithe and ling), except for saithe, acoustic mapping of fish abundance did not suggest displacement from fishing grounds.

Not all results from studies have resulted in behavioural alteration. Feeding Atlantic herring (*Clupea harengus*) schools off northern Norway showed no changes in swimming speed, direction or school size in response to a transmitting seismic vessel as it approached from a distance of 27 km to 2 km, over a 6-hour period (Peña *et al.* 2013). As fishing areas are large and commercial fish species are free-swimming, if fish are 'scared' temporarily from an area, based on evidence presented, it is likely they will be displaced temporarily to another area still within the fishing zone and so able to be caught.

A recent critical review of the potential impacts of marine seismic surveys on fish and invertebrates (Carroll et al. 2017) found that other studies on fish have positive, inconsistent, or no effects from seismic surveys on catch rates or abundance. A desktop study of four species (gummy shark, tiger flathead, silver warehou, school whiting) in Bass Strait, Australia, found no consistent relationships between catch rates and seismic survey activity in the area, although the large historical window of the seismic data may have masked immediate or short-term effects which cannot therefore be excluded (Przeslawki et al. 2016). A subsequent desktop study targeting a single seismic survey in 2015 found that catch rates in the six months following the seismic survey were different than predicted in nine out of the 15 species examined. Across two fishing gear types, six species indicated increases in catch after the seismic survey, and three species indicated decreases in catch. The authors concluded that "These results support previous work in which the effects of seismic surveys on catch seem transitory and vary among studies, species, and gear types" (Przeslawski et al. 2016).

The body of peer-reviewed literature does not indicate any long-term abandonment of fishing grounds by commercial species, with several studies indicating that catch levels returned to pre-survey levels after seismic activity had ceased (Carroll et al. 2017).

6.4 Sharks

Limited research has been conducted on shark responses to marine seismic surveys. Myrberg (2001) stated that sharks differ from bony fish in that they have no accessory organs of hearing such as a swim bladder and therefore are unlikely to respond to acoustical pressure. The study also suggested that the lateral line system does not respond to normal acoustical stimuli and is unable to detect sound-induced water displacements beyond a few body lengths, even with large sound intensities (Myrberg, 2001). Other reports indicate that sharks are highly sensitive to sound between approximately 40 and 800 Hz, which overlaps with seismic sound frequencies. Klimley and Myrberg (1979) established that an individual shark will suddenly turn and withdraw from a sound source of high intensity (more than 20 dB re 1 µPa above broadband ambient SPL) when approaching within 10 m of the sound source.

6.5 Sea turtles

Morphological studies of green sea turtles (*Chelonia mydas*) and loggerhead sea turtles (*Caretta caretta*) (Ridgway et al. 1969, Wever 1978, Lenhardt et al. 1985) found that the turtle ear is similar to other reptile ears but has adaptations for underwater listening. In-air electrophysiological and behavioural studies on green and loggerhead sea turtles found their hearing frequency range is approximately 50–2000 Hz, with highest sensitivity to sounds between 200 and 400 Hz (Ridgway et al. 1969, Bartol et al. 1999, Ketten and Bartol 2005, Bartol and Ketten 2006, Yudhana et al. 2010, Piniak et al. 2011, Lavender et al. 2012, 2014).

Underwater audiograms are only available for three species, all of whom have poor hearing sensitivity. Two of these species, the red-eared slider (*Trachemys scripta elegans*, semi-aquatic) (Christensen-Dalsgaard et al. 2012) and the loggerhead turtle (Martin et al. 2012), demonstrated highest sensitivity at around 500 Hz (Willis 2016). Piniak et al. (2016) found that green turtles have maximum underwater sensitivity between 200 and 400 Hz. Very little research has been performed on the hearing capabilities of hawksbill turtles (*Eretmochelys imbricate)*. Yudhana et al. (2010) measured auditory brainstem responses from two hawksbill turtles in Malaysia and found that peak frequency sensitivity occurred at 457 Hz in one turtle and at 508 Hz in the other.

There is no robust information on the susceptibility of sea turtles to noise-induced effects. Most studies researching the effect of seismic noise on sea turtles focused on behavioural responses, as physiological impacts are more difficult to observe in living animals. Turtles avoid low-frequency sounds (Lenhardt 1994) and sounds from an airgun (O'Hara and Wilcox 1990), but these reports did not note received sound levels. Moein et al. (1995) found that penned loggerhead turtles initially reacted to an airgun but then showed little or no response to the sound (habituated to it). Caged green and loggerhead sea turtles increased their swimming activity in response to an approaching airgun when the received SPL was above 166 dB re 1 µPa, and they behaved erratically when the received SPL was approximately 175 dB re 1 µPa (McCauley et al. 2000).

Injury/mortality/potential mortality impacts have not been reported to have occurred in turtles as a result of noise emissions during seismic surveys. Popper *et al.* (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}). However, Finneran et al. (2017) presented revised thresholds for turtle injury and hearing impairment, considering both PK and frequency weighted SEL, suggesting that PTS may occur in response to 204 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}) or 232 dB re 1 µPa (PK) and TTS may occur in response to189 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}) or 226 dB re 1 µPa (PK).

6.6 Cetaceans: mysticetes (baleen whales) and odontocetes (dolphins, sperm and beaked whales)

The sounds emitted by the seismic sources and vessels during the operation have the potential to cause effects in marine fauna present in the area. The type and severity of the effects depends on the sensitivity of the receiving individual and may be influenced by a variety of biological and physical factors.

The potential impacts of anthropogenic noise on marine mammals have been the subject of considerable research (see reviews by Nowacek et al. 2007; Southall et al. 2007; Weilgart 2007; Wright et al. 2007).

