Santos

Petrel Sub-Basin South-West 3D Marine Seismic Survey Environmental Plan

<SO-00-BI-20006>

PROJECT / FACILITY	Petrel Sub-Basin SW MSS
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	YES

Rev	**Owner**	**Reviewer/s** *Managerial / Technical / Site*	**Approver**
	Manager – Operations Geophysics	**HSE Team Lead – Drilling and Exploration**	**General Manager Subsurface and Technical Upstream Northern Australia, Timor Leste & PNG**
0	Michael Giles	Adam Kestel	Andrew McPhail
	[signature]	[signature]	[signature]

Any hard copy of this document, other than those identified above, are uncontrolled. Please refer to the Santos Offshore Business Document Management System for the latest revision.

Rev	Rev Date	Author / Editor	Amendment
A	31/05/2021	ERM	Draft for Santos Review
B	11/06/2021	ERM	Draft for Santos Review
C	30/06/2021	ERM	Draft for Santos Review
0	12/07/2021	ERM/Santos	Issued for NOPSEMA completeness check and public comment

Contents

Santos

Figures

Tables

Acronyms

Abbreviation	Description
$	Dollars (Australian dollars unless specified otherwise)
%	Percent
‘	Minutes
“	Seconds
°	Degrees
°C	Degrees Celsius
<	Less than
AASM	Airgun Array Source Model
ABARES	Australian Bureau of Agricultural and Resource Economics
AET	Australian External Territory
AF	Aquarium Fishery (NT)
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AHO	Australian Hydrographic Office
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 Standard Institute
APASA	Asia-Pacific Applied Science Associates
API	American Petroleum Institute gravity (A measure of how heavy or light a petroleum liquid in comparison to water)
APPEA	Australian Petroleum Production and Exploration Association
ARPA	Automatic Radar Plotting Aid
AS	Australian Standard
BF	Barramundi Fishery
BIA	Biologically Important Area
BMF	Beche-de-Mer Managed Fishery
BNF	Bait Net Fishery
BOM	Bureau of Meteorology

Abbreviation	Description
BWMP	Ballast Water Management Plan
CAES	Catch and effort systems
CFA	Commonwealth Fisheries Association
CH_4	Methane
CLF	Coastal Line Fishery
CM	Control Measure
CMID	Common Marine Inspection Audit
CO_2	Carbon dioxide
COLREGS	International Regulations for Preventing Collisions at Sea
COO	Chief Operations Officer
cP	Centipoise (unit of viscosity)
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
cui / cu. in.	Cubic inches
dB	Decibel
DBCA	WA Department of Biodiversity, Conservation and Attractions (*formerly Department of Parks and Wildlife*)
DEWHA	Commonwealth Department of Sustainability, Environment, Water, Heritage and Arts (*superseded by Department of the Environment and Energy*)
DF	Demersal Fishery (NT)
DMIRS	WA Department of Mines, Industry Regulations and Safety
DNER	NT Department of Natural Environmental Resources
DRA	Due Regard Area
DO	Dissolved Oxygen
DoA	Commonwealth Department of Agriculture (*superseded by Department of Agriculture, Water and the Environment*)
DoD	Department of Defence
DoEE	Commonwealth Department of the Environment and Energy
DoE	Commonwealth Department of Environment (*superseded by Department of the Environment and Energy*)
DoF	WA Department of Fisheries (*superseded Department of Primary Industries and Regional Development*)
DNP	Director of National Parks
DAWE	Commonwealth Department of Agriculture, Water and the Environment (*formerly Department of Agriculture*)

Abbreviation	Description
DAWR	Commonwealth Department of Agriculture and Water Resources (*superseded by Department of Agriculture*)
DITT	NT Department of Industry, Tourism and Trade (*formerly NT Department of Primary Industry and Resources*)
DoIIS	Commonwealth Department of Industry, Innovation and Science (*superseded by Department of Industry, Science, Energy and Resources*)
DNP	Director of National Parks
DoT	WA Department of Transport
DPaW	WA Department of Parks and Wildlife (*superseded by the Department of Biodiversity, Conservation and Attractions*)
DPIRD	WA Department of Primary Industries and Regional Development (*formerly Department of Fisheries*)
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (*superseded by Department of the Environment*)
EEZ	Exclusive Economic Zone
EHS	Environment, Health and Safety
EMBA	Environment that may be affected
ENVID	Environmental Risk Assessment
EP	Environment Plan
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPO	Environmental Performance Outcome
EPS	Environmental Performance Standard
ERM	Environmental Resources Management Australia Pty Ltd
ESD	Ecologically Sustainable Development
FRC	Fast Rescue Craft
FRDC	Fisheries Research and Development Corporation
GFW	Global Fishing Watch
GHG	Greenhouse Gas
HF	High Frequency
HFO	Heavy Fuel Oil
hrs	hours
HSE	Health, Safety and Environment
Hz	Hertz
IAGC	International Association of Geophysical Contractors
IAPP	International Air Pollution Prevention

Abbreviation	Description
IFO	Intermediate Fuel Oil
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMO	International Maritime Organisation
IMS	Invasive marine species
IMT	Incident Management Team
IOGP	International Association of Oil and Gas Producers
IOPP	International Oil Pollution Prevention
IPIECA	International Petroleum Industry Environmental Conservation Association
ISO	International Organisation for Standardisation
ISPP	International Sewage Pollution Prevention
ITF	Indonesian Throughflow
ITOPF	International Tanker Owners Pollution Federation
ITQ	Individual Transferable Quota
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
JASCO	JASCO Applied Science
JBG	Joseph Bonaparte Gulf
JHA	Job Hazard Analysis
JRCC	Joint Rescue Coordination Centre
KEF	Key Ecological Feature
kg	Kilograms
kHz	Kilo-Hertz
km	Kilometres
km^2	Square kilometres
Km/h	Kilometres per hour
LAT	Lowest Astronomical Tide
LNG	Liquefied Natural Gas
m	Metres
m^3	Cubic metres
MAFMF	Marine Aquarium Fish Managed Fishery (WA)
MARPOL	(Marine Pollution) International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978
MDO	Marine Diesel Oil

Abbreviation	Description
MF	Mid-Frequency
MFO	Marine Fauna Observer
mg/l	Milligrams per litre
MGO	Marine Gas Oil
mins	minutes
mm	Millimetres
MMF	Mackerel Managed Fishery (WA)
MNES	Matters of National Environmental Significance
MoC	Management of Change
MOP	Marine Oil Pollution
MOU	Memorandum of Understanding
MSDS	Material Safety Data Sheet
MSS	Marine Seismic Survey
N_2O	Nitrous Oxide
National Plan	National Plan for Maritime Environmental Emergencies
NAXA	Northern Australia Exercise Area
NDSMF	Northern Demersal Scalefish Managed Fishery (WA)
NEATS	National Electronic Approvals Tracking System
NEBA	Net Environmental Benefit Analysis
NERP	National Environmental Research Program
NKMP	North Kimberley Marine Park
nm	Nautical Miles
NMFS	National Marine Fisheries Service
NMR	North Marine Region
NNTT	National Native Title Tribunal
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPIMS	National Offshore Petroleum Information Management System
NOPTA	National Offshore Petroleum Titles Administrator
NOx	Nitrogen Oxides
NPF	Northern Prawn Fishery
NPFI	Northern Prawn Fishing Industry Pty Ltd
NPRAG	NPF Resource Assessment Group

Abbreviation	Description
NRSMPA	National Representative System of Marine Protected Areas
NSW	New South Wales
NT	Northern Territory
NTM	Notice To Mariners
NTSC	Northern Territory Seafood Council
NWA	North West Alliance
NWMR	North-west Marine Region
NWS	North-west Shelf
NZ	New Zealand
ODS	Ozone-Depleting Substances
ONLF	Offshore Net and Line Fishery (NT)
OPEP	Oil Pollution Emergency Plan
OPGGS (E)R	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
OSMP	Oceanic Shoals Marine Park
OVID	Offshore Vessel Inspection Document
PAM	Passive Acoustic Monitoring
PK	Peak Pressure
PMI	Potential Mortality Injury
PMST	Protected Matters Search Tool
POB	Persons On Board
Polarcus	Polarcus Seismic Limited
POMF	Pearl Oyster Managed Fishery (WA and NT)
ppm	Parts per million
psi	pounds per square inch
psu	Practical Salinity Unit
PTS	Permanent Threshold Shift
PTTEP	PTTEP Australasia (Ashmore Cartier)
QLD	Queensland
SAFS	Status of Australian Fish Stocks
SBTF	Southern Bluefin Tuna Fishery
SDS	Safety Data Sheets
SEL	Sound Exposure Level
SMF	Spanish Mackerel Fishery

Abbreviation	Description
SMPEP	Shipboard Marine Pollution Emergency Plant
SMS	Santos Management System
SOPEP	Shipboard Oil Pollution Management Plan
SO_x	Sulphur Oxides
SOLAS	Safety Of Life At Sea
SPL	Sound Pressure Level
SRA	Stock Reduction Analysis
SSMF	Specimen Shell Managed Fishery
SW	South West
t	Tonnes
TECs	Threatened Ecological Communities
TTS	Temporary Threshold Shift
WA	Western Australia
WTBF	Western Tuna and Billfish Fishery
WTO	Wildlife Trade Operation
WAFIC	Western Australian Fishing Industry Council
UXO	Unexploded Ordinance

Santos

Environmental Plan Summary

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

Table EP-1: EP Summary Table

EP Summary Material Requirement	Relevant EP Section
Details of the titleholders nominated liaison person for the activity	**Section 1.3**, page 2-4
The location of the activity	**Section 2.3**, page 9
A description of the activity	**Section 2**, page 7-16
A description of the receiving environment	**Section 3**, pages 17-184
Consultation already undertaken and plans for ongoing consultation	**Section 4**, pages 187-231
Details of the environmental impacts and risks	**Section 6** and **7**, pages 240 -409 and 411-503
The control measures for the activity	**Section 8.6**, pages 510-530
The arrangements for ongoing monitoring of the titleholder's environmental performance	**Section 8**, pages 504-542
Response arrangements in the oil pollution emergency plan (OPEP)	**Section 8.11**, page 535 (EP); and in the OPEP (SO-00-BI-2006.01)

1 Introduction

1.1 Background

Santos Ltd (Santos) plans to acquire a three-dimensional (3D) marine seismic survey (MSS) in Commonwealth waters in the southern Bonaparte Basin. The proposed activity is required to complete exploration and appraisal of the hydrocarbon resources within Santos' petroleum permits (WA-454-P, WA-545-P, WA-27-R and WA-40-R) and surrounding waters in the Petrel Sub-Basin. Results from previous exploration drilling and seismic acquisition undertaken in the area have highlighted potential for further oil and gas resources. In order to evaluate this potential and provide adequate coverage and data quality, Santos requires additional subsurface data via the seismic survey, called the Petrel Sub-Basin South West (SW) 3D MSS.

Multi-client seismic company Polarcus Seismic Ltd (Polarcus) originally commenced drafting of this Environment Plan (EP), with associated stakeholder consultation commencing in September 2019. As a result of global events, EP preparation and stakeholder consultation were suspended by Polarcus in June 2020. Santos replaced Polarcus as the titleholder for the Petrel Sub-Basin SW 3D MSS EP in March 2021. Santos resumed consultation with stakeholders regarding the survey in early May 2021.

1.2 Purpose of this Environment Plan

The Petrel Sub-Basin SW 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 Petrel Sub-Basin SW 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 also 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) (**Figure 1-2**) 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 31 March 2023.

1.3 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).

1.3.1 Details of Titleholder

Santos will undertake the Petroleum Activity within petroleum permit areas WA-454-P, WA-545-P, WA-27-R and WA-40-R and surrounding waters (**Figure 1-1**). Bonaparte Oil and Gas Pty Ltd is the operator of both retention leases (WA-27-R and WA-40-R) and Santos Offshore Pty Ltd is the operator of both exploration permits (WA-454-P and WA-545-P). Both are solely owned entities of Santos Ltd. Titleholder details are provided in **Table 1-1**.

1.3.2 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.

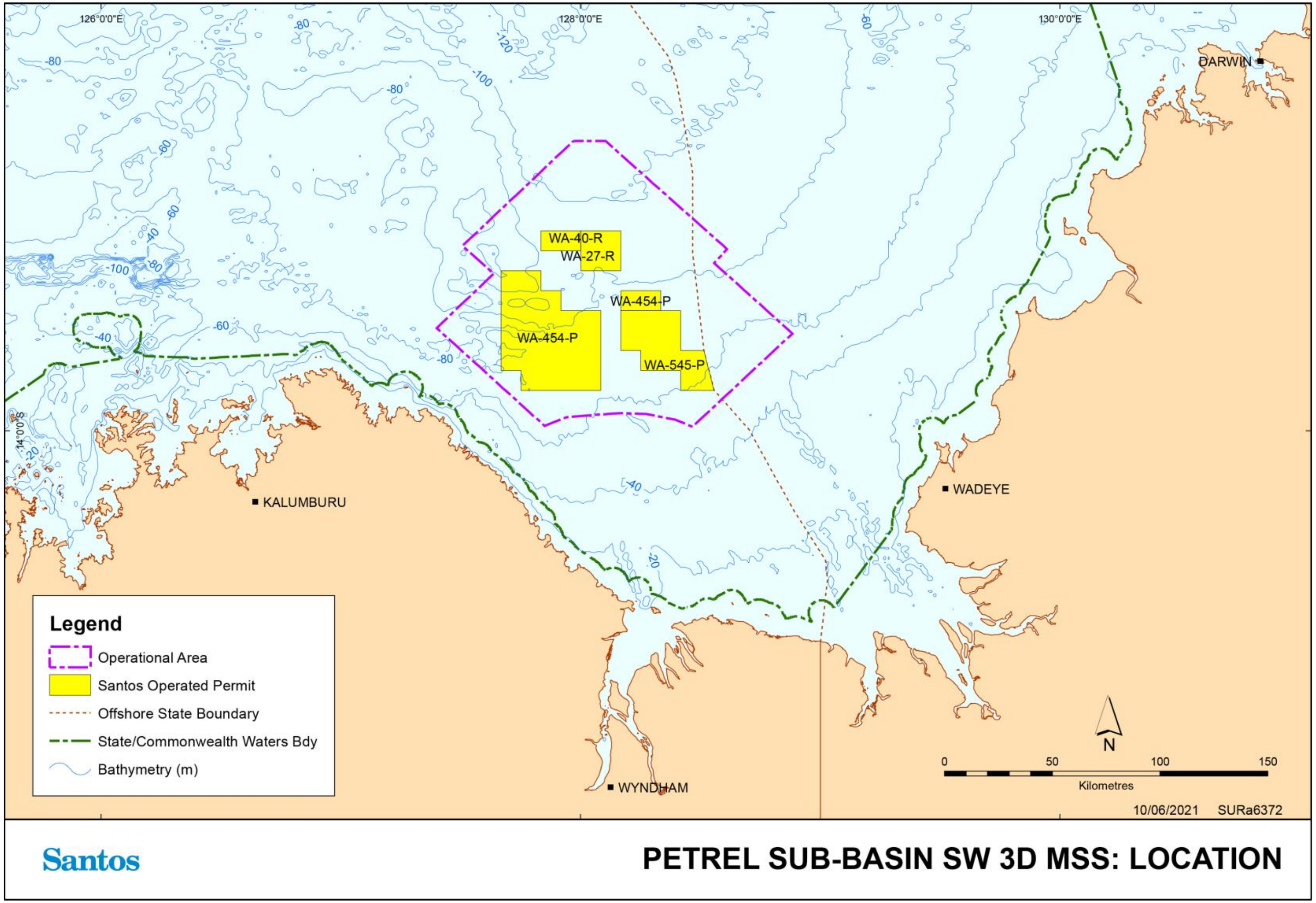


Figure 1-1: Location of the Petrel Sub-Basin SW 3D MSS and Santos Operated Permit Areas

1.3.3 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.

Table 1-1: Titleholder Details

<table>
<tr><th rowspan="2">Titleholder</th><th rowspan="2">ACN/ABN</th><th colspan="4">% Title Interest</th><th rowspan="2">Address</th></tr>
<tr><th>WA-454-P</th><th>WA-545-P</th><th>WA-27-R</th><th>WA-40-R</th></tr>
<tr><td>Santos Ltd</td><td>ACN 007 550 923
ABN 80 007 550 923</td><td>-</td><td>-</td><td>35%</td><td>35%</td><td rowspan="3">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</td></tr>
<tr><td>Santos Offshore Pty Ltd</td><td>ACN 005 475 589
ABN 38 005 475 589</td><td>50%</td><td>50%</td><td>-</td><td>-</td></tr>
<tr><td>Bonaparte Gas & Oil Pty Ltd</td><td>ACN 060 530 109
ABN 72 060 530 109</td><td>-</td><td>-</td><td>65%</td><td>65%</td></tr>
<tr><td>Beach Energy (Operations) Ltd</td><td>ACN 007 845 338
ABN 66 007 845 338</td><td>50%</td><td>-</td><td>-</td><td>-</td><td rowspan="2">Business Address:
Level 8, 80 Flinders Street,
Adelaide, South Australia 5000
Telephone number: (08) 8338 2833
Fax number: (08) 8338 2336
Email address:
tenures@beachenergy.com.au</td></tr>
<tr><td>Beach Energy (Offshore) Pty Ltd</td><td>ACN 639 514 935
ABN 59 639 514 935</td><td>-</td><td>10%</td><td>-</td><td>-</td></tr>
<tr><td>Neptune Energy Bonaparte Pty Ltd</td><td>ACN 138 853 728
ABN 13 138 853 728</td><td>-</td><td>40%</td><td>-</td><td>-</td><td>Business Address:
Level 2, 5 Mill Street,
Perth, Western Australia 6000
Telephone number: (08) 6205 3900
Email address:
Johan.Janssen@neptuneenergy.com</td></tr>
</table>

1.4 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.

1.4.1 Health, Safety and Environment Policy

The Activity will be conducted in accordance with the Santos EHS Policy (QE-91-IQ-00047) **(Figure 1-2**) 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.

1.4.2 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**.

1.4.3 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**.

Environment, Health & Safety

Santos

Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Jodie Hatherly, General Counsel and VP Legal, Risk and Governance		
Approved by:	The Board	Version:	3

20 August 2019 Page 1 of 1

Figure 1-2: Santos EHS 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 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
Petroleum Activity (the Activity)	The Petrel Sub-Basin SW 3D MSS, including all supporting activities.
Full-fold Acquisition Areas	These are the areas within which the seismic source will be operated in full acquisition mode to acquire the seismic data and achieve the geophysical objectives of the survey. Within these areas, 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 these zones, such as during source testing.
Active Source Zones	These are the zones that surround the Full-fold Acquisition Areas. Typically, the zones will be used to: + incrementally build the power of the seismic source from non-operation to full capacity, for the purpose of soft starts during line run-ins; + complete seismic acquisition and data collection along sail lines in the Full-fold Acquisition Areas, during which the seismic source will be operated at full capacity; and + complete line run-outs, during which the seismic source will be operated at full capacity for approximately half a streamer length beyond the end of the full-fold acquisition line, in order to complete the required data collection.

Term	Explanation
	Additionally, these zones may also be used for occasional source testing at, or below, full capacity.
Operational Area	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-fold Acquisition Areas and the Active Source Zones, but also a working buffer beyond these zones. The operations to be conducted within the Operational Area include active acquisition within the Full-fold Acquisition Areas, source emissions within the Active Source Zones, line changes and equipment maintenance. 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 (which are sometimes necessary to complete during line changes). 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 discharge timing. Testing and maintenance of the seismic source may occur anywhere within the Operational Area, whether inside or outside of the Active Source Zones and Full-fold Acquisition Areas.
Racetrack	The method by which sail lines (also known as acquisition 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'.

[1] 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 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. When vessels are outside the Operational Area (e.g. transiting to or from location or holding position outside the Operational Area) and remain within Australian waters, they come under the regulatory jurisdiction of AMSA and the Navigation Act 2012. Accordingly, this EP and associated OPEP do not cover activities performed by the vessels while outside the Operational Area.

2.2 Activity Overview

Santos plans to conduct the Petrel Sub-Basin SW 3D MSS in the Bonaparte Basin within petroleum permits WA-454-P, WA-545-P, WA-27-R and WA-40-R 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, as defined in **Section 2.3**. The seismic source will emit pulses of low-frequency sound, which once reflected from the underlying rock layers beneath the seabed are recorded by the towed streamers. The seismic survey vessel will be supported by other marine vessel and helicopter operations.

2.3 Location and Operational Area

The Petrel Sub-Basin SW 3D MSS is located in Commonwealth waters of the southern Bonaparte Basin (the Petrel Sub-Basin), in the Joseph Bonaparte Gulf (JBG). There are three areas defined for the Activity (**Table 2-1**) based on the type of activities that will be undertaken and the output of the seismic source. These are:

1. Full-fold Acquisition Areas;
2. Active Source Zones; and
3. Operational Area.

These areas are presented in **Figure 2-1**, and coordinates for each area are provided in **Table 2-2**.

The Operational Area is located approximately 28 kilometres (km) from the nearest Western Australia (WA) coastline and approximately 80 km from the nearest Northern Territory (NT) coastline. The Operational Area is located approximately 114 km from Kulumburu and approximately 169 km from Wyndham in WA. The Operational Area is located approximately 246 km from Darwin and approximately 99 km from Wadeye in the NT (**Figure 2-1**).

Water depths in the Operational Area range between 40 metres (m) and 107 m (below mean sea level). Water depths range between 60 m and 103 m within the Full-fold Acquisition Areas.

2.4 Activity Duration and Timing

The survey is planned to be acquired over three areas, Areas A, B and C, as shown in **Figure 2-1**. The survey is estimated to take up to 95 days to complete. 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 within the Operational Area. 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 factors are difficult to predict. An additional five contingency days of operation within the Operational Area has been taken in consideration as part of the environmental assessment. Therefore, including contingency time, the survey is estimated to take up to 100 days to complete, across Areas A, B and C. Operations will be undertaken on a 24-hour basis.

Santos intends to acquire the full survey between 1 December 2021 and 31 March 2022. However, should this not be achievable, then some or all of the survey may instead be acquired the following year, between 1 December 2022 and 31 March 2023. The proposed timing of the survey has been determined in consultation with commercial fishery stakeholders.

The precise timing of the survey is subject to NOPSEMA's acceptance of the EP, weather conditions, vessel availability and other operational considerations, and will take into account the seasonality of environmental sensitivities, where practicable. The exact start and end dates of the survey will be communicated to stakeholders (in accordance with the ongoing stakeholder consultation process described in **Section 4**).

Santos

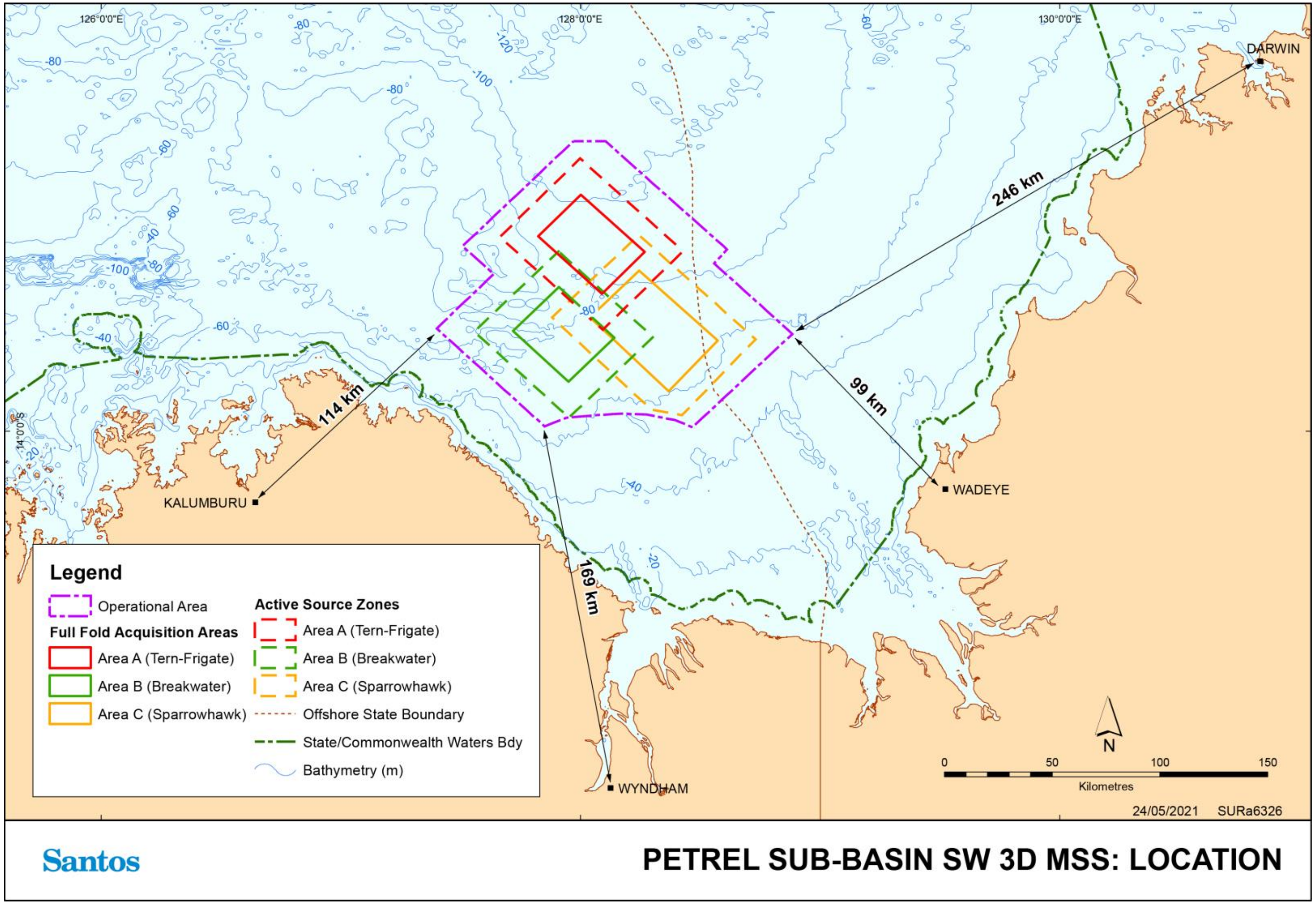


Figure 2-1: Petrel Sub-Basin SW 3D MSS Location

Table 2-2: Proposed Petrel Sub-Basin SW 3D MSS areas and coordinates

Operational Area		Active Source Zones		Full-fold Acquisition Areas	
Total Area: 12,833 km^2		Total combined area: 10,282 km^2 Area A: 3,235 km^2 Area B: 3,089 km^2 Area C: 3,958 km^2		Total combined area: 3,584 km^2 Area A: 1,065 km^2 Area B: 994 km^2 Area C: 1,526 km^2	
Water depths: 40 m to 107 m		Water depths: 45 m to 105 m Area A: 74 m to 105 m Area B: 60 m to 95 m Area C: 45 m to 92 m		Water depths: 60 m to 103 m Area A: 78 m to 103 m Area B: 62 m to 85 m Area C: 60 m to 84 m	
Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
Operational Area (single area)		**Area A (Tern-Frigate)**		**Area A (Tern-Frigate)**	
12° 47' 25.415" S	127° 58' 14.408" E	13° 14' 58.455" S	128° 25' 38.998" E	13° 00' 47.416" S	128° 00' 04.810" E
12° 47' 25.408" S	128° 06' 13.317" E	13° 34' 36.815" S	128° 05' 33.293" E	13° 15' 10.422" S	128° 16' 02.607" E
13° 14' 31.792" S	128° 36' 41.531" E	13° 11' 23.071" S	127° 39' 48.254" E	13° 25' 36.122" S	128° 05' 22.187" E
13° 18' 0.247" S	128° 33' 25.748" E	12° 51' 46.712" S	127° 59' 53.843" E	13° 11' 12.458" S	127° 49' 24.428" E
13° 35' 39.968" S	128° 53' 1.534" E	**Area B (Breakwater)**		**Area B (Breakwater)**	
13° 59' 1.469" S	128° 28' 0.862" E	13° 14' 59.104" S	127° 54' 27.684" E	13° 34' 57.167" S	127° 43' 02.997" E
13° 58' 53.931" S	128° 27' 44.199" E	13° 36' 26.421" S	128° 18' 9.040" E	13° 23' 57.906" S	127° 54' 34.648" E
13° 57' 12.266" S	128° 23' 42.394" E	13° 56' 35.876" S	127° 57' 5.203" E	13° 36' 34.665" S	128° 08' 29.890" E
13° 55' 46.776" S	128° 16' 29.821" E	13° 35' 3.311" S	127° 33' 23.933" E	13° 47' 36.418" S	127° 56' 58.167" E
13° 55' 33.635" S	128° 10' 1.287" E	**Area C (Sparrowhawk)**		**Area C (Sparrowhawk)**	
13° 55' 59.732" S	128° 03' 27.864" E	13° 10' 52.785" S	128° 14' 31.955" E	13° 31' 29.821" S	128° 02' 24.796" E
13° 56' 36.016" S	127° 56' 37.435" E	13° 36' 57.847" S	128° 43' 48.137" E	13° 19' 49.364" S	128° 14' 40.812" E
13° 58' 46.545" S	127° 51' 1.238" E	13° 55' 59.849" S	128° 25' 24.157" E	13° 37' 19.097" S	128° 34' 18.334" E
13° 34' 17.433" S	127° 23' 59.483" E	13° 55' 21.705" S	128° 22' 12.843" E	13° 49' 57.490" S	128° 22' 04.702" E
13° 20' 39.415" S	127° 38' 14.817" E	13° 54' 31.284" S	128° 17' 38.404" E		
13° 13' 42.271" S	127° 30' 26.542" E	13° 31' 31.103" S	127° 52' 50.372" E		

2.5 Acquisition Parameters

During the proposed seismic acquisition, the seismic survey vessel will traverse a series of pre-determined sail lines within the Full-fold Acquisition Areas and Active Source Zones 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. Adjacent sail lines will be spaced approximately 560 – 600 m apart. The seismic survey vessel will typically complete the lines in a 'racetrack' (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 the first line, offset by approximately 560 – 600 m. The racetrack pattern is repeated as the seismic survey vessel gradually moves across the Full-fold Acquisition Area.

Sail lines will either be acquired in a north-west to south-east orientation or in a north-east to south-west orientation. As the acquisition direction has not yet been confirmed, this EP allows acquisition to occur in either direction; however, acquisition within each Full-fold Acquisition Area will only occur in one direction. Examples of potential sail line configurations are presented in **Figure 2-2**.

The three Full-fold Acquisition Areas are separate from one another, but sail lines may overlap within the Active Source Zones, with the seismic source potentially operating over a previously acquired area of seabed during line run-ins or run-outs.

The seismic source will be towed behind the seismic survey vessel and at a depth of approximately 5-10 m below sea level. The seismic source will be discharged every 8.33 m to 12.5 m, depending on the specific seismic source selected to complete the survey. Although the discharge interval is not yet confirmed, the most conservative discharge interval applicable to the survey has been used for acoustic modelling and EP purposes.

The streamers will be towed at a depth of between 10 m and 30 m below sea level, but always greater than 10 m above the seabed. The streamers may be up to 9,000 m in length and therefore extending up to approximately 9.5 km behind the seismic vessel. The total width of the streamer spread may range between approximately 800 m and 1,400 m.