Southall et al. (2007), Finneran and Jenkins (2012) Wood et al. (2012), Finneran (2015) and more recently NMFS (2013, 2018) reviewed available literature to determine noise exposure criteria, determined based on the onset levels of non-recoverable permanent hearing loss (PTS) and temporary hearing threshold shift (TTS) in cetaceans. The NMFS (2018) criteria incorporate the best available science to inform assessment of PTS and TTS.

6.6.1 Hearing sensitivity

Current data and predictions show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity, as well as frequency band of hearing (Richardson et al. 1995, Wartzok and Ketten 1999, Southall et al. 2007). While hearing measurements are available for a small number of species based on captive animal studies, direct measurements of many odontocetes and all mysticetes do not exist. As a result, hearing ranges for many odontocetes are grouped with similar species, and predictions for mysticetes are based on other methods, such as anatomical studies and modelling (Houser et al. 2001, Parks et al. 2007, Tubelli et al. 2012, Cranford and Krysl 2015), vocalizations (see reviews in Richardson et al. 1995, Wartzok and Ketten 1999, Au and Hastings 2008), taxonomy, and behavioural responses to sound (Dahlheim and Ljungblad 1990)

To better reflect the auditory similarities between phylogenetically closely related species, but also significant differences between species groups among the marine mammals, Southall et al. (2007) assigned the extant marine mammal species to functional hearing groups based on their hearing capabilities and sound production. This division into broad categories was intended to provide a realistic number of categories for which individual noise exposure criteria were developed. These groups were revised by NMFS (2018), but the categorisation as such has proven to be a scientifically justified and useful approach in developing auditory weighting functions and deriving noise exposure criteria for marine mammals.

6.6.1.1 Functional hearing groups

Low-frequency (LF) cetaceans	This functional hearing group comprises all baleen whale species (mysticetes); to this date, there has been no direct measurement of hearing sensitivity in any of these species. Instead, vocalization frequency ranges have been used as a proxy to determine the range of hearing for these species. However, it has to be noted that vocalisation frequencies not necessarily represent the full extent of the frequency range of best hearing and therefore are a poor predictor of best hearing thresholds (Houser *et al*. 2017). In the complete absence of direct data on auditory sensitivity in any baleen whale species, behavioural reactions provide further insight into the sound perception capabilities and sensitivities of mysticetes. Reviews or new studies presenting data on behavioural reactions of mysticetes have been published by Nowacek *et al*. (2007, 2015). However, behavioural reactions are strongly contexted specific (Ellison *et al*. 2012) and are consequently also of limited use in delineating hearing ranges or even predicting hearing sensitivity.

	The existing data so far suggest that some species (e.g., blue whale, fin whale) having better low-frequency sensitivity and others (e.g., humpback whale, minke whale) having better sensitivity to higher frequencies. In another approach, anatomical data are used to predict hearing ranges in mysticetes (e.g., Parks *et al*. 2007; Manoussaki *et al*. 2008). Most recently functional models were developed focussing on different components of the hearing system (Tubelli *et al*. 2012; Cranford and Krysl 2015); in combination with anatomical data on the hearing system the audible frequency range of mysticetes – collectively treated as a single functional hearing group – is approximately between 10 Hz to 30 kHz.
Mid-frequency (MF) cetaceans	Based on the frequency range of their vocal emissions as well as the known hearing ranges, most dolphin species, all beaked whale species and the sperm whale belong to this functional hearing group. These species produce a wide range of whistles, clicks, pulsed sounds and echolocation clicks. The frequency range of their sounds excluding echolocation clicks are mostly <20 kHz with most of the energy typically around 10 kHz, although some calls may be as low as 100 to 900 Hz, ranging from 100 to 180 dB re 1 µPa (Richardson *et al*. 1995). The sounds produced are very complex and appear to be used for communication between members of a pod during socialising and feeding activities.
High frequency (HF) cetaceans	Porpoises, dwarf and pygmy sperm whales (*Kogia spp*.), river dolphins, as well as hourglass dolphins and Peale's dolphin produce narrow-band high-frequency echolocation signals. The few species out of this group which were tested for their hearing sensitivity have their best hearing sensitivity at higher frequencies and show a wider hearing range compared to all other cetaceans. Accordingly, this group of species have been collectively classified as high-frequency cetaceans.

Table 6-1: Marine mammal functional hearing groups and range (NMFS 2018)

Hearing group	Generalized hearing range
Low-frequency cetaceans (mysticetes or baleen whales)	7 Hz to 35 kHz
Mid-frequency cetaceans (odontocetes: dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
High-frequency cetaceans (other odontocetes: true porpoises, Kogia, river dolphins, cephalorhynchid, Hourglass dolphin, Peale's dolphin)	275 Hz to 160 kHz

6.6.2 Behaviour

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate sound exposure metric for assessing behavioural reactions. Southall et al. (2007) presented a severity-index ranking the intensity of behavioural responses that was later amended by Ellison et al. (2012), Miller et al. (Miller 2012), and Sivle et al. (2015).

NMFS currently uses a step function with a 50% probability of inducing behavioural responses at an SPL of 160 dB re 1 µPa to assess behavioural impact. This threshold value was derived from the HESS (1999) report, which, in turn, was based on the responses of migrating mysticete whales to an airgun sounds (Malme et al. 1983, Malme et al. 1984). The HESS team recognized that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above an SPL of 140 dB re 1 µPa. An extensive review of behavioural responses to sound was undertaken by Southall et al. (2007, their Appendix B). They found varying responses for most marine mammals between an SPL of 140 and 180 dB re 1 μPa, consistent with the HESS (1999) report, but a lack of convergence in the data prevented them from suggesting explicit step functions. Absence of controls, precise measurements, appropriate metrics, and context dependency of responses (including the activity state of the animal) all contribute to variability. In 2012, Wood et al. (2012) proposed a graded probability of response for impulsive sounds using a frequency weighted SPL metric. They also designated behavioural response categories for sensitive species (such as harbour porpoises, *Phocoena phocoena*, and beaked whales) and for migrating mysticetes (**Table 6-2**).

Table 6-2: Predicted probability of behavioural response in marine mammals as a function of frequency-weighted sound pressure level(SPL, dB re 1 μPa) (Wood et al. 2012); probabilities are not additive.

Marine mammal group	Probability of response to frequency-weighted SPL (dB re 1 μPa)			
	120	140	160	180
Sensitive species	50%	90%		
All other species		10%	50%	90%

McCauley *et al*. (2000a) monitored the effects of seismic survey sounds on humpback whales in the Exmouth Gulf region of Western Australia. They documented rapid swimming on the surface, breaching and localised avoidance behaviour by migrating whales during the seismic operation, indicating that the 'risk factor' associated with the MSS was confined to a comparatively short period and small range displacement. During their migration and breeding season, humpback whales rarely display deep dives. This tendency to stay close to the surface has been interpreted as actively utilising the 'sound shadow' (Lloyd's Mirror effect) near the surface; irrespective of the motivation for this behaviour, it reduces the risk for noise-induced effects unless at very short range from a large seismic source array.

A comparison of behavioural observations of humpback whale behaviour during seismic surveys shows the variability and context dependence of these responses (Richardson *et al*. 1995). McCauley *et al*. 2000a) estimated that humpback whales would avoid seismic surveys in key habitat (such as breeding, resting or feeding areas) at distances between 7 and 12 km, whereas migrating individuals generally showed an avoidance range of around 3 km. Some males have even been recorded approaching seismic survey vessels to within 1 to 2 km (McCauley *et al.* 2000a). It is considered that avoidance behaviour represents a temporary and minor effect, unless avoidance results in displacement of whales from breeding, resting or feeding areas.

Humpback whales migrating from winter breeding grounds to summer feeding grounds showed moderate avoidance of an active seismic source at received levels >140 dB re 1μPa²·s (SEL) only when they were within 3 km of the source. The magnitude of response was measured as change in migration speed and course deviation (Dunlop *et al*. 2017). These results indicate that the proximity of the sound source has to be considered as another factor with regard to behavioural reactions in this species.

Blackwell *et al*. (2015) found evidence for two behavioural thresholds in migrating bowhead whales responding to seismic operations in the Beaufort Sea. A moderate cessation or modification of vocal behaviour (interpreted as compensation behaviour) was found at received SEL over a 10-minute period of 94 dB re 1μPa²·s (increase of calling rates) and 127 dB re 1μPa²·s (decrease in calling rates). At received levels of >160 dB re 1μPa²·s, however, whales were completely silent. Robertson *et al*. (2013) detected changes in surfacing, respiration and diving behaviour of bowhead whales in response to seismic survey activity but did not provide any qualitative information on the received levels. Castellote *et al*. (2010) documented avoidance behaviour in fin whales in response to seismic survey activity in the Mediterranean Sea lasting over 10 days.

Observations of sperm whale behaviour during seismic surveys provided conflicting results: Stone (2003) identified that while sperm whales were frequently (visually) detected during seismic surveys, these animals did not show any observable behavioural reactions. Jochens *et al*. (2008) found sperm whales tolerant of seismic activity; however, a decrease in foraging activity was observed for a small number of animals but no horizontal avoidance was measured. In a tagging study, Jochens and Biggs (2003) found that sperm whales did not show any behavioural reaction (horizontal avoidance of the seismic vessel, change in feeding rates) at maximum received levels of 148 dB re 1µPa.

In the Gulf of Mexico, sperm whales were equipped with multisensory tags to investigate their behaviour in response to seismic surveys. The animals did not show any statistically significant changes in horizontal movement, diving and echolocation behaviour at received levels of approximately 118–131 dB re 1mPa²·s ($SEL_{M\text{-weighted}}$) (Miller *et al*. 2009).

The hearing of dolphins (MF cetaceans) is less sensitive in the low frequency range of airgun impulses (< 500 Hz) and seismic operators sometimes report dolphins and other small toothed whales near operating seismic source arrays. However, there is a component of seismic pulses in the higher spectrum and in general most toothed whales do show some limited avoidance of operating seismic vessels. Goold (1996) studied the effects of seismic surveys common dolphins (*Delphinus delphis*) in the Irish Sea. The results indicated that there was a local displacement of dolphins around the seismic operation. This observation is consistent with visual data compiled by Stone (2003) from marine mammal surveys in the North Sea that shows small toothed whale species tend to move away from operating compressed air seismic sources. In a review of behavioural effects of seismic surveys on marine mammals in UK waters Stone *et al*. (2003) reported that small odontocetes (dolphins, LF cetaceans and porpoises, HF cetaceans) showed the strongest avoidance response to the seismic survey activity, were seen less often during periods of seismic acquisition, remaining further from the airguns and showing altered behaviour (e.g. less bow-riding, orienting away from the survey vessel, faster swimming). The same study documented that killer whales also showed some localised avoidance to seismic surveys.

A reduction in feeding activity in response to seismic survey activity has been documented for harbour porpoises at estimated received SEL of 150 – 165 dB re 1µPa²·s (Pirotta *et al*. 2014). Due to the permanently high energy demands of harbour porpoises (Wisniewska *et al*. 2016) a prolonged cessation of feeding can have significant effects on the fitness of affected animals.

6.6.3 Masking

Masking is the process by which the threshold of hearing for one sound is raised by the presence of another (masking) sound (Erbe and Farmer 1998; Erbe 2008; Erbe *et al*. 2016). This describes the reduction in audibility for one sound (termed 'signal') caused by the simultaneous presence of another sound (termed 'noise'). For this to occur, the sound must be loud enough, have similar frequency content to the signal, and must happen at the same time. Masking depends on the spectral and temporal characteristics of signal and noise and is reduced if the signal and noise are separated in time, frequency, or direction (space); it can occur if the noise happens shortly before or after the signal (forward and backward masking). The zone of masking can maximally be as large as the zone of audibility, as a faint noise might mask a faint signal. The masking effect can be reduced or remedied by various active or passive mechanisms for masking-release, such as spatial or temporal release from masking, the Lombard effect, or co-modulation masking release.