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

Table 2-3: Acquisition Parameters

Parameter	Seismic Survey Parameters
Volume of seismic source	Max. 3,500 cubic inches (in^3)
Operating pressure	2,000 psi
Seismic source depth	Approx. 5 – 10 m
Vessel speed	Approx. 4.5 knots (8.33 km/hr)
Seismic source interval	Approx. 8.33 – 12.5 m
Seismic streamer length	Approx. 9.5 km
Total seismic streamer spread width	Approx. 800 – 1,400 m
Seismic streamer depth	Between 10 m and 30 m
Sail line spacing	Approx. 560 – 600 m
Survey azimuth (line orientation)	Either north-east / south-west or north-west / south-east
Full-fold Acquisition Areas	Total combined area: 3,584 km^2
Time to traverse a single sail line	Approx. 4 hours (hrs) and 5 minutes (mins) to 9 hrs and 40 mins (depending on line lengths)
Sail line turn time	Approx. 3 – 4 hrs
Total expected duration (includes contingency)	100 days

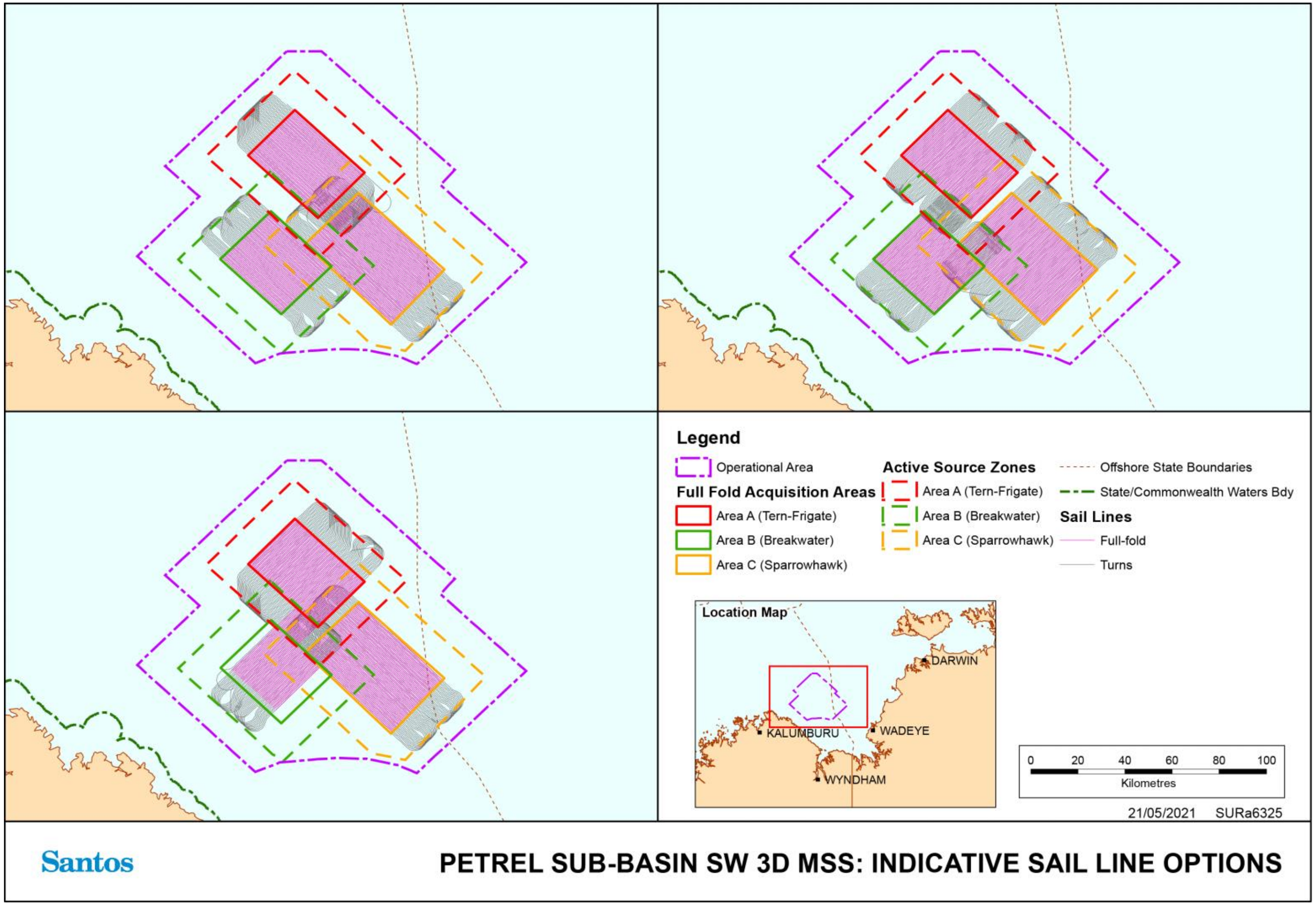


Figure 2-2: Example sail line plans

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 a small 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 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 presented in **Figure 2-1** and described in **Table 2-1**; and
+ The EMBA, as 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, 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 6.3**) 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 scenarios for unplanned vessel hydrocarbon spills considered for the EMBA and assessed in **Section 7.1** 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**, were undertaken to inform the EMBA. The EMBA has therefore been based on the largest credible hydrocarbon spill scenario – the instantaneous release of 1,062 cubic metres (m^3) of marine diesel oil/ marine gas oil (MDO/MGO) from the seismic survey vessel within the Operational Area. The spill trajectories from three modelled release locations have been combined 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 100 different simulations for any one-spill event (with three events modelled in total). Simplistically, each simulation considers a different combination of metocean conditions over time. An actual spill event is realistically represented by only one of the simulations and hence, have a much smaller spatial footprint.

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	1,062 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 in this section of the EP.

The Department of Agriculture, Water and the Environment (DAWE) Protected Matters Search Tool (PMST) was used to determine potential receptors such as Matters of National Environmental Significance (MNES) listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) within the Operational Area and the EMBA. The results of these searches are provided in **Appendix B**. 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 of the EP.

Table 3-2 below identifies the key values and sensitivities relevant to the Operational Area and EMBA and cross-references the relevant sections of this EP where the values and sensitivities are described.

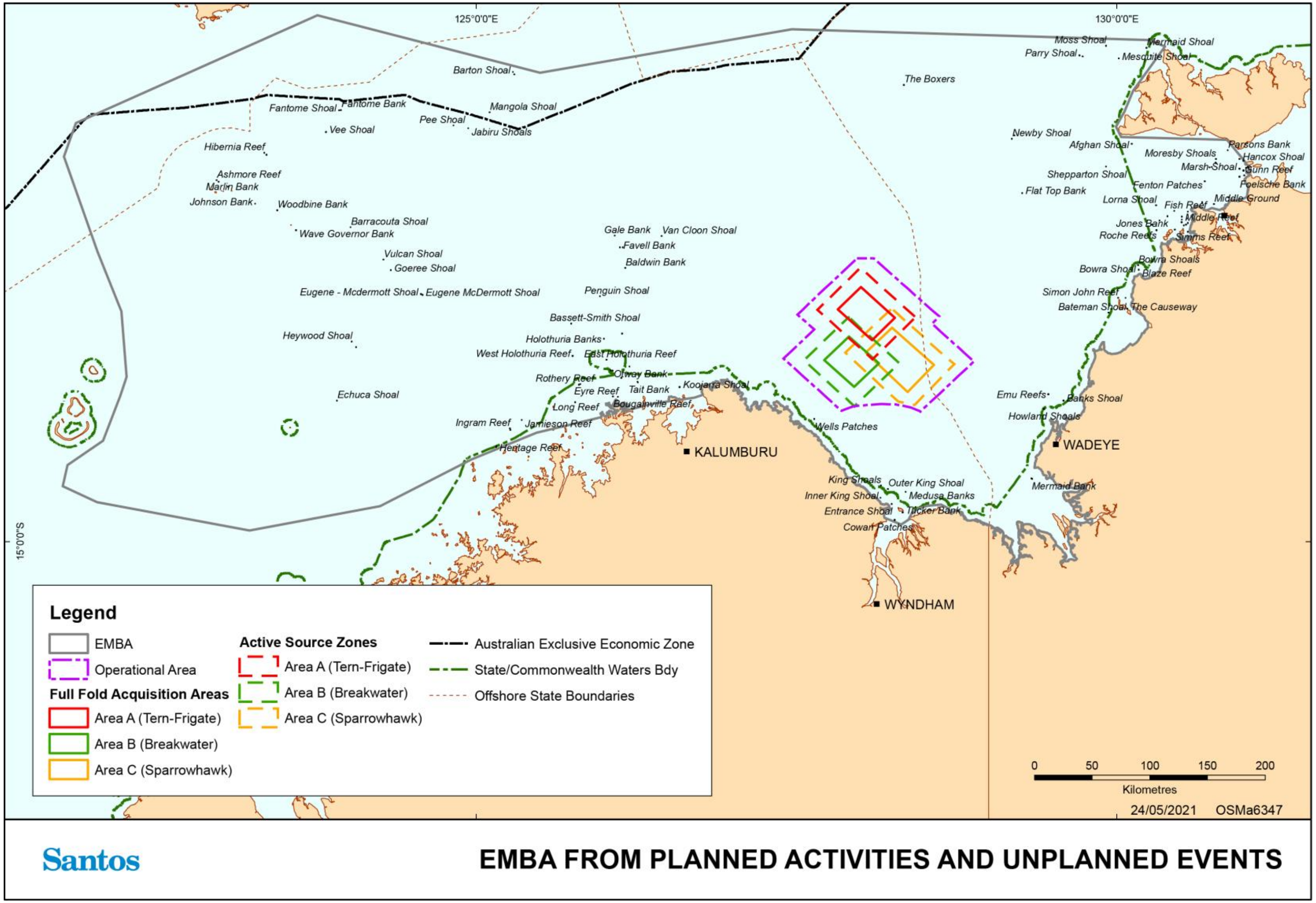


Figure 3-1: EMBA from planned activities and unplanned events

Table 3-2: Key environmental values and sensitivities relevant to the EMBA

Category	Key values and sensitivities within the EMBA	Proximity to Operational Area	Relevant Sections of this EP	Relevant events that may impact on the receptors
North-west Marine Region	-	Present in Operational Area and EMBA	3.3.1	N/A
North Marine Region	-	Present in Operational Area and EMBA		
Provincial Bioregions	Northwest Shelf Transition	Present in Operational Area and EMBA	3.3.2	
	Northwest Shelf Province	219 km W		
	Timor Province	255 km W		
Climate	-	Present in Operational Area and EMBA	3.4.1	N/A
Oceanography	-	Present in Operational Area and EMBA	3.4.2	
Bathymetry and Geomorphology	-	Present in Operational Area and EMBA	3.4.3	
Sedimentology	-	Present in Operational Area and EMBA	3.4.4	
Australian Marine Parks	Oceanic Shoals AMP (IUCN Category VI)	10 km N	3.5.1	Unplanned: • MDO/MGO release from vessel collision • Spill response operations
	Oceanic Shoals AMP (IUCN Category IV)	170 km NE		
	Oceanic Shoals AMP (IUCN Category II)	253 km NE		

Category	Key values and sensitivities within the EMBA	Proximity to Operational Area	Relevant Sections of this EP	Relevant events that may impact on the receptors
	JBG AMP (IUCN Category VI – Special Purpose)	12 km SE		
	JBG AMP (IUCN Category VI – Multiple Use)	35 km SE		
	Kimberley AMP	105 km W		
	Cartier Island AMP (IUCN Category Ia)	429 km WNW		
	Ashmore Reef AMP (IUCN Category Ia)	473 km WNW		
	Ashmore Reef AMP (IUCN Category IV)	500 km WNW		
State/Territory Marine Parks	North Kimberley Marine Park	23 km SW	3.5.23.5.2	
Key Ecological Features (KEF)	Pinnacles of the Bonaparte Basin	Present in Operational Area and EMBA	3.6.1	
	Carbonate bank and terrace system of the Sahul Shelf	Present in Operational Area and EMBA		
	Carbonate bank and terrae system of Van Diemen Rise	105 km NE		
	Ancient coastline at 125 m depth contour	280 km W		
	Continental slope demersal fish communities	405 km W		

Category	Key values and sensitivities within the EMBA	Proximity to Operational Area	Relevant Sections of this EP	Relevant events that may impact on the receptors
	Ashmore reef and Cartier Island and surrounding Commonwealth waters	428 km NW		
Commonwealth Heritage Places	Ashmore reef National Nature Reserve	472 km NW	3.5.4	
National Heritage Places	The west Kimberley	23 km SW	3.5.4	
Wetlands of International Importance (Ramsar wetlands)	Ashmore Reef National Nature Reserve	472 km NW	3.5.5	
Non-coral benthic Invertebrates	-	Present in Operational Area and EMBA	3.6.3	Planned: • Noise emissions Unplanned: • MDO/MGO release from vessel collision • Spill response operations • Introduction of invasive marine species
Coral Reefs	Ashmore Reef, Hibernia Reef and Cartier Island	430 km NW	3.6.4	Unplanned: • MDO/MGO release from vessel collision • Spill response operations
	Browse Island	420 km W		
	Coastal fringing reefs	Within the EMBA		
Seagrasses and Macroalgae	-	Within the EMBA	3.6.5	
Mangroves	-	Within the EMBA	3.6.2	Unplanned: • MDO/MGO release from vessel collision
Islands	-	Within the EMBA	3.6.2	

Category	Key values and sensitivities within the EMBA	Proximity to Operational Area	Relevant Sections of this EP	Relevant events that may impact on the receptors
				• Spill response operations
Marine Mammals	Australian snubfin dolphin foraging Biologically Important Area (BIA)	23 km SW	3.7.3	Planned: • Noise emissions • Light emissions • Planned operational discharge Unplanned: • Hazardous and non-hazardous unplanned discharges – liquid and solid • MDO/MGO release from vessel collision • Minor hydrocarbon release • Spill response operations • Marine fauna collisions • Introduction of invasive marine species
	Australian snubfin dolphin breeding BIA	23 km SW		
	Indo-Pacific humpback dolphin breeding BIA	228 km NE		
	Indo-Pacific humpback dolphin foraging BIA	95 km W		
	Indo-Pacific spotted bottlenose dolphin Breeding BIA	251 km NE		
	Pygmy blue whale migration BIA	317 km NW		
	Dugong foraging BIA	490 km NW		
	Dugong breeding BIA	506 km NW		
Marine Turtles	Loggerhead turtle foraging BIA	Present in Operational Area and EMBA	3.7.4	Planned: • Noise emissions • Light emissions • Planned operational discharge Unplanned: • Hazardous and non-hazardous unplanned discharges – liquid and solid
	Flatback turtle foraging BIA	Present in Operational Area and EMBA		
	Flatback turtle internesting BIA	Adjacent to Operational Area		
	Olive ridley turtle foraging BIA	Present in Operational Area and EMBA		

Category	Key values and sensitivities within the EMBA	Proximity to Operational Area	Relevant Sections of this EP	Relevant events that may impact on the receptors
	Olive ridley turtle internesting BIA	178 km NE		• MDO/MGO release from vessel collision • Minor hydrocarbon release • Spill response operations • Marine fauna collisions • Introduction of invasive marine species
	Green turtle foraging BIA	Present in Operational Area and EMBA		
	Green turtle interesting BIA	175 km W		
	Green turtle nesting BIA	190 km W		
	Green turtle mating BIA	500 km NW		
	Hawksbill turtle internesting BIA	480 km NW		
	Hawksbill turtle foraging BIA	500 km NW		
EPBC Act-listed Threatened and Migratory Fish Species	Whale shark foraging BIA	185 km	3.7.5	
Seabirds	Lesser crested tern breeding BIA	Present in Operational Area and EMBA	3.7.6	Planned: • Noise emissions • Light emissions • Planned operational discharge Unplanned: • Hazardous and non-hazardous unplanned discharges – liquid and solid • MDO/MGO release from vessel collision • Minor hydrocarbon release • Spill response operations • Introduction of invasive marine species
	Roseate tern breeding BIA	63 km W		
	Lesser frigatebird breeding BIA	63 km W		
	Greater frigatebird breeding BIA	395 km NW		
	Wedge-tailed shearwater breeding BIA	390 km NW		
	White-tailed tropicbird breeding BIA	395 km NW		
	Red-footed booby breeding BIA	390 km NW		

Category	Key values and sensitivities within the EMBA	Proximity to Operational Area	Relevant Sections of this EP	Relevant events that may impact on the receptors
	Brown booby breeding BIA	455 km W		
	Greater crested tern breeding BIA	285 km NE		
	Little tern breeding BIA	173 km W		
	Little tern resting BIA	480 km NW		
Commercial Fisheries	Commonwealth Northern Prawn Fishery	Historical fishing effort within the Operational Area	3.8.1	Planned: • Physical interaction • Noise emissions (to target species) Unplanned: • MDO/MGO release from vessel collision • Spill response operations • Introduction of invasive marine species
	Northern Demersal Scalefish Managed Fishery (WA)	Limited historical fishing effort within the Operational Area		
	WA Mackerel Managed Fishery (Area 1 – Kimberley)	Limited historical fishing effort within the Operational Area		
	NT Demersal Fishery	Limited historical fishing effort within the Operational Area		
	NT Spanish Mackerel Fishery	Limited historical fishing effort within the Operational Area		
	NT Offshore Net and Line Fishery	Limited historical fishing effort within the Operational Area		
Key Commercial Fish and Shellfish Species	Banana prawns	Present within the Operational Area and EMBA	3.8.1	Planned: • Noise emissions • Light emissions • Planned operational discharge Unplanned:
	Tiger prawns			
	Goldband snapper			
	Red emperor			
	Saddletail snapper			

<table>
<tr><th>Category</th><th>Key values and sensitivities within the EMBA</th><th>Proximity to Operational Area</th><th>Relevant Sections of this EP</th><th>Relevant events that may impact on the receptors</th></tr>
<tr><td rowspan="2"></td><td>Crimson snapper</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">Hazardous and non-hazardous unplanned discharges – liquid and solid
MDO/MGO release from vessel collision
Minor hydrocarbon release
Spill response operations
Introduction of invasive marine species</td></tr>
<tr><td>Spanish mackerel</td></tr>
<tr><td>Shipping</td><td>Vessel traffic</td><td>Overlaps the Operational Area</td><td>3.8.2</td><td>Planned:
Physical interaction
Unplanned:
MDO/MGO release from vessel collision
Spill response operations</td></tr>
<tr><td>Oil and Gas Activities</td><td>-</td><td>Present in EMBA</td><td>3.8.3</td><td rowspan="3">Planned:
Physical interaction
Unplanned:
MDO/MGO release from vessel collision
Spill response operations</td></tr>
<tr><td>Tourism and recreation</td><td>-</td><td>Present in EMBA</td><td>3.8.4</td></tr>
<tr><td>Defence</td><td>Northern Australian Exercise Area (NAXA)</td><td>Overlaps the Operational Area</td><td>3.8.5</td></tr>
<tr><td rowspan="3">Maritime and Cultural Heritage</td><td>Historic shipwrecks</td><td>53 km N</td><td rowspan="3">3.8.6</td><td rowspan="3">Unplanned:
MDO/MGO release from vessel collision
Spill response operations</td></tr>
<tr><td>Aboriginal heritage sites</td><td>Present on shoreline of EMBA</td></tr>
<tr><td>Native Title areas</td><td>25 km SW</td></tr>
</table>

3.3 Bioregions

3.3.1 Marine Regions

In 2008, the former Department of the Environment, Water, Heritage and the Arts (DEWHA) (now the DAWE) introduced marine bioregional planning. Under these plans, the Australian marine environment was categorised into six broad marine regions. Marine Bioregional Plans describe the marine environment and conservation values of each marine region, set out broad biodiversity objectives, identify regional priorities and outline strategies and actions to address these priorities (DoEE, n.d.).

The majority of the Operational Area is located within the North-west Marine Region (NWMR), however the eastern portion of the Operational Area also overlap with the North Marine Region (NMR) (Commonwealth waters offshore from the NT).

The Bioregional Plans for the NWMR (DSEWPaC 2012a) and NMR (DEWHA 2008b; DSEWPaC 2012b) have been used in conjunction with other relevant management plans, reports and published papers to inform this description of the environment.

3.3.1.1 North-west Marine Region

The NWMR comprises Commonwealth waters from the Western Australian-Northern Territory (WA-NT) border to Kalbarri, south of Shark Bay. The NWMR is characterised by the large area of continental shelf and continental slope, highly variable tidal regions and very high cyclone incidence. The NWMR is characterised by shallow-water tropical marine ecosystems, which is home to globally significant populations of internationally threatened species (DSEWPaC 2012a). Main physical features of the marine region include:

+ Extensive areas of continental shelf and slope, plateaux and terraces.
+ The narrowest continental shelf on Australia’s coastal margin.
+ Coralline algal reefs, and carbonate pinnacles and shoals.
+ Coral reefs which support high delivery of corals and associated fish and other species.
+ The JBG, a muddy basin with sparse coverage of sessile filter-feeding organisms and mobile invertebrates.
+ A number of major canyons on the continental slope that act as conduits for sediment and nutrient transport.
+ Two areas of abyssal plain with deep waters.
+ The Indonesian Throughflow (ITF).

3.3.1.2 North Marine Region

The NMR comprises Commonwealth waters from west Cape York Peninsula to the WA-NT border. The marine environment of the NMR is known for its high diversity of tropical species but relatively low endemism, in contrast to other bioregions. This region is highly influenced by tidal flows and less by ocean currents. The region is dominated by monsoonal climatic patterns characterised by a pronounced wet season and a generally dry season. Tropical cyclones are a dominant feature in the wet season (DEWHA 2008b). Physical features of the region include:

+ A wide continental shelf with water depths generally less than 70 m.

- The Van Diemen Rise, characterised by complex geomorphology with features including shelves, shoals, banks, terraces and valleys.
- The north of the region, a series of shallow canyons approximately 80-100 m deep.
- Numerous limestone pinnacles.
- The Arafura Shelf, an area of continental shelf.
- Submerged patch and barrier reefs that form a broken margin around the perimeter of the Gulf of Carpentaria.
- The Gulf of Carpentaria coastal zone – waters up to 20 m deep.
- Currents driven largely by strong winds and tides.
- Complex weather cycles and a tropical monsoonal climate.

3.3.2 Provincial Bioregions

Based on the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) Version 4.0, the Operational Area overlaps the Northwest Shelf Transition within both the North-west Marine Region (NWMR) and North Marine Region (NMR). The EMBA also overlaps this province, as well as the Northwest Shelf Province and Timor Province of the NWMR (refer to **Figure 3-2**).

3.3.2.1 Northwest Shelf Transition

The Northwest Shelf Transition, which straddles both the NWMR and NMR, is characterised by the following biophysical features (DSEWPaC 2012a):

- Located mostly on the continental shelf, with some small areas extending onto the continental slope.
- Water depths range between 0-330 m, with the majority of the bioregion occurring in depths of 10-100 m.
- The Indonesian Throughflow (ITF) is the dominant oceanographic feature and dominates the majority of the water column.
- The strength of the ITF and its influence in the bioregion varies seasonally in association with the North-west Monsoon.
- Contains a variety of geomorphic features, including terraces, plateaus, sand banks, canyons and reefs.
- The biological communities of the North-west Shelf Transition are typical of Indo-west Pacific tropical flora and fauna, and occur across a range of soft-bottom and harder substrate habitats.

3.3.2.2 Northwest Shelf Province

The Northwest Shelf Province, within the NWMR, is characterised by the following biophysical features (DEWHA 2008a):

- Located mostly on the continental shelf between North West Cape and Cape Bougainville.
- Water depths range between 0-200 m.
- Dynamic oceanographic environment, influenced by strong tides, cyclonic storms, long-period swells and internal tides. Warm, oligotrophic waters derived from the ITF.

- The biological communities include diverse benthic and pelagic fish communities associated with different depth ranges, seabird breeding sites and cetacean (humpback whale) migration route.

3.3.2.3 Timor Province

The Timor Province, within the NWMR, is characterised by the following biophysical features (DEWHA 2008a):

- Covers almost 15% of the NWMR, predominantly covering the continental slope and abyss between Broome and Cape Bougainville.
- Water depths range from 200 m near the shelf break to over 5,920 m over the Argo Abyssal Plain.
- Major geomorphic features include the Scott Plateau, the Ashmore Terrace, part of the Rowley Terrace and the Bowers Canyon.
- Important features include Ashmore Reef, Cartier Island, Seringapatam Reef and Scott Reef.
- Dominated by warm, oligotrophic waters derived from the ITF. The thermocline in the water column in particularly pronounced and associated with the generation of internal tides.
- Several distinct habitats and biological communities occur within the region, and the reefs and islands are regarded as biodiversity hotspots. A high level of endemicity exists in the demersal fish communities of the continental slope in the Timor Province.

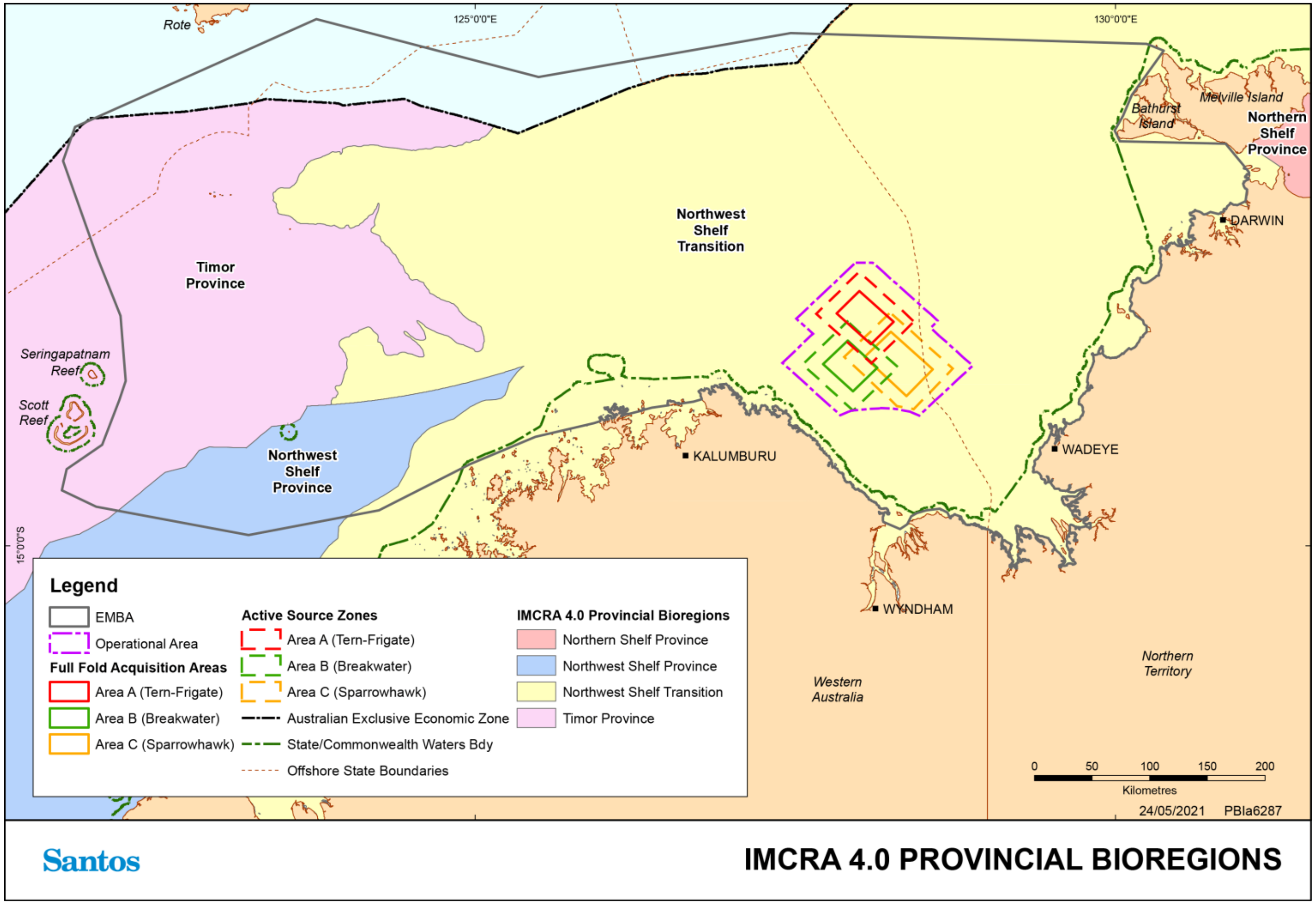


Figure 3-2: IMCRA 4.0 Provincial Bioregions

Santos

3.4 Physical Environment

3.4.1 Climate

The region has a tropical monsoonal climate with two distinct seasons known as the North-west Monsoon or “wet season” (late October to mid-March) and the South-east Monsoon or “dry season” (May to mid-October) (DSEWPaC 2012a). The North-west Monsoon is characterised by regular and high rainfall, particularly over coastal areas and during cyclones. This is due to large amounts of moisture being gathered as the monsoon crosses the sea from the Asian high-pressure belt on its way to the intertropical convergence zone, which migrates southward close to or over northern Australia. Conversely, the South-east Monsoon originates from the Southern Hemisphere high-pressure belt and is relatively dry and cool (DSEWPaC 2012a).

Tropical cyclones are common in the region, occurring between December and April (BoM 2019a). These phenomena result in severe storms with gale force winds and a rapid rise in water levels. Tropical cyclones usually form in an active monsoon trough, producing heavy rains, strong wind, large swells and storm surges. On average, about five cyclones occur each year in the NWMR, two of which make landfall and one of which is severe (Category 3 or higher). The chance of a severe cyclone occurring is highest in March and April (BoM 2019a).

Dum In Mirrie Airstrip, Channel Point, Port Keats Airport and Truscott are four weather stations near to the Operational Area, providing an overview of the localised climate. A summary of the seasonal ranges in mean temperature, rainfall and wind speeds recorded are summarised in **Table 3-3**.

Table 3-3: Seasonal mean temperature, rainfall and wind speed ranges

Weather Station	Distance from Operational Area	Season	Temperature (°C)	Monthly Rainfall (mm)	Wind Speed (km/h)
Dum In Mirrie Airstrip	190 km east-north-east	Wet	25.4 – 33.1	128.3 – 424.2	10.2 – 15.5
		Dry	18.3 – 32.3	1.0 – 60.7	9.5 – 15.7
Channel Point	140 km east	Wet	24.7 – 32.3	130.1 – 459.8	5.4 – 10.7
		Dry	17.2 – 32.3	0.1 – 66.1	5.6 – 13.0
Port Keats Airport	100 km south-east	Wet	20.2 – 34.4	80 – 312.2	No data
		Dry	16.8 – 34.4	0.7 – 43.8	No data
Truscott	135 km south-west	Wet	25.2 – 35.1	28.6 – 325.0	No data
		Dry	18.5 – 30.3	0.2 – 24.5	No data

BoM 2019b, 2019c, 2019d and 2019e. N.B. Wind speed ranges include both 9 am and 3 pm conditions.

3.4.2 Oceanography

3.4.2.1 Currents

The Operational Area is dominated by surface currents heavily influenced by both tidal motions and the ITF, which transports warm waters from the Pacific Ocean into the Indian Ocean through the Indonesian seas. The strength of the ITF is seasonal; it is weakened during the wet season when the strong south-westerly winds cause intermittent reversals of the currents (Brewer et al. 2007). The strengthening of the ITF in the dry season coincides with the development of the prevailing south-westerly flowing Holloway Current, which transports waters from the Banda and Arafura seas and the Gulf of Carpentaria southwards along the shelf (DEWHA 2008b).

Circulation in the JBG is dominated by the large tidal currents, which rotate in a clockwise direction. Current speeds increase towards the shoreline and become increasingly directed longshore. These large currents are responsible for the generation of dune forms on the seabed, as noted in Admiralty Charts for the region (ENI 2006).

3.4.2.2 Waves

Short period waves within the JBG are generated by local synoptic winds and are typically largest during winter months when the south-easterly trade winds dominate (Maxwell et al. 2004).

Long period waves are influenced by swells generated in the Southern Ocean. In the Bonaparte Basin, the Southern Ocean swell is slightly higher during winter than in summer due to the northerly migration of swell-generating storms. The wave period and significant wave height generated by this swell is highly dependent on the exact location within the basin. For example, the JBG is protected from the Southern Ocean swell and therefore swells affecting the area are limited to those generated by cyclones or prolonged storm winds (Maxwell et al. 2004).

The region is a moderate-energy environment except when influenced by tropical cyclones, which generate short-term major fluctuations in sea levels. Depending on the size, intensity, speed and relative location of the cyclone, swells generated may have periods of 6-18 s and wave heights of 0.5-9 m.