Auditory masking can lead to disruption of a behaviour, lack of appropriate behavioural reactions, increased vulnerability to predators, reduced access to prey, reduced communication, changes in vocal behaviour, disruption of spawning activities, and stress. The biological significance of acoustic masking is directly linked to the duration of the masking sound. While masking can be detrimental to the fitness, reproduction, and survival of individuals, it ends immediately after the masking sound ceases. Both anthropogenic and natural marine sound can affect hearing and partially or completely reduce an individual's ability to effectively communicate; detect important predator, prey, and/or conspecific signals; and detect important environmental features associated with spatial orientation (Clark *et al*. 2009). This is true for all marine fauna; however, masking is most frequently associated with marine mammals. Masking in fishes has not been studied in detail.

Masking reduces the communication space of marine mammals (Clark et al. 2009, Hatch et al. 2012). A calculation of reductions in communication range can be a useful proxy for impact. So far, a direct assessment and quantification of masking effects in wild animals has proven impossible (Tougaard et al. 2015). It depends on the positions of the signalling and the receiving animal relative to the sound source and to each other. In humpback whales (*Megaptera novaeangliae*), tonal and grunting sounds acting as contact calls between a mother and its calf were recorded at comparatively low levels (Videsen et al. 2017). While there is controversy about the validity of conclusions, such low levels would create a small communication space (<100 m) which, in turn, would be sensitive to increases in ambient noise.

Most studies related to masking effects in marine mammals have investigated the auditory parameters that are most relevant in this context, such as auditory sensitivity, frequency-tuning (critical bandwidth and critical ratio), auditory integration time, and critical interval. Erbe et al. (2016) reviewed the current knowledge on masking in marine mammals, summarising data on marine mammal hearing as they relate to masking and discussing masking release processes of receivers. The variability seen in auditory sensitivity (Section 4.1) indicates the variability seen with respect to auditory masking.

6.6.4 TTS/PTS

In marine mammals, the onset level and growth of TTS is frequency specific, depends on the temporal pattern, duty cycle, and the hearing test frequency of the fatiguing stimuli. Exposure to intense impulse noise might be more hazardous to hearing than non-impulsive noise, and there is a positive relationship between exposure duration and the amount of TTS induced. TTS can accumulate across multiple exposures, but the resulting TTS will be less than the TTS from a single, continuous exposure with the same total SEL. Sounds generated by seismic airguns, pile-driving and mid-frequency sonars have directly been tested and proven to cause noise-induced threshold shifts in marine mammals at high received levels. Finneran (2015) reviewed the current state of knowledge on TTS and PTS. TTS typically decreases in marine mammals relative to the logarithm of the increasing recovery time. There is, however, considerable individual difference in all TTS-related parameters between subjects and species tested so far.

PTS is considered injurious in marine mammals, but there are no published data on the sound levels that cause PTS in marine mammals. Regeneration of sensory cells, as known to occur in fishes, has not been documented for any marine or terrestrial mammal. Onset levels of PTS onset are typically extrapolated from TTS onset levels and assumed growth functions (Southall et al. 2007). The NMFS (2018) criteria incorporate the best available science to estimate PTS onset in marine mammals from sound energy (SEL_{24h}), or very loud, instantaneous peak sound pressure levels (**Table 6-3**).

Table 6-3: Noise exposure criteria for onset of TTS and PTS (NMFS 2018). Criteria are given separately for each cetacean functional hearing group and discriminate between impulsive and non-impulsive sounds

Hearing group	PTS onset thresholds (received level)		TTS onset thresholds (received level)	
	Impulsive	Non-impulsive	Impulsive	Non-impulsive
Low-frequency cetaceans	L_{pk}, flat: 219 dB $L_{E,LF}$, 24h: 183 dB	$L_{E,LF}$, 24h: 199 dB	L_{pk}, flat: 213 dB $L_{E,LF}$, 24h: 168 dB	$L_{E,LF}$, 24h: 179 dB
Mid-frequency cetaceans	L_{pk}, flat: 230 dB $L_{E,MF}$, 24h: 185 dB	$L_{E,MF}$, 24h: 198 dB	L_{pk}, flat: 224 dB $L_{E,MF}$, 24h: 170 dB	$L_{E,MF}$, 24h: 178 dB
High-frequency cetaceans	L_{pk}, flat: 202 dB $L_{E,HF}$, 24h: 155 dB	$L_{E,HF}$, 24h: 173 dB	L_{pk}, flat: 196 dB $L_{E,HF}$, 24h: 140 dB	$L_{E,HF}$, 24h: 153 dB

The role of the temporal pattern of sound on TTS in marine mammals has been studied in MF and HF cetaceans (Mooney *et al*. 2009a; Finneran *et al*. 2010b; Kastelein *et al*. 2014a; Kastelein *et al*. 2015b). The results of these studies show that TTS can accumulate across multiple exposures, but the resulting TTS will be less than the TTS from a single, continuous exposure with the same total SEL.

Only a few studies have investigated TTS in marine mammals in response to exposure to impulsive sounds such as airgun impulses. Lucke *et al*. (2009) tested the effect of a single airgun on a male harbour porpoise. They documented onset of TTS at received (unweighted) SEL of 164 dB re 1 µPa²·s. This equates to a (HF) weighted SEL_{24h} of 140 dB re 1 µPa²·s (NOAA 2016). The main energy of the fatiguing stimulus (airgun pulse) was centred below 500 Hz, but a substantial amount of energy was also present at higher frequencies. Kastelein *et al*. (1997) tested the auditory tolerance of a harbour porpoise to playbacks of broadband pile driving sounds. After one hour of exposure an unweighted SEL 146 dB re 1 µPa²·s and a SEL_{24h} of 180 dB re 1 µPa²·s, a TTS of 2.3 dB and 3.6 dB occurred at 4 kHz and 8 kHz, respectively. The average weighted SEL_{24h} from these exposures was 144 dB re 1 µPa²·s. In a study using playbacks of pile driving sounds, Kastelein *et al*. (2016) exposed harbour porpoises to a maximum single-strike unweighted broadband SEL of 145 dB re 1 µPa²s and a cumulative SEL_{24h} of up to 187 dB re 1 µPa²·s. TTS increased from 0 dB after 15 min exposure to 5 dB after 360 min exposure. Based on their results, they calculated an onset of TTS for this type of sound at a SEL_{24h} of approximately 175 dB re 1 µPa²·s. Kastelein *et al*. (2017) exposed a harbour porpoise to 10 and 20 consecutive airgun impulses at received SEL_{24h} of 188-191 dB re 1 µPa²·s with a mean shot intervals of around 17 seconds. TTS of ~4.4 dB was measured at 4 kHz.

Finneran *et al*. (2015) tested the exposed three bottlenose dolphins to 10 impulses produced by a seismic air gun. The highest exposures were conducted at peak sound pressure levels (PK) of 210 dB re 1 µPa, peak-peak sound pressure levels (PK-PK) of 212 dB re 1 µPa, and cumulative (unweighted) SEL_{24h} of 195 dB re 1 µPa²·s. This exposure induced 9 dB TTS in one animal at 8 kHz.

6.6.5 Mortality

The only evident case of an injury to a marine mammal caused by what can clearly be considered an underwater sound source was reported by Ketten et al. (1993). However, as the most likely sound source in this case was an underwater explosion of undefined charge weight and distance to the animals, the physical cause of the injury may have been the shock wave created by the explosion.

6.7 Seabirds

Only bird species that plunge dive (such as tropicbirds, boobies, shearwaters and tern species) could potentially be exposed to underwater noise, although little or no impact is expected. Stemp (1985; as cited in LGL 2012) conducted observations on the effects of seismic exploration on seabirds and did not observe any negative effects. Lacroix *et al.* (2003; as cited in LGL 2012) investigated the effect of near shore seismic surveys on moulting long-tailed ducks in the Beaufort Sea, Alaska, and also failed to detect any negative effects. Furthermore, they noted that seismic activity did not appear to change the diving intensity of the ducks significantly.

There are no thresholds or assessment criteria for noise impacts to seabirds from seismic surveys.

6.8 Divers

Divers exposed to high levels of underwater sound can suffer from dizziness, hearing damage or other injuries to other sensitive (mainly air-filled) organs, depending on the frequency and intensity of the sound. The human auditory system is significantly less sensitive underwater than in air and is further degraded if diving equipment obstructs the ears or face (e.g. diving with a hood or full facemask).

Under water, the human ear is about 20 dB less sensitive than it is in air at low frequencies (20 Hz), increasing to 40 dB at mid-frequencies (less than 1 kHz), and increasing to 70–80 dB less sensitive at higher frequencies (Parvin 1998). Divers who wear neoprene hoods have even higher hearing thresholds (lower sensitivity) above 500 Hz because the hood material absorbs high-frequency sounds (Sims *et al*. 1999). Exposure studies related to divers have typically focused on military sonar exposure, with little information on seismic survey operations, and as such care is required when considering thresholds for non-military divers, particularly for impulsive sounds such as seismic source impulses (Ainslie 2008).

Underwater auditory threshold curves indicate that the human auditory system is most sensitive to waterborne sound at frequencies between 400 Hz to 1 kHz (Parvin *et al*. 1994); cited in Anthony *et al*. 2009), and these frequencies have the greatest potential for damage. Within the literature (all as cited in Ainslie, 2008), there is some variation in acceptable SPLs for divers as discussed below.

The auditory threshold of hearing under-water was lowest at 1 kHz (70 dB re 1 μPa SPL) and increased for lower and higher frequencies to around 120 dB re 1 μPa at 20 Hz and at 20 kHz (Parvin 1998). Fothergill *et al*. (2000) and Fothergill *et al*. (2001) conducted controlled acoustic exposure experiments on military divers under fully controlled conditions at a US Ocean Simulation Facility and an US Open water test facility; in all tests, the divers were covered with soft or hard shell dive suits and their position and distance relative to sound source, signal characteristics and received levels were controlled and documented (Pestorius *et al*. 2009). A total of 89 male Navy divers were exposed to pure tone signals and sweeps between 160-320 Hz at SPLs up to 160 dB re 1 μPa. The divers were exposed to these sounds over 100 seconds at depths from 10 to 40 m. The divers rated the sounds on a severity scale. For frequencies between 100 and 500 Hz, at a received SPL of 130 dB re 1 μPa, divers and swimmers detected body vibration. None of the divers tested rated levels of 140 dB re 1 μPa as “very severe”; however, at 157 dB re 1 μPa, sound was rated as “very severe” 19 per cent of the time. No physiological damage was observed at the highest levels tested: 160 dB re 1 μPa (Fothergill *et al*. 2001). In a subsequent study, recreational divers were exposed to tonal signals or 30 Hz-sweeps at frequencies between 100 and 500 Hz at received levels of 130-157 dB re 1 μPa (Pestorius *et al*. 2009). Each exposure lasted for seven seconds. Nine female and 17 male scuba divers were tested, all wearing full body neoprene wetsuits. Diver aversion and perception of body vibration were used as test parameters. The results showed no sex-specific differences. The results differed as a function of frequency – while test results showed a strong overall variation between subjects, signals at 100 Hz elicited the strongest aversion in all tests and even at 148 dB a few diver ratings indicated extreme aversion. Due to this and the strong variation between test subjects, the following exposure limit for both military and recreational divers was suggested as a conservative measure: For frequencies between 100 and 500 Hz, the maximum SPL should be 145 dB re 1 μPa over a maximum continuous exposure of 100 seconds or with a maximum duty cycle of 20 per cent and a maximum daily cumulative total of three hours. The trading relation between the maximum SPL and duration was 4 dB per doubling of duration (e.g., 141 dB SPL for a 200 second exposure) (Pestorius *et al*. 2009).