3.4.2.3 Tides

The tides of the region are mixed and predominantly semi-diurnal (two high tides and two low tides per day), with well-developed spring to neap tidal variation (DSEWPaC 2012a). The oceanographic environment of the JBG features some of the largest tidal ranges, exceeding 8 m along the western side of the Gulf during the spring tide (CSIRO 2005). There is a well-defined spring-neap lunar cycle, with spring tides occurring two days after the new and full moon.

Within the Northwest Shelf Transition provincial bioregion, tides range from 2-3 m offshore (micro-tidal) rising to 3-4 m inshore (meso-tidal). The tidal range within the Operational Area is expected to be variable, with the highest ranges occurring nearshore the JBG along the western portion of the Operational Area, and a relatively low range along the eastern portion, following a north-east to south-west contour. The predicted tidal range south-west of the Operational Area at Rocky Island (approximately 32 km away) is expected to be between 0.12 m and 3.32 m (BOM 2019f).

Superimposed on the astronomical tide are 'meteorological' tides resulting from changes in atmospheric pressure and strong onshore or offshore winds. Seasonal changes of mean sea level in

Darwin are only approximately 0.15 m while offshore, the changes are expected to be considerably less and quite insignificant (approximately 0.05 m) (RPS 2011).

3.4.2.4 Sea Temperature and Salinity

Sea temperatures and salinity in the region are heavily influenced by the ITF, which transports warm, low salinity water from the western Pacific Ocean through to the Indian Ocean (DSEWPaC 2012a). Although water temperatures in the region are among the highest in Australia and considered high by global standards (DSEWPaC 2012a), during the North-west Monsoon, a thermocline flow of relatively cool water dominates resulting in the tropical Indian Ocean being cooled rather than warmed. Average surface water temperature in the Operational Area ranges from 26.0°C to 30.2°C (**Table 3-4**).

Salinity in the Operational Area ranges from 33.4 psu to 34.7 psu (**Table 3-4**). Modelled seawater salinity profiles in the Bonaparte Basin indicated that there is little variation in salinity through the water column, monthly or seasonally (RPS 2011).

Table 3-4: Monthly average sea surface temperature and salinity in the Operational Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	29.6	30.2	29.6	29.9	27.3	27.2	26.2	26.0	27.4	28.8	29.3	29.5
Salinity (psu)	35.1	34.5	35.2	35.3	34.5	34.8	34.6	35.5	35.4	35.1	34.9	34.8

NOAA 2019a, 2019b

Environmental Resources Management Australia Pty Ltd (ERM) undertook two marine baseline studies in 2010 (wet season) and 2011 (dry season) within the Bonaparte Basin (in particular within the following petroleum titles: WA-6-R, NT/RL1, WA-27-R) in support of GDF SUEZ Bonaparte LNG Project (ERM 2011). The studies indicated that temperature gradients throughout the water column did not display a thermocline. Instead, a vertical gradient in seawater temperature was observed in which temperature decreased progressively from the surface to the bottom ranging from 32.1°C to 25.3°C (ERM 2011).

3.4.2.5 Water Quality

The ITF brings in oligotrophic (low in nutrients) waters from the western Pacific Ocean through to the Indian Ocean (DEWHA 2008b). Exceptions in the region occur in the event of local or regional upwelling activity at the shelf break, where deeper, cooler nutrient rich water is brought to the surface (DEWHA 2008b). These upwelling activities include, but are not limited to, internal wave and tide regimes, horizontal shear due to strong tidal currents and tropical cyclones. However, understanding of the nature and spatial distribution of biological productivity in the region is limited (DEWHA 2008b).

The marine baseline studies undertaken by ERM in 2010 and 2011 showed that water quality in the Bonaparte Basin is relatively pristine with results typical of nutrient poor offshore northern Australian waters. The surveys measured dissolved oxygen (DO) concentrations and total suspended solids (TSS). DO concentrations ranged from a minimum of 3.64 mg/L (49.8%) near the seabed to 7.80 mg/L (117.2%) at the sea surface. DO was found to decrease with depth consistently. This is often linked to higher photosynthetic activity at the seawater surface and wave/wind generated mixing. These values are typical of unpolluted seawater (ERM 2011). TSS levels were low across the area during the time of sampling. The data represents relatively low suspended solid values as would be expected for offshore waters in the region (ERM 2011).

3.4.3 Bathymetry and Geomorphology

The Operational Area is predominately characterised by a relatively flat and largely featureless seabed, which gradually slopes from south (approximately 40 m deep) to north (approximately 107 m deep). The water depths of the Active Source Zones and Full-fold Acquisition Areas are outlined in **Table 3-5**.

Table 3-5: Water depths in the Active Source Zones and Full-fold Acquisition Areas

	Water Depth Range (m)	
	Active Source Zones	**Full-fold Acquisition Areas**
Area A	74 – 105	78 – 103
Area B	60 – 95	62 – 85
Area C	45 – 92	60 – 84

Seabed morphology in parts of the JBG is influenced by the strong tidal movement and channels of the Ord, Keep, Victoria and Fitzmaurice rivers. A series of extensive sandbars, known as the King Shoals and Medusa Banks (approximately 50 km south of the Operational Area), have been generated by the strong outflows of sediment-laden water from Cambridge Gulf. Similar sandbars can be found in the south-east of the JBG.

Ten key geomorphic features have been identified in the JBG (Przeslawski et al. 2011). The inner gulf comprises mostly 'shelf' with 'sand banks' and 'valleys'. The outer gulf and Timor Sea mostly comprise 'basin' with 'banks/shoals', 'terraces' and 'pinnacles' separated by 'deep/hole/valley' features and escarpment. Four of these features are present in the Operational Area, as detailed below and as shown in **Table 3-6** and **Figure 3-3**.

The majority of the Operational Area is characterised as relatively featureless 'shelf' and 'basin' geomorphologic features. The western corners of the Active Source Zones for Area A and Area B overlap with a series of banks, which form part of the carbonate bank and terrace system of the Sahul Shelf Key Ecological Feature (KEF) (refer to **Section 3.6.1**). At their shallowest points, these banks rise to approximately 62 m below surface.

A single 'pinnacle' is located within the north-west corner of the Full-fold Acquisition Area for Area A and another pinnacle in the north-west of the associated Active Source Zone. The pinnacles form part of the pinnacles of the Bonaparte Basin KEF (refer to **Section 3.6.1**). It is noted that the bathymetry of these two particular pinnacle features (defined due to their relatively steep gradient) does not differ significantly from the surrounding basin; at their shallowest points, these two features rise from water depths of approximately 90 m to approximately 75 m of the sea surface.

The bank and pinnacle features in the Operational Area are therefore relatively deep water features which are not as shallow or prominent as other bank, shoal or pinnacle features that occur in the wider Bonaparte Basin and EMBA. Some of the banks and pinnacles present in the wider region can rise to within less than 30 m of the sea surface (Brewer et al. 2007; Nichol et al. 2013).

Table 3-6: Geomorphic features relevant to the Operational Area (Przeslawski et al. 2011; DSEWPaC 2012a).

Geomorphic Feature	Operational Area	Active Source Zones		
		Area A	Area B	Area C
Shelf - sediment plains that are swept by strong tidal currents and are subject to large influxes of suspended sediment and freshwater.	✓	✓	✓	✓
Pinnacle - hard substrate in an otherwise soft sediment environment.	✓	✓		
Bank/ Shoals - elevated features with a relatively high proportion of hard substrate that support patches of moderately dense flora and fauna.	✓	✓	✓	
Basin - low-relief expanses of unconsolidated sediment.	✓	✓		✓

3.4.4 Sedimentology

The sedimentology of the NWMR is varied due to the diversity of physical features from coral reefs to a number of major canyons that act as conduits for sediment and nutrient transport (DSEWPaC 2012a). Sedimentology in the NMR is also varied, with physical features including shallow canyons, which mainly consist of calcium carbonate, based sediments, as well as limestone pinnacles and reefs (DEWHA 2008b).

The continental shelf in the JBG is the widest in Australia, extending up to 400 km from the shore. The sedimentology of the JBG is unique, with most of the inner shelf being characterised by relatively flat expanses of soft sediment seabed with localised rocky outcrops, gravel deposits and sands banks. The soft sediments in the region typically consist of sandy and muddy substrate, occasionally made up of patches of coarser sediments (Baker et al. 2008). The inner shelf section of the JBG receives significant loads of sediments from several large rivers including the Daly and Victoria rivers (Przeslawski et al. 2011).

The distribution of seabed sediments in the JBG, and in particular within the Sahul Shelf, reflects the present-day oceanographic condition and displays a distinct seaward fining pattern (Lees 1992, in Baker et al. 2008).

Sediment sampling undertaken by ERM in 2010 and 2011 (within WA-6-R and NT/RL1) confirms that the area is mainly dominated by sand, with similar proportions of smaller gravel, silt and clay (ERM 2011).

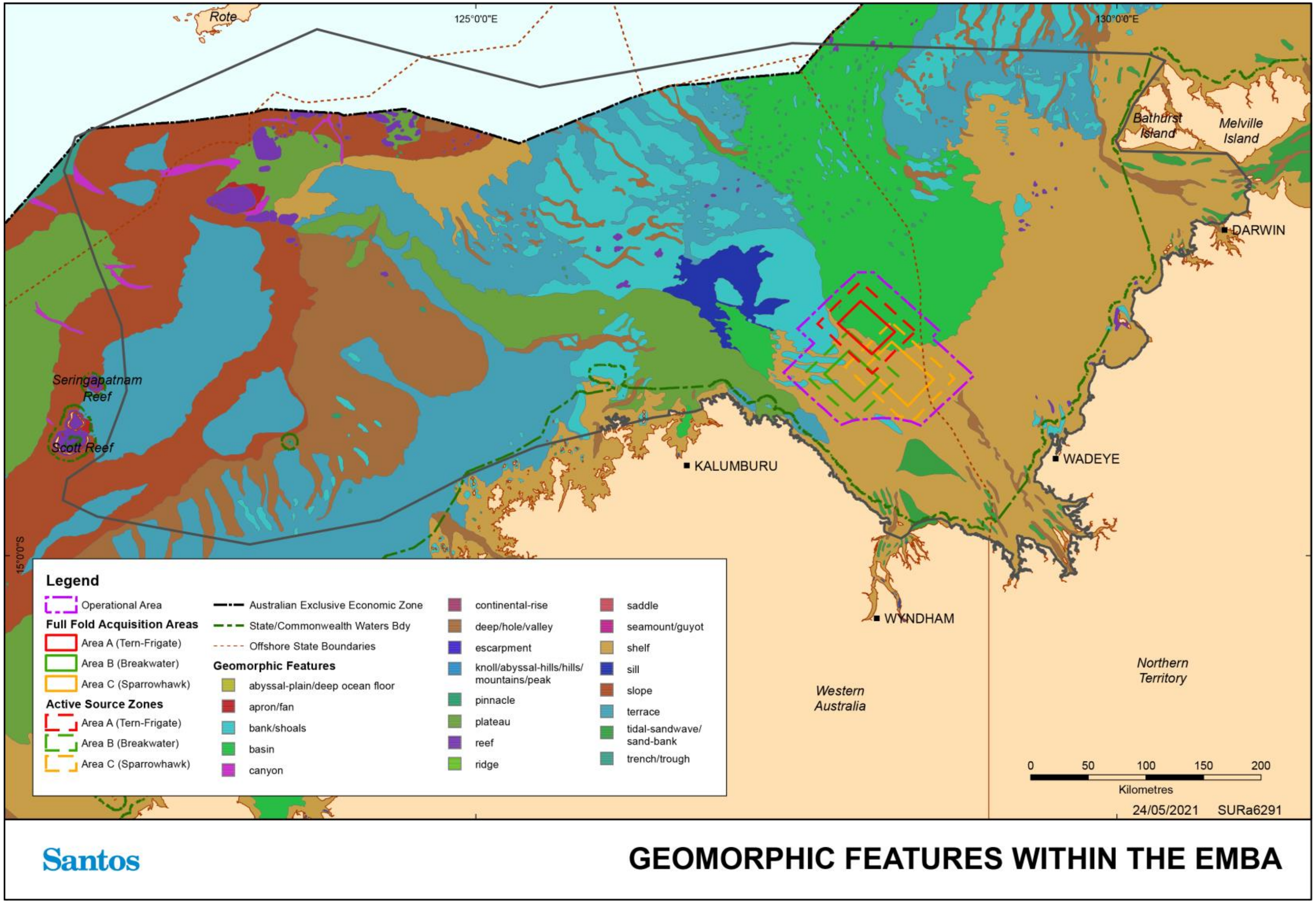


Figure 3-3: Geomorphic features of the EMBA

3.5 Protected / Significant Areas

3.5.1 Australian Marine Parks

The Australian Marine Park (AMP) Network has been established around Australia as part of the National Representative System of Marine Protected Areas (NRSMPA). The primary goal of the NRSMPA is to establish and effectively manage a comprehensive, adequate and representative system of marine parks to contribute to the long-term conservation of marine ecosystems and protect marine biodiversity.

Under the EPBC Act, the AMP Network, and any zones within it, must be assigned to an International Union for Conservation of Nature (IUCN) Category. Conservation objectives for IUCN categories include:

+ Ia: Strict Nature Reserve
+ Ib: Wilderness Area
+ II: National Park
+ III: Natural Monument or Feature
+ IV: Habitat/Species Management Area
+ V: Protected Landscape
+ VI: Protected area with sustainable use of natural resources – allows human use but prohibits large-scale development.

The Operational Area does not overlap with any AMPs; however, five AMPs overlap with the EMBA (**Figure 3-4**). These are presented in **Table 3-7**.

Table 3-7: Australian Marine Parks relevant to the EMBA

AMP	IUCN Category Zone	Distance to the Operational Area
Oceanic Shoals AMP	Multiple Use Zone (IUCN VI)	10 km north
	Special Purpose Zone (Trawl) (IUCN VI)	114 km north
	Habitat Protection Zone (IUCN IV)	170 km north-east
	National Park Zone (IUCN II)	253 km north-east
JBG AMP	Special Purpose Zone (IUCN VI)	12 km south-east
	Multiple Use Zone (IUCN VI)	35 km south-east
Kimberley AMP	Multiple Use Zone (IUCN VI)	105 km west
Cartier Island AMP	Sanctuary Zone (IUCN Ia)	429 km west-north-west
Ashmore Reef AMP	Sanctuary Zone (IUCN Ia)	473 km west-north-west
	Recreational Use Zone (IUCN IV)	500 km west-north-west

The Kimberley, Cartier Island and Ashmore Reef AMPs are formally managed under the NWMR management framework, whilst the Oceanic Shoals and JBG AMPs are formally managed under the NMR management framework (see **Section 3.3.1**).

Each AMP and their values are summarised below based on the values described in the North-west Marine Parks Network Management Plan (Director of National Parks [DNP] 2018a) and North Marine Parks Network Management Plan (DNP 2018b).

The overarching values of the North-west Marine Parks Network Management Plan and North Marine Parks Network Management Plan are:

+ **Natural values** – habitats, species and ecological communities within marine parks, and the processes that support their connectivity, productivity and function.
+ **Cultural values** – living and cultural heritage recognising Indigenous beliefs, practices and obligations for country, places of cultural significance and cultural heritage sites.
+ **Heritage values** – non-indigenous heritage that has aesthetic, historic, scientific or social significance.
+ **Socio-economic values** – the benefit of marine parks for people, businesses and the economy.

3.5.1.1 Joseph Bonaparte Gulf AMP

The JBG AMP is located approximately 15 km west of Wadeye, NT, and approximately 90 km north of Wyndham, WA, in the JBG. The JBG AMP covers an area of 8,597 km² with water depths from less than 15 m to 100 m. The JBG AMP is designated as IUCN Category VI, with two zones assigned under this category: Special Purpose Zone (VI) and Multiple Use Zone (VI). Commercial activities, such as fishing, tourism, and oil and gas exploration, are permitted within the JBG AMP Multiple Use Zone and Special Purpose Zone.