In alignment with these studies, and considering only frequencies between 100 and 500 Hz, Parvin (2005) suggested 145 dB re 1 μPa as a safety criterion for recreational divers and swimmers. Seismic airgun sources are broadband sources, and therefore, for this assessment the most precautionary and conservative diver acoustic impact threshold is the 145 dB re 1 μPa SPL suggested by Parvin (2005). This does not imply that this level is associated with the onset of injury.

The latest guidance issued by the Diving Medical Advisory Committee (DMAC 2019) suggests that adverse effects to divers may be experienced at distances of up to 27 km from the seismic source, which is a considerably greater distance than has previously been recognised. However, the basis for this conclusion is not provided.

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Appendix J – Hydrocarbon Pathways and Thresholds

The hydrocarbon fate and transport modelling method described in this EP is able to track hydrocarbon concentrations of floating oil, entrained oil (total water accommodated fraction (WAF)) and dissolved WAF below biologically significant impact levels. Consequently, exposure values are specified for the model to control what contact is recorded for surface (floating oil) and subsurface locations (entrained and dissolved) to ensure that recorded contacts are for biologically meaningful concentrations.

The determination of biologically meaningful impact levels is complex since the degree of impact will depend on the sensitivity of the biota contacted, the duration of the contact (exposure) and the toxicity of the hydrocarbon mixture making the contact. The toxicity of a hydrocarbon will change over time, due to weathering processes altering the composition of the hydrocarbon. To ensure conservatism in the environmental impact assessment process, the exposure values applied to the model are selected to adopt the most sensitive receptors that may be exposed, the longest likely exposure times and the more toxic hydrocarbons.

Impact pathways and exposure values are detailed below for surface (floating) oil, entrained oil (total WAF) and dissolved WAF. Exposure values are consistent with NOPSEMA Bulletin #1 Oil Spill Modelling (2019).

Exposure Values	Surface oil concentration (g/m^2)	Total water accommodated fraction (WAF) concentration (ppb)	Dissolved water accommodated fraction (WAF) concentration (ppb)	Time-integrated Dissolved water accommodated fraction (WAF) concentration (ppb.hr)	Hydrocarbon Ashore – accumulated (g/m^2)
Low	1	10	10	-	10
Moderate	10	-	50	4,800	100
High	50	100	400	38,400	1000

Surface Hydrocarbons

Exposure Pathways

Marine/coastal fauna, habitats and socio-economic receptors may be impacted by floating oil in the following way:

- Marine mammals, reptiles and birds can be exposed to oil when at the water surface. For marine mammals and reptiles this can occur when surfacing within a slick to breathe while for birds this includes contact from diving into a slick or floating on the sea surface while feeding or resting. For marine fauna surfacing in floating oil contact to sensitive areas may occur (e.g. eyes, mouth and respiratory system) creating irritation and potentially cell damage. Volatile compounds evaporating form surface oil may be inhaled by marine mammals and reptiles, particularly when the oil is fresh and relatively unweathered. Inhalation of these compounds may cause damage to internal respiratory structures. It is generally considered that marine mammals with smooth skin (e.g. cetaceans) are less susceptible to coating of oil than those covered with hair given hair has a greater potential to trap and retain oil causing longer exposure times. Birds are particularly susceptible to impact from floating oil in that feathers retain oil, particularly when the oil is ‘sticky’ (e.g. heavy crudes and heavy fluid oil (HFO)). The coating of oil on birds may hinder flight and feeding, reduce the ability of the bird to thermoregulate (control body temperature) and irritate/damage sensitive surfaces such as eyes, ears and nasal structures. Secondary impacts can occur through the ingestion of oil as birds attempt to preen contaminated feathers. Ingestion may lead to oil absorption and further toxic impacts.

- Surface oil can coat emergent habitats such as coral or rocky reefs and intertidal and shoreline areas around islands or along coastlines. Habitats that can be affected include rocky shorelines, sandy beaches, mangrove communities and intertidal areas which may support seagrass, algae and coral reef communities. The physical coating of mangroves, in particular their root system, can prevent gas exchange and/or cause toxicity at the cellular level. Mangrove response to oil contact includes deforestation, yellowing of leaves and mortality. Other chronic responses include reduced growth, reduced reproductive output and success, and genetic mutation. Intertidal areas may be contacted at low tides where emergent habitat is coated by oil. Seagrass, algae and sessile fauna such as hard corals, soft corals and sponges may be smothered as well as small low mobility fauna that live in close association with these and other benthic habitats or within/on sediments. Smothering of intertidal photosynthetic organisms such as seagrass, algae and hard coral may reduce their capacity for photosynthesis (energy production) or lead to a toxic response at the cellular level. For seagrass and algae this could lead to plant death, shedding of leaves/thalli, reduced growth, reduced reproductive output/success and genetic mutation. Similarly, for hard corals, bleaching, colony death, reduced growth and reduced reproductive capacity may occur. Such impacts may be exacerbated if these organisms are already under stress from marginal environmental conditions or if impacts occur during critical life-history stages (e.g. spawning periods). Small fauna smothered by oil may be hindered in their ability to move and feed or may suffer a toxic response from mortality to reduced growth rate or reproductive success. The coating of habitats can lead to secondary impacts to marine/coastal fauna. For example, marine turtles and shorebirds may be contacted by oil when using nesting beaches or when roosting/feeding along shorelines, respectively. Marine/coastal fauna may also ingest oil when feeding on coated habitats, e.g. dugongs or turtles ingesting coated seagrass/algae and shorebirds ingesting coated intertidal organisms such as molluscs and crabs.
- Surface oil may impact on socio-economic receptors such as the oil and gas industry, commercial shipping, fisheries/aquaculture and tourism. The presence of floating oil may pose a human health risk from volatile compounds depending on the nature and freshness of the oil (i.e. fresh light oils and condensates posing the greatest risk) while oil spill response activities targeting floating oil may preclude or disrupt activities by other users in the area both offshore and at oil affected shorelines. This could have an economic impact on affected industries. In addition, floating and stranded oil may be highly visible to the general public and have a resultant negative effect on tourism in affected areas. Real or perceived deterioration of nearshore and coastal habitats may also have long lasting effect on the tourism value of an area and of fisheries activities that may rely on those areas to support healthy fish stocks.