The JBG AMP is characterised by:

+ A number of prominent shallow seafloor features including an emergent reef system, shoals, and sand banks.
+ Habitats connecting to and complementing the adjacent WA State North Kimberley Marine Park.
+ Ecosystems representative of the Northwest Shelf Transition— a dynamic environment influenced by strong tidal currents, monsoonal winds, cyclones and wind generated waves. The large tidal ranges and wide intertidal zones near the AMP create a physically dynamic and turbid marine environment.
+ Biologically Important Areas (BIAs) for foraging and internesting marine turtles and the Australian snubfin dolphin. Further information on BIA and species of conservation interest is provided in **Section 3.7.2**.
+ Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing.
+ Tourism, commercial fishing, mining and recreation (including fishing) are important activities in the AMP.
+ The presence of the carbonate bank and terrace system of the Sahul Shelf KEF (refer to Section **3.6.1**).

3.5.1.2 Oceanic Shoals AMP

The Oceanic Shoals AMP is located west of the Tiwi Islands, approximately 155 km north-west of Darwin, Northern Territory and 305 km north of Wyndham, Western Australia. It extends to the limit of Australia's Exclusive Economic Zone (EEZ). The Oceanic Shoals AMP covers an area of 71,743 km^2 and water depths from less than 15 m to 500 m, and is the largest marine park in the North Marine Parks Network.

The Oceanic Shoals AMP is characterised by:

+ Examples of ecosystems representative of the Northwest Shelf Transition. The pinnacles, carbonate banks and shoals within the AMP are sites of enhanced biological productivity.
+ Four KEFs (refer to **Section 3.6.1**), namely:
  - Carbonate bank and terrace systems of the Van Diemen Rise;
  - Carbonate bank and terrace system of the Sahul Shelf;
  - Pinnacles of the Bonaparte Basin; and
  - Shelf break and slope of the Arafura Shelf.
+ Foraging and internesting BIA for marine turtles (**Section 3.7.2**).
+ Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing.
+ Commercial fishing and mining are important activities in the AMP.

3.5.1.3 Kimberley AMP

The Kimberley AMP is approximately 100 km north of Broome, WA and the central part of the Kimberley AMP is adjacent to the WA Camden Sound State Marine Park. It covers 74,469 km^2, with depths from less than 15 m to 800 m.

The Kimberley AMP is characterised by:

+ High numbers of marine mammals such as dolphins, whales and dugong. The humpback whale breeds and calves in the Kimberley AMP annually after undertaking an extensive migration from Antarctica. Three dolphin species (Australian snubfin dolphin, Info-Pacific humpback dolphin and spotted bottlenose dolphin) use the Kimberley AMP to forage within and travel to coastal waters to calve and raise their young in inshore, protected waters.
+ Important foraging rounds for seabirds and shorebirds known to breed on Adele Island (outside of the EMBA), including critically endangered eastern curlews and curlew sandpipers.
+ Sea country within the AMP is valued for Indigenous cultural identity, health and wellbeing.
+ Tourism, commercial fishing, mining, recreation (including fishing) and traditional use are important activities in the AMP.

There are no KEFs within the Kimberley AMP.

3.5.1.4 Cartier Island AMP

The Cartier Island AMP lies in the Timor Sea within the Australian External Territory (AET) of Ashmore and Cartier Islands, approximately 600 km north of Broome, WA. It covers 172 km², with water depths from less than 15 m to 500 m. The south-flowing Leeuwin Current originates in this region, and transports marine life southwards.

The entire Carter Island AMP is characterised by:

+ Important habitat for seasnakes, turtles, whale sharks, corals, sea fans and sponges. This marine park and the nearby Ashmore Reef AMP are marine biodiversity hotspots, supporting a rich diversity of species and high numbers of individuals.
+ Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing.
+ Scientific research is an important activity in the AMP.
+ Two KEFs, namely:
  - The continental slope demersal fish communities KEF, characterised by high levels of endemic fish; and
  - The Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF, characterised by enhanced primarily productivity and aggregations of marine life.

Further information on the KEFs is provided in **Section 3.6.1**.

3.5.1.5 Ashmore Reef AMP

The Ashmore Reef AMP is in the AET of Ashmore and Cartier Islands, approximately 630 km north of Broome, WA. It covers 583 km², with depths less than 15 m to 500 m. The Ashmore Reef AMP is comprised of three small islands, lagoons, sand flats, reef flats with a high diversity of hard and soft corals and sponges, and large seagrass meadows. The AMP is a Sanctuary Zone with a small Recreational Use Zone allowing access to the most westerly island (Australian Marine Parks, 2021b).

The Ashmore Reef AMP is characterised by:

+ The presence of around 100,000 seabirds than come to breed each year, including greater crested terns, white-tailed tropicbirds and greater frigatebirds, and 10,000's of migratory shorebirds that forage in the surrounding waters, such as curlew sandpipers, bar-tailed godwits and great knots. It is also a breeding site for green turtles.
+ Sea country within the AMP is valued for Indigenous cultural identity, health and wellbeing.
+ Tourism, recreation and scientific research are important activities in the Marine Park.
+ Two KEFs, namely:
  - The continental slope demersal fish communities KEF; and
  - The Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF.
+ The presence of the Ashmore Reef National Nature Reserve Ramsar site (Australian Marine Parks, 2021b).

Further information on KEFs and Ramsar sites is provided in **Section 3.6.1** and **Section 3.5.5** respectively.

3.5.2 State/Territory Marine Parks

A review of the WA-NT marine parks and reserves did not identify any current or proposed marine parks or reserves within the Operational Area. The closest State/Territory marine park is the North Kimberley Marine Park (NKMP), located within the EMBA and in WA waters, approximately 23 km south-west of the Operational Area (DPaW 2016a) (**Figure 3-4**). Values for this marine park are outlined below.

3.5.2.1 North Kimberley Marine Park

The North Kimberley Marine Park is located in the Indian Ocean and Timor Sea, in the waters of WA's Kimberley region. It extends north-east from York Sound, around Cape Londonderry and the JBG, to the WA-NT border, and from the mainland high water mark to the limit of state coastal waters (DPaW 2016b). It covers approximately 18,450 km², and is the largest marine park in WA and the second largest state marine park in Australia (DPaW 2016b).

The marine park surrounds thousands of islands with diverse and rich habitats. Marine turtle nesting sites and breeding sites for seabirds and migratory shorebirds have been identified within the marine park, and fringing reefs line the shores of almost all of the islands (DPaW 2016b). The productive deep waters that surround the islands and open sea reefs provide foraging habitat for marine mammals and pelagic fish, such as mackerel (DPaW 2016b). The complex coastline of the mainland also creates a variety of habitats and communities, including important areas for dugongs, Australian snubfin dolphins and Australian humpback dolphins (DPaW 2016b).

The marine park also contains many places of cultural and spiritual importance to traditional owners (DPaW 2016b).

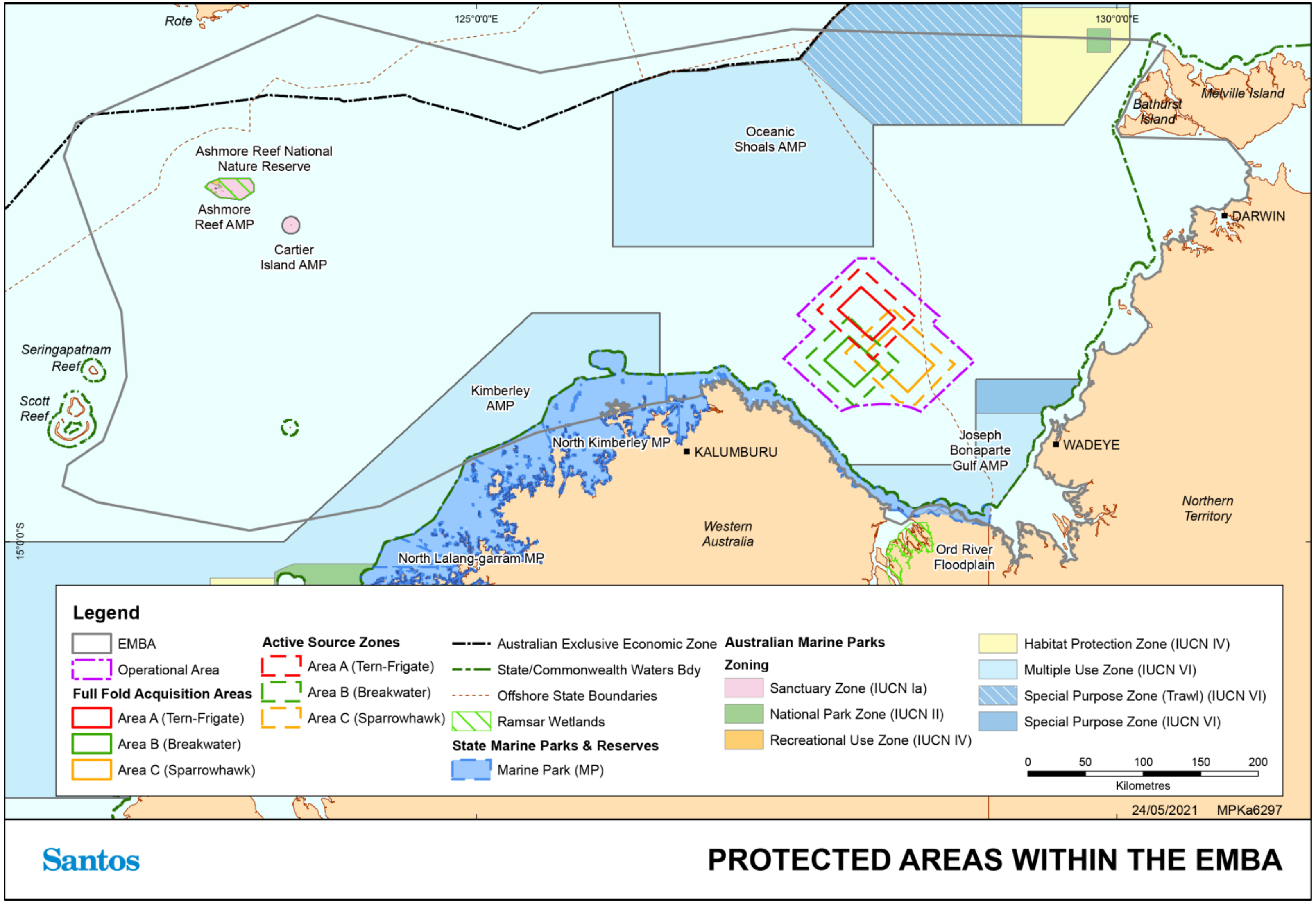


Figure 3-4: Protected areas within the EMBA

Santos

3.5.3 Threatened Ecological Communities

There are no Threatened Ecological Communities (TECs) within the Operational Area or EMBA.

3.5.4 World, Commonwealth and National Heritage Places

World heritage sites are natural or man-made sites, areas, or structures recognized as being of outstanding universal value by the United Nations Educational, Scientific and Cultural Organization (UNESCO). No listed World or National Heritage places were identified within the Operational Area; however, the west Kimberley National Heritage place is located within the EMBA, approximately 23 km south-west of the Operational Area.

Australia's National Heritage List contains natural, historic and Indigenous places of significance to the nation, which are protected under the EPBC Act (DoEE n.d.g). The Ashmore reef National Nature Reserve Commonwealth place is found within the EMBA, 472 km west north-west of the Operational Area.

3.5.5 Wetlands of International Importance

The Ramsar Convention on Wetlands is an intergovernmental treaty that aims to conserve wetlands of international importance. Ramsar wetlands are recognised as a matter of national environmental significance under the EPBC Act (DoEE n.d.g).

No Ramsar wetlands occur within the Operational Area; however the Ashmore Reef National Nature Reserve Ramsar site is located within the EMBA, approximately 473 km west north-west of the Operational Area.

3.6 Biological Environment

3.6.1 Key Ecological Features

KEFs are parts of the marine environment that are considered to be of importance for a marine region's biodiversity or ecosystem function and integrity (DoEE n.d.g). KEFs have been identified by the Australian Government using advice from scientists about the ecological processes and characteristics of the area. There are five KEFs within the EMBA, as listed in **Table 3-8** and described in the following sections. The Operational Area overlaps two KEFs:

+ Pinnacles of the Bonaparte Basin, and
+ Carbonate bank and terrace system of the Sahul Shelf.

Table 3-8: Key Ecological Features within the EMBA

KEF	Overlap (%)	
	Operational Area	Active Source Zones
Pinnacles of the Bonaparte Basin	1.52	1.52
Carbonate bank and terrace system of the Sahul Shelf	3.36	1.23
Carbonate bank and terrace system of the Van Diemen Rise	0	0
Ancient Coastline at 125 m Depth Contour	0	0
Continental slope demersal fish communities	0	0
Ashmore Reef and Cartier Island and surrounding Commonwealth waters	0	0

3.6.1.1 Pinnacles of the Bonaparte Basin

The limestone pinnacles of the Bonaparte Basin lie on the mid-outer shelf in the western JBG. The pinnacles are defined as a KEF because they are a unique seafloor feature with ecological properties of regional significance.

The pinnacles provide areas of hard substrate in an otherwise soft sediment environment and are therefore important for sessile species. Pinnacles typically rise steeply from depths of about 80 m and emerge to within 30 m of the water surface, allowing light dependent organisms to thrive. Pinnacles that rise to within at least 45 m of the water surface support more biodiversity. Communities include sessile benthic invertebrates including hard and soft corals, sponges, whips, fans, bryozoans and aggregations of demersal fish species such as snappers, emperors and groupers (Brewer et al. 2007; Nichol et al. 2013). The pinnacles are also recognised as a biodiversity hotspot for sponges as they are home to more sponge species and different communities than the surrounding seafloor (NERP MBH 2014).

The Active Source Zone for Area A overlaps with two pinnacles, which rise from water depths of approximately 90 m to approximately 75 m, and each occupies an area of less than 5 km^2 (refer to **Figure 3-5**).

3.6.1.2 Carbonate bank and terrace system of the Sahul Shelf

The carbonate bank and terrace system of the Sahul Shelf KEF is located in the western JBG and to the north of Cape Bougainville and Cape Londonderry. The carbonate banks and terrace system of the Sahul Shelf is defined as a KEF for its role in enhancing biodiversity and local productivity relative to its surrounds as it is a unique seafloor feature supporting relatively high species diversity, making it regionally significant.

The KEF provides areas of hard substrate in an otherwise soft sediment environment, important for sessile species. Banks rise from depths of approximately 80 m to within 30 m of the surface. Banks that rise to within 45 m water depth support more biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans (Brewer et al. 2007; Nichol et al. 2013). Brewer et al. (2007) also noted that banks within the KEF support aggregations of demersal fish species such as snappers, emperors and groupers.

The banks are recognised as a biodiversity hotspot for sponges with more species and different communities than the surrounding seafloor (NERP MBH 2014). The KEF is also known as a foraging area for flatback, olive ridley and loggerhead turtles (DSEWPaC 2012a). Common threats to the KEF include changes in sea temperature and ocean acidification, both derived from climate change, as well as extraction of living sources from illegal, unreported and unregulated fishing (Brewer et al. 2007; Nichol et al. 2013).

3.6.1.3 Carbonate bank and terrace system of Van Diemen Rise

The carbonate bank and terrace system of the Van Diemen Rise KEF is located on the north-eastern side of the JBG and partially overlaps with the north-east of the EMBA (**Figure 3-5**). The KEF is considered important for its role in enhancing biodiversity and local productivity relative to its surrounds and for supporting relatively high species diversity. The KEF covers an area of 31,278 km^2.

The KEF is characterised by banks, ridges and terraces with relatively high proportions of hard substrate (DAWE 2021). Channel systems between the banks range from approximately 60–150 m to 10–40 m in depth (Anderson et al. 2011) and supports sponge and octocoral gardens by providing epifauna habitat in an otherwise flat environment (Przeslawski et al. 2011). Whilst reef-forming corals are rare throughout the JBG, some locally dense hard corals were found on the banks of the Van Diemen rise during marine surveys in 2009 and 2010 (Przeslawski et al., 2011).

A study of the sponge diversity and ecology of the Van Diemen Rise identified the region as a sponge biodiversity hotspot (Przeslawski et al. 2014). Sponges were collected with a benthic sled from five geomorphic features (banks, terrace, ridge, plain and valley), resulting in the identification of 283 species. The study found that sponge diversity was generally highest further offshore and on raised geomorphic features, particularly banks. Pelagic fish such as mackerel, red snapper and a distinct gene pool of goldband snapper are found in the Van Diemen Rise (Blaber et al. 2005; Salini et al. 2006). Olive ridley turtles, seasnakes and sharks have also been reported to occur in the area (DAWE 2021).

3.6.1.4 Ancient coastline at 125 m depth contour

The ancient coastline at 125 m depth contour KEF comprises a series of several steps and terraces that form an escarpment along north-west WA centred around the 125 m isobath, although this feature is not continuous.

The KEF is an important divide between carbonate, cemented sands and the fine, less cemented slope materials found offshore. It is valued as a unique seabed feature with ecological properties of regional significance. Hard substrate areas of the ancient coastline are thought to provide biologically important habitat in an area predominantly made up of soft sediment (DEWHA 2008a).

3.6.1.5 Continental slope demersal fish communities

The continental slope demersal fish communities KEF is considered important due to its high levels of endemism (DEWHA 2008a). The diversity of demersal fish assemblages on the continental slope in the Timor Province, the Northwest Transition and the Northwest Province is high compared to elsewhere along the continental slope (DEWHA 2008a). The KEF supports two distinct demersal community types (biomes) associated with the upper slope (water depth of 225–500 m) and the mid-slope (750–1,000 m) (DAWE 2021). Although poorly known, demersal-slope communities are thought to rely on bacteria and detritus-based systems comprised of infauna and epifauna, which in turn become prey for a range of teleost fish, molluscs and crustaceans (Brewer et al. 2007). Higher-order consumers may include carnivorous fish, deepwater sharks, large squid and toothed whales (Brewer et al. 2007).

3.6.1.6 Ashmore Reef and Cartier Island and surrounding Commonwealth waters

The Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF is regarded as a biodiversity hotspot which supports a diverse array of pelagic and benthic marine species. The KEF is considered important due to its aggregations of marine life and enhanced primarily productivity in an otherwise low-nutrient environment.

Ashmore Reef and Cartier Island are situated on the shallow upper slope of the Sahul Shelf, north of Scott and Seringapatam reefs. They form part of a series of submerged reef platforms along the outer edge of the continental slope of the NWMR. Localised upwelling and turbulent mixing in the surrounding Commonwealth waters provide nutrients to support the reef structure and ecology (DEWHA 2008b).

Ashmore Reef and Cartier Island and the surrounding Commonwealth waters are regionally important for feeding and breeding aggregations of birds and other marine life, including an unusually high diversity of seasnakes, a genetically distinct breeding population of green turtles and foraging grounds for green, loggerhead and hawksbill turtles (Limpus 2008). The reef system is an important staging post for seabirds and migratory shorebirds and the area is home to some of the most important seabird colonies in the NWMR (Milton 2005). Ashmore Reef supports the highest number of coral species of any reef off the WA coast.

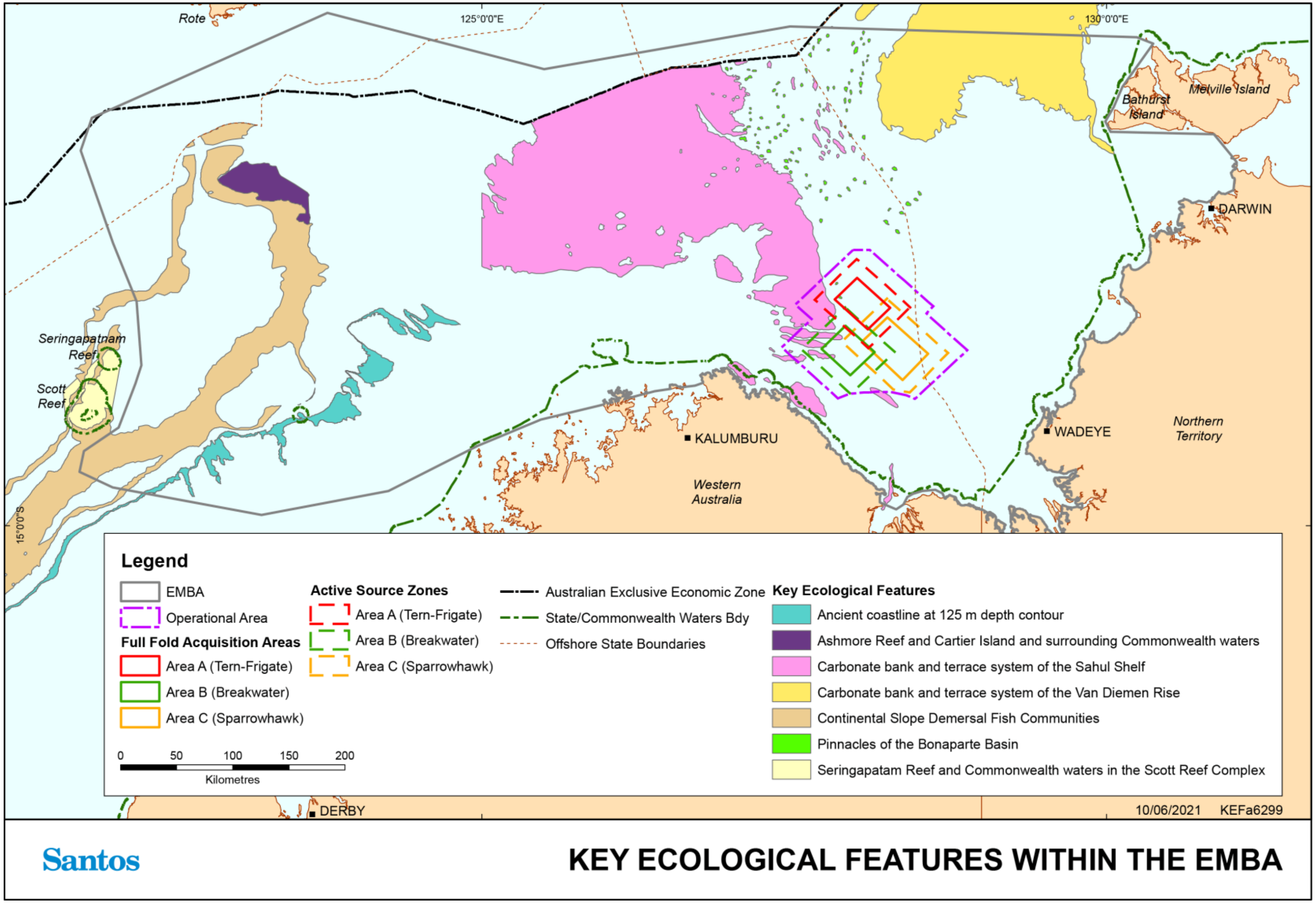


Figure 3-5: Key ecological features within the EMBA

3.6.2 Shoreline Habitats

Shoreline habitats are defined as those habitats that are adjacent to the water along the mainland and 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 that were identified to potentially occur within the EMBA: mangroves and islands. These communities are discussed in **Section 3.6.2.1** to **Section 3.6.2.2**.

3.6.2.1 Mangroves

Mangroves commonly occur in sheltered coastal areas in tropical and sub-tropical latitudes (Kathiresan and Bingham, 2001). 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).

Mangroves are important primary producers and have a number of ecological and economic values, including reducing coastal erosion and providing habitat for 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, while water channels of the system support various finfish. 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).

There are no mangrove habitats within the Operational Area. However, mangrove habitats are present in coastal waters of the JBG, the Tiwi Islands and Vernon Islands. The Tiwi Islands and Vernon Islands are located at the most north-easterly limit of the EMBA, about 230 km north-east and 285 km north-east of the Operational Area, respectively.

3.6.2.2 Islands

No islands or emergent reef systems are located within the Operational Area. However, 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, including small islands along the north Kimberley coast, Browse Island, sand islands at Ashmore Reef and Cartier Island. The Tiwi Islands and the Vernon Islands are located are located at the most north-easterly limit of the EMBA. Information on these reefs and islands is summarised below.

Ashmore Reef

Ashmore Reef is located 840 km west of Darwin and 610 km north of Broome, and comprises a shelf-edge reef system of approximately 583 km^2, rising from the westward limit of the Sahul Shelf (Geoscience Australia 2021). The reef boasts high species and habitat diversity with 14 varieties of seasnake, 433 species of mollusc and 70 fish species identified in the area, along with 255 varieties of coral. The reef flats have a high diversity of hard and soft corals and sponges, and large seagrass meadows. The sand islands at Ashmore Reef also have significant marine turtle nesting areas and migratory bird populations, while dugong, various cetaceans and whale sharks are sighted regularly around the reef (Geoscience Australia 2021). Ashmore Reef is located approximately 500 km north-west of the Operational Area.

Cartier Island

Cartier Island is located in the West Sahul region of the Indian Ocean, about 300 km off Australia's Kimberley coast and 70 km from Ashmore Reef (Geoscience Australia 2021). The reef flat surrounding Cartier Island rises steeply from the surrounding depths to an un-vegetated sand cay at its centre. These surrounding reefs are high in biodiversity including 547 identified species of fish, which represent about 16% of Australia's fish species (Geoscience Australia 2021), and provide important habitat for seasnakes, turtles, whale sharks, corals, sea fans and sponges (Director of National Parks 2018a). Cartier Island is located approximately 435 km north-west of the Operational Area.

Vernon Islands

The Vernon islands are located in the Clarence Strait in the Northern Territory, between the Australian mainland at Gunn Point and Melville Island's southernmost point, Cape Gambier (Tiwi Land Council 2013). There are three major islands making up the Vernon Islands group; north-west Vernon Island, south-west Vernon Island and east Vernon Island, plus a large reef and numerous lesser reefs and sand islands (Tiwi Land Council 2013). The Vernon Islands are rich in mangrove forests, reef systems, rocky shelves and stacks, and seagrass and algal beds (Tiwi Land Council 2013). The islands are an important coral reef locality, and there is a small number of naturally occurring deep holes (up to 20 m deep) which support coral communities with high species diversity (Tiwi Land Council 2013). The waters surrounding the Vernon Islands support populations of dugong and turtles (Tiwi Land Council 2013). The Vernon Islands are located approximately 285 km east of the Operational Area.

Tiwi Islands

The Tiwi Islands are located 20 km north of Darwin and include Australia’s second and fifth largest islands - Melville and Bathurst Islands, respectively (Department of Natural Resources, Environment, the Arts and Sport [DNREAS] 2009). The coasts of the Tiwi Islands support important nesting sites for marine turtles, internationally significant seabird rookeries, and some major aggregations of migratory shorebirds (DNREAS 2009). The Tiwi Islands are located approximately 230 km east of the Operational Area.

3.6.3 Benthic Habitats and Communities

Benthic habitats are defined as those subtidal habitats lying below the lowest astronomical tide (LAT). 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 distribution of benthic fauna depends on water depth, the substrate and sediment characteristics, the nature of the substrate and available food. The soft sediment habitats that cover the majority of the Operational Area are only sparsely covered by sessile filter-feeding organisms (e.g. gorgonians, sponges, ascidians and bryozoans) and mobile invertebrates (e.g. echinoderms, prawns and detritus-feeding crabs) (Brewer et al. 2007; DSEWPaC 2012a). Previous surveys in the JBG have not recorded seagrass or macroalgae beyond coastal habitats (Brewer et al. 2007).

The benthic habitats and communities associated with the various geomorphic features identified by Przeslawski et al. (2011) and Brewer et al. (2007) are outlined below:

+ Shelf – sediment plains that are swept by strong tidal currents and are subject to large influxes of suspended sediment and freshwater, particularly during the wet season. Support diverse infaunal communities that play a key ecological role by contributing to nutrient cycling and sediment turnover (bioturbation) at the local scale. Low abundance of crustaceans, echinoderms and sessile epifauna.

+ Banks/shoals - elevated features with a relatively high proportion of hard substrate that support patches of moderately dense octocorals and sponges which in turn provide habitat for other epifauna and cryptofauna. Banks support high numbers of epifaunal species. Infaunal species richness is moderately high in bank sediments. Very few macroalgae (including *Halimeda*) or reef-forming hard corals have been recorded.
+ Basin - low-relief expanses of unconsolidated sediment, where available biological data suggests habitats are dominated by infauna with limited epifauna.
+ Pinnacles - hard substrate in an otherwise soft sediment environment. They can be important for sessile benthic invertebrates including hard and soft corals, sponges, whips, fans, bryozoans.

As evident in **Figure 3-6**, the dominant habitat type across most of the Operational Area is infaunal plains, which are characterised by flat, soft substrates with occasional rocky outcrops, scattered epifauna and biota dominated infauna (Przeslawski et al. 2011). This habitat type is dominant across all shelf and basin features. Sponges and octocorals are predominately located along the western portion of the Operational Area (associated with the Carbonate Banks and Terrace System of the Sahul Shelf KEF).

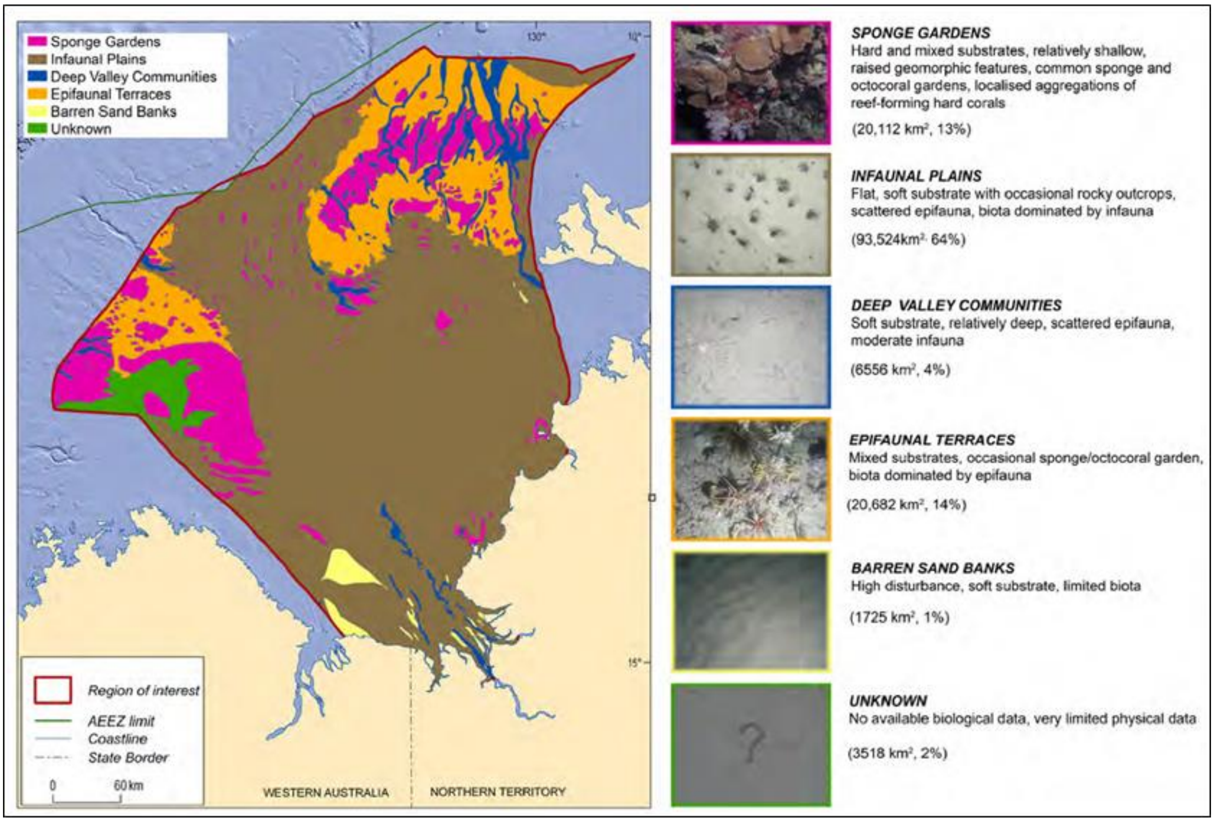


Figure 3-6: Distribution of Habitats and Biological Communities in the JBG (Przeslawski et al. 2011)

Infauna studies conducted within the Blacktip Project area (within the Operational Area) found infauna to be diverse and abundant, with two major phyla, Arthropoda (crustaceans) and Annelida (polychaete worms) contributing over 80% of the total number of individuals (Woodside 2004). Arthropoda species recorded include tanaids (shrimps), brachyurans (crabs) and grammarid amphipods. Annelida were diverse comprising of 36 families, with the most abundant families being Terebellidae, Spionidae, Onphidae, Maldanidae and Ampharetidae. Members of these families are mainly tube-dwelling worms that feed on detrital material on the surface or in the surface sediments.