Exposure Values

The low exposure value of 1 g/m^2 represents the area within which socio-economic impacts to the visual amenity of the marine environment may occur, but is below concentrations at which ecological impacts are expected to occur.

The moderate exposure value of 10 g/m^2 represents the minimum oil thickness at which ecological impacts (e.g. to birds and marine mammals) are expected to occur. There is a paucity of data on floating oil concentrations with respect to impacts to marine organisms. The impact of floating oil on birds is better understood than other receptors. Estimates for the minimum oil thickness that will harm seabirds (through ingestion from preening of contaminated feathers or loss of thermal protection of their feathers) range from at 10 g/m^2 (O'Hara and Morandin, 2010) to 25 g/m^2 (Koops *et al*., 2004). A conservative exposure value of 10 g/m^2 has been applied to impacts from marine gas oil (MDO/MGO). This hydrocarbon exposure value is also considered appropriate for turtles, sea snakes and marine mammals (NRDAMCME, 1997) and has also been applied herein to determine impacts of surface oils to emergent habitats.

The high exposure value of 50 g/m^2 approximates the estimated minimum floating hydrocarbon threshold for containment and recovery and informs response planning.

Entrained Oil and Dissolved Aromatic Hydrocarbons

Exposure Pathways

Entrained oil is oil that is dispersed within the water column as oil droplets and could also be referred to as 'total water accommodated fraction'. For oil spills released at surface, entrained oil is created in the top few meters of the water column through mixing (entrainment) of surface oil by wave (wind and current induced) action. For oil spills released subsea (e.g. pipelines leaks, subsea well blowouts) entrained oil may be distributed deeper within the water column due to the hydrocarbon plume entraining ambient water (thus counter balancing the buoyancy force) as it rises. Dissolved aromatic hydrocarbons (DAHs) are the water soluble portion of the entrained and floating oil and include Monocyclic Aromatic Hydrocarbons (MAHs, including BTEX - Benzene, Toluene, Ethylbenzene and Xylene) and low molecular weight Polycyclic Aromatic Hydrocarbons (PAHs). Aromatic hydrocarbons dissolve more favourably from entrained oil than floating oil since oil droplets within the water column have a greater surface area across which these aromatics can dissolve. In conditions where entrainment is minimal (e.g. calm conditions) evaporation plays a greater role in the loss of aromatic hydrocarbons from the discharged oil.

Due to the toxic nature of MAHs, low molecular weight PAHs and the ability for these to be transferred across cellular structures, DAHs contribute to the acute toxicity of an oil. The proportion of BTEX, and other DAHs that are readily dissolved or evaporated, diminish over time. DAH concentration is therefore higher around fresh oil than weathered oil. The toxicity of DAHs to an organism is dependent on both the concentration of the oil and the amount of time an organism is exposed to a given concentration.

Marine/coastal fauna, habitats and socio-economic receptors may be impacted by entrained oil and DAHs in the following ways:

- Marine mammals, reptiles, fish and plankton (including invertebrates and invertebrate/fish larvae) may be exposed to entrained oil and DAHs following a spill at surface or subsea. Birds may also be exposed while diving but this is likely to be of less significance than exposure to floating oil. Physical contact of oil to sensitive tissues (e.g. eyes, mouth and respiratory system) may lead to irritation and cell damage. Plankton assemblages contain eggs, larvae and early life stages of marine invertebrates and fish. These organisms are particularly sensitive to toxic impacts from DAHs given they are going through important processes of organ differentiation and development and are passive or of low mobility organisms restricting their ability to avoid entrained oil and DAHs. Impacts to eggs/larvae include mortality, reduced growth and growth defects. Fish are also highly susceptible to entrained oil through contact of oil across gill structures which promotes uptake of toxic compounds from entrained oil. Other internal contact and uptake can occur by ingestion during feeding. Ingestion/uptake of compounds from entrained oil can potentially lead to toxic impacts, within fish in particular, including reduced swimming and feeding ability, increased risk of predation, lowered growth rates and reduced reproductive output and success. Susceptibility of small/juvenile fish is likely to be greater due to restricted capacity for avoiding entrained oil/DAHs while benthic fish in deeper waters are likely to be less affected since entrained oil is most likely to within the upper water column in deeper water.
- Entrained oil can contact subtidal/intertidal habitats such as rocky reefs, bare sediments, seagrass, algae and coral reef communities. Contact to photosynthetic organisms such as seagrass, algae and hard coral may reduce capacity for photosynthesis either through a reduction in light availability or through toxic effects of DAH uptake or direct contact by entrained oil. For seagrass and algae this could lead to shedding of leaves/thalli, reduced growth and reproductive output/success. For hard corals, bleaching may occur (expulsion of zooxanthellae), sediment clearing and feeding ability may be diminished, growth or reproductive capacity may be reduced, and reproductive success may be diminished. Small fauna associated with the above mentioned habitats may be hindered in their ability to move and feed or may suffer a toxic response such as mortality, reduced growth or reproductive success. Habitats particularly susceptible during important life-cycle stages such as spawning periods or when other physiological stresses are present (e.g. when water temperature at upper range of tolerance or where a high degree of sedimentation is occurring).
- The coating of habitats can lead to secondary impacts to marine/coastal fauna. For example, marine/coastal fauna may ingest oil when feeding on coated habitats, e.g. dugongs or turtles ingesting

coated seagrass/algae and shorebirds ingesting coated intertidal organisms such as molluscs and crabs. The loss or damage of habitat may also impact associated epi- and in-faunal communities which rely on the habitat (e.g. seagrass meadows, algae beds, coral reefs) for shelter and food.