3.6.4 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 and MPRA 2005a). 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 2011c). The distribution of corals in an area is governed by the availability of hard substrate for attachment and light availability.

Within the EMBA, offshore coral reefs include Ashmore reef and Hibernia Reef, Cartier Island, Browse Island, the Vernon Islands, with many other islands in coastal waters supporting fringing coral reefs. No coral reefs are located within or adjacent to the Operational Area.

3.6.5 Seagrasses and Macroalgae

Seagrass and macroalgae are important contributors to primary production and nutrient cycling in the region, providing food and habitat for vertebrate and invertebrate fauna. Macroalgae generally require adequate light and a hard substrate, and therefore they largely occur in intertidal and shallow waters less than 5 m deep. Macroalgae exhibit very high seasonal and interannual variation in biomass (Heyward et al. 2006) and distribution, abundance and biodiversity (Rio Tinto 2009, BHPBIO 2011).

Seagrass predominantly occur in sheltered, shallow coastal waters, although they can occur in deeper waters at 30-40 m. A survey of intertidal seagrasses carried out by the WA Museum did not record any seagrasses in the JBG (Walker et al. 1996). The Operational Area is located entirely in water depths greater than those in which macroalgae and seagrass beds typically occur. However, seagrass habitats are reported to be present in the EMBA, including at Ashmore Reef and at the Vernon Islands and Tiwi Islands at the most north-easterly limit of the EMBA.

3.6.6 Crustaceans

In a study of prawn trawl bycatch in the JBG, which included sampling locations within the Operational Area, Tonks et al. (2008) found that four crustacean species dominated the invertebrate component of the bycatch: *Charybdis callianassa* (Portunidae); *Trachypenaeus gonospinifer* (Penaeidae); *Metapenaeopsis novaeguineae* (Penaeidae); and *Solenocera australiana* (Solenoceridae).

The dominant prawn species of the JBG are the penaeid species, namely tiger prawn (*Penaeus esculentus*), banana prawn (*P. merguiensis*) and red-legged banana prawn (*P. indicus*). These species can be found from coastal waters to depths of approximately 200 m, and are widely distributed through subtropical and tropical waters, from WA to NSW (Jones and Morgan 1994). Shallower inshore waters such as river and tidal creek systems of the JBG act as nursery grounds for juveniles. Small numbers of prawns can also be found in mangrove habitats. More is known about the distribution and abundance of prawns in the JBG compared to other crustaceans because a number of species are commercially harvested.

As discussed in detail in **Section 3.8.1**, prawns are commercially targeted in areas of the JBG, mainly in the west of the gulf and in Fog Bay, near Darwin (NT). The juvenile prawns that migrate offshore to the fishery come from mangrove nursery habitats from the Victoria River in the east of the Gulf, to the Ord River and Cambridge Gulf in the west, forming a very extensive migration throughout the lower region of the JBG. Migration of juveniles is thought to be triggered by rainfall and river discharge.

There are occasional reports of very large catches of the cornflake or swimming crab (*Charybdis callianassa*) as bycatch of the Northern Prawn Fishery (NPF), which are believed to be because of spawning aggregations of this species (Brewer et al. 2007).

3.6.7 Molluscs

The JBG has relatively low mollusc species diversity due to the restricted number of habitats available and silty conditions, with less than 100 species (mainly bivalves) recorded in the region (Walker et al. 1996). There is some recreational fishing of rock oysters, and squid are a large bycatch of the NPF. Many different types of molluscs are found in the mangroves including clams (Walker et al. 1996). The soft sediment infaunal plains habitat that dominates the Operational Area (Przeslawski et al. 2011) does not provide extensive hard substrate for bivalve molluscs or other fixed invertebrates to attach.

The Pearl Oyster Managed Fishery (POMF) management area extends to the WA-NT border, including the JBG. However, the JBG is not an area of commercial interest to the fishery. Based on 2009 – 2019 FishCube data, no fishing for pearl oysters (*Pinctada maxima*) has occurred in the JBG. Irregular fishing for pearl oysters by the NT pearl oyster fishery has also occurred in the JBG since 1994. Within the EMBA, the closest location where fishing for pearl oysters has occurred is at Holothuria Reefs, located 140 km west of the Operational Area. Pearl oyster fishing grounds, holding sites and farm leases are primarily located outside of the EMBA, on the north Kimberley coast, near Broome and Eighty Mile Beach. Pearl oysters are primarily located in shallow sub-tidal waters, but can occur to depths in excess of 50 m (Hart et al. 2016). However, studies by Santos (RPS 2019) and AIMS (Miller 2017) of the main pearl oyster fishing grounds near Eighty Mile Beach have found very low abundances of pearl oysters in water depths greater than 40 m. Hart et al. (2016) note that the soft bottom shelf habitats of the JBG are likely to support mobile invertebrate communities, but limited filter feeder habitat associated with pearl oysters. The shallower coastal turbid zone, although poorly understood, may support more suitable habitat for filter-feeders and bivalves (Hart et al. 2016). Given that the Operational Area is located in water depths greater than 40 m, limited suitable habitat on the shelf in the JBG, and the absence of commercial pearl oyster fishing activities, significant numbers of pearl oysters are unlikely to be present in the Operational Area.

3.6.8 Plankton Communities

Plankton consists of microscopic organisms typically divided into phytoplankton (algae) and zooplankton (fauna including larvae). Plankton play a major role in the trophic system with phytoplankton being a primary producer and zooplankton a primary consumer. Phytoplankton rapidly multiply in response to bursts of nutrient availability and are subsequently consumed by zooplankton that in turn are consumed by other fauna species.

Nutrients and planktonic organisms (including many species of larval recruits) are transported to and from the JBG by the southerly movement of the ITF and the south-east and north-west monsoonal wind driven currents. The primary driver of planktonic primary productivity in the region is from seasonal influences (Brewer et al. 2007).

3.6.8.1 Phytoplankton

In the tropical northern regions of Australia, higher phytoplankton concentrations (as indicated by surface chlorophyll concentrations) generally occur during the winter months (June to August) and are lower in summer (December to February) (Brewer et al. 2007).

Phytoplankton assemblages recorded by ERM in 2010 and 2011 in the JBG were typically characteristic of offshore tropical waters. Phytoplankton assemblages were mainly dominated by cyanobacteria during the 2010 wet season survey, which comprised 99.7% of identified algal cells. During the 2011 dry season survey, diatoms (Bacillariophyceae) dominated the phytoplankton assemblage. Overall, phytoplankton densities were typical of offshore oceanic waters and indicative of a classically oligotrophic (low nutrient) system as is the case across offshore WA and the Timor Sea, which feeds the Leeuwin Circulation in the NWMR (ERM 2011).

3.6.8.2 Larval fish and zooplankton

Sampling undertaken by ERM (2011) indicated that larval fishes in the JBG were found to be dominated by Serranidae (cods) and Lutjanidae (snappers), both of which are commercially targeted species in the region. Larval fish density varied seasonally with the 2011 dry season recording highest densities of larval fishes in the zooplankton. This seasonal effect is consistent with the notion of an extended spawning season (and possibly planktonic larval duration) of the species dominating the larval fish assemblage in the area (ERM 2011).

Zooplankton sampling indicated that copepods represented the most dominant group within the macro-zooplankton assemblage in both the 2010 wet season and 2011 dry season. The density of these macro-zooplankton varied significantly among seasons, with an overall greater density of these animals recorded during the 2010 wet season. The greater density of macro-zooplankton may be indicative of higher primary productivity in the summer months fuelling population increases of the zooplankton (secondary productivity) at this time.

Overall zooplankton density varied at the level of the assemblage with statistically distinct assemblages found within both the 2010 wet season and 2011 dry season.

3.6.9 Fish Assemblages

Demersal bycatch records from the Northern Prawn Fishery (NPF) in the JBG indicate that the area's demersal communities have a relatively high biomass and further suggest that the JBG is an area of high species diversity.

The Protected Matters Search (**Appendix B**) identified 27 pipefish species, five seahorse species, four pipehorse species and one seadragon that may potentially occur in the EMBA. These species are listed as marine species but are not listed as threatened or migratory under the EPBC Act. The species group report card – bony fishes (DEWHA 2008b), which supplements and supports the NWMR and NMR bioregional plans, states that almost all syngnathids (pipefish, seahorses and pipehorses) live in nearshore and inner shelf habitats, usually in shallow, coastal waters, among seagrasses, mangroves, coral reefs, macroalgae dominated reefs, and sand or rubble habitats. Temperate water species predominately inhabit seagrasses and macroalgae, while tropical species are primarily found among coral reefs.

A review of information on habitat preference and water depth range has been conducted for the 35 syngnathid species identified in the protected matters search (**Table 3-9**). The water depths of the Operational Area range from 40 – 107 m. Only ten syngnathid species have been recorded in water depths greater than 40 m. Therefore, the majority of the identified species are not expected to occur across the flat, soft substrates and deeper waters that predominate throughout the Operational Area. These species are more likely to be associated with low reef habitats found in shallower coastal waters of the JBG.

Seahorses and pipefishes have been recorded as bycatch in the region from trawl operations of the NPF (DEWHA 2008b); however, no pipefish, seahorse or pipehorse species were identified in a study of species composition of prawn trawl bycatch undertaken within and surrounding the Operational Area (Tonks et al. 2008).

A marine baseline survey undertaken by ERM (2011) recorded a total of 22 genera representing 17 families of fish. The most common families by density were Terapontidae (grunters), Nemipteridae (threadfin breams), and Lutjanidae (snappers). Terapontidae and Nemipteridae are small scavenging opportunists that are often caught as bycatch in demersal trawl and trap fisheries in the NMR. The lutjanids are larger predatory fishes targeted by commercial and recreational fishers in tropical Australia. These species assemblages are known to occur in coastal waters to depths of approximately 200 m, and are widely distributed through subtropical and tropical waters from WA (ERM 2011).

Tonks et al. (2008) identified 112 teleost fish species from 61 families from 53 NPF commercial trawls over two years. The species with the highest mean catch rates were glassy bombay duck (*Harpadon translucens*), threadfin scat (*Rhinoprenes pentanemus*), largehead hairtail (*Trichiurus lepturus*), blackfin threadfin (*Polydactylus nigripinnis*) and smooth croaker (*Johnius laevis*).

As described in **Section 3.6.3**, the Operational Area predominantly overlaps with the 'infaunal plains' habitat type (Przelawski et al. 2011). The Operational Area also overlaps with the 'sponge gardens' habitat type, a benthic habitat characterised by hard and mixed substrates, relatively shallow water depths, raised geomorphic features, common sponge and octocoral gardens and localised aggregations of reef-forming hard corals.

Therefore, it is unlikely that habitats within the Operational Area support significant assemblages of site-attached fishes given the shallowest parts of the bank and pinnacle features in the Operational Area are at water depths greater than 60 m and 80 m respectively. At these water depths, given reduced light availability, occurrences of hard corals and other benthos that may support significant site-attached fish assemblages are expected to be limited.

Santos

Table 3-9: Summary of Habitat Preference and Depth Range for Syngnathid Species that may occur within the Operational Area and EMBA

Assemblage	Species	Habitat	Depth Range (m)
Low reef	Corrugated pipefish, Barbed *Bhanotia fasciolata*	Demersal individuals are most common in reef and tidepool habitats. This species lives openly on muddy or silty substrates in depths of 3-25 m	3-25
Low reef	Three-keel pipefish *Campichthys tricarinatus*	Sand, coral rubble, algae (including *Sargassum*), isolated coral knolls, soft corals, small sponges, low coral outcrops, sheltered reef and rocky islets	3-11
Low reef/ bedrock/terraces	Pacific Short-bodied pipefish, Short-bodied pipefish *Choeroichthys brachysoma*	Commonly occurs in seagrass, reef and coral habitats in depths of less than 5 m. They also can be found in coral and shell rubble, coral rock, beach rock, sandstone terraces, isolated rock pools, caves, lagoons, mud, sand, and silt	0-24
Low reef	Pig-snouted pipefish *Choeroichthys suillus*	Occurs in inshore reef habitats or in association with coral knolls, live corals, coral rubble, shell rubble, coral rock, ledges, sand, seagrass and algae	1-14
Low reef	Fijian Banded pipefish, Brown-banded pipefish *Corythoichthys amplexus*	This species prefers protected coral habitats, also found in shallow reefs as well as deep walls, with algae and is known from clear coastal to outer reef crests	0-31
Low reef	Reticulate pipefish, Yellow-banded pipefish, Network pipefish *Corythoichthys flavofasciatus*	Association with fringing coral reefs, coral reef crests, reef flats, live corals (including *Acropora*), gorgonians, limestone rock platforms, soft corals, dead corals, algae, encrusting organisms, rubble, rocky shores, gutters, drop-offs, bomboras, pools, caves and sand.	0-30
Low reef	Australian Messmate pipefish, Banded pipefish *Corythoichthys intestinalis*	Sand, coral or 'grass' bottoms. They occur on sheltered coastal reefs, often in silty habitat among algae as well as on coral slopes, reef flats, reef edges, bomboras, live corals (including *Acropora*), soft corals, dead corals, rocky shore, mangroves, seagrass, sand rubble, rock rubble, caves, lagoons, mud, sand and silt.	0-10
Low reef	Schultz's pipefish *Corythoichthys schultzi*	Common on rubble and in corals. It also occurs on sand and among reef on crests and slopes in protected habitats	0-30
Low reef	Roughridge pipefish *Cosmocampus banneri*	Coral reefs (including outer reefs), ledges, lagoons, live corals, rock, sponges, sand and rubble	6 - 30
Low reef	Banded pipefish, Ringed pipefish	Free-swimming fishes that are usually found at the front of caves or reef overhangs. This species	10-25

Assemblage	Species	Habitat	Depth Range (m)
	Doryrhamphus dactyliophorus	inhabits protected coastal reefs, in large caves or among boulders with long-spined urchins	
Low reef	Bluestripe pipefish, Indian blue-stripe pipefish, Pacific blue-stripe pipefish *Doryrhamphus excisus*	Free-swimming benthic fishes found in various reef habitats in coastal to outer reefs, and usually stay close to small caves or narrow crevices into which they retreat when threatened	0-49
Low reef	Cleaner pipefish, Janss' pipefish *Doryrhamphus janssi*	Found in various reef habitats in coastal to outer reefs, and usually stay close to small caves or narrow crevices	5-30
Low Reef	Tiger pipefish *Filicampus tigris*	Usually seen in estuaries on rubbly, sandy or weedy bottoms	2-30
Low Reef	Brock's pipefish *Halicampus brocki*	Occurs on coral and rocky reefs with algae. Inhabits patches of coral and macro-algae on coastal reefs	3-45
Low Reef	Red-hair pipefish, Duncker's pipefish *Halicampus dunckeri*	A reef associated species usually found on sandy and algal-rubble habitats	1-25
Deep	Mud pipefish, Gray's pipefish *Halicampus grayi*	Inhabits silty and muddy soft bottoms on the continental shelf from inshore bays to deep offshore areas to 100 m	0-100
Low Reef	Spiny-snout pipefish *Halicampus spinirostris*	Inhabits shallow coral rubble areas in lagoons and intertidal zones of inshore coral reefs	5-10
Low Reef	Ribboned pipefish, Ribboned seadragon *Haliichthys taeniophorus*	Inhabits a variety of inshore shallow water areas including weedy regions bordering open substrates, coral reefs, rocky, gravel, sandy and muddy substrates