- Entrained oil and DAHs may impact socio-economic receptors such as fisheries/aquaculture and tourism. Fisheries and aquaculture may potentially be impacted from a decrease in stock levels. Reduced marketability of product could also arise from a real or perceived tainting of flesh caused from contact of target species with oil. While entrained oil and DAHs are largely invisible from the water's surface tourism may be impacted from a real or perceived reduction in health or mortality of habitats that support tourism activities such as snorkelling, diving and fishing. Aquaculture facilities growing pearl oysters may be affected by oil or DAH in the water column through reduction in water quality and through direct ingestion (toxicity) by stock.

<u>Exposure Values - Entrained</u>

The low exposure value of 10 ppb for entrained hydrocarbons has been adopted to represent the planning area for scientific monitoring in the event of a diesel spill based on potential for exceedance of water quality triggers in the ANZECC 2000 Guidelines (ANZECC 2000).

The high exposure value of 100 ppb is based on an detailed expert review of hydrocarbon toxicity undertaken by French McCay (2018). French McCay reports 100 ppb to be a highly conservative threshold for total water accommodated fraction that could result in sub-lethal effects to marine biota, including sensitive organisms and early life stages of fish (e.g. embryos, larvae).

<u>Exposure Values – Dissolved (Instantaneous)</u>

For dissolved aromatic hydrocarbons, toxicity is a function of the aromatic content and composition in the hydrocarbon, the fate and partitioning of those components in the environment and the duration of exposure by sensitive receptors.

The low exposure value of 10 ppb for dissolved hydrocarbons has been adopted to represent the planning area for scientific monitoring in the event of a diesel spill based on potential for exceedance of water quality triggers in the ANZECC 2000 Guidelines (ANZECC 2000).

Global data shows species sensitivity (95 per cent of fish and invertebrates tested) to polycyclic aromatic hydrocarbon (PAH), for exposure periods greater than 96 hours under varying environmental conditions, varied in tests considering sensitive life stages such as eggs and larvae across test organisms (French, 2000; French-McCay, 2002).

Based on this information, a moderate contact threshold of 50 ppb is considered a conservative exposure value for the assessment of impacts from dissolved hydrocarbons for MDO/MGO, representing potential toxic effects, particularly sublethal effects, to highly sensitive species. The high exposure value of 400 ppb represents the threshold at which lethal effects to sensitive species may occur.

<u>Exposure Values – Dissolved (Time-Averaged)</u>

It is noted that the use of instantaneous exposure values for dissolved hydrocarbons is highly conservative and they are considered more relevant to time-based exposures (i.e. applied across a 96-hour interval). Using the moderate (50 ppb) and high (400 ppb) exposure values as appropriate for assessment of impacts of dissolved aromatic hydrocarbons, contact threshold for dosage were determined based on an exposure period of greater than 96 hours (French, 2000; French-McCay, 2002). The resulting time-averaged exposure values are 4,800 ppb.hrs (moderate) and 38,400 ppb.hrs (high).

Accumulated Hydrocarbons

<u>Exposure Pathways</u>

Shoreline and intertidal habitats comprise of mangroves, sandy beaches and rocky shorelines. These habitats and marine fauna known to use shorelines are most at risk of exposure to shoreline accumulations of oil, due to smothering of intertidal habitats (such as mangroves and emergent coral reefs) and coating of marine fauna. Shoreline hydrocarbons can impact shorebirds and also nesting turtles when they come ashore, with exposure to skin and cavities, such as eyes, nostrils, and mouths. Eggs may also be exposed during incubation, potentially resulting in increased egg mortality and detrimental effects on hatchlings. Turtle hatchlings may be particularly vulnerable to toxicity and smothering, as they emerge from the nests and make their way over the intertidal area to the water (Milton et al., 2003).

Exposure Values

The low exposure value of 10 g/m^2 represents light oiling (equivalent to 2 teaspoons of oil per m^2) and predicts the area within which socio-economic impacts to the visual amenity may occur, but is below concentrations at which ecological impacts are expected to occur. Owens and Sergy (2004) classifies a shoreline 'stain' as oil accumulation below 0.1 mm thick (i.e. below ~100 g/m^2) which creates a visible mark on coarse shoreline sediments or bedrock that cannot be scratched off easily. Oil well below this threshold manifests as a transparent or translucent film or sheen (Owens and Sergy, 2004).

The moderate exposure value of 100 g/m^2 represents the minimum oil thickness at which potentially lethal ecological impacts (e.g. to intertidal invertebrates) are expected to occur. Shoreline accumulation of hydrocarbons above this exposure value may result in lethal impacts for benthic epifaunal invertebrates on intertidal habitats that consist of hard substrates (e.g. rocky, artificial/man-made rip rap) and sediments (i.e. mud, silt, sand and gravel) (French-McCay et al, 2003, French-McCay et al, 2004; French-McCay, 2009). The moderate exposure value also predicts areas likely to require clean-up effort.

The high exposure value of 1000 g/m^2 predicts areas likely to require intensive clean-up effort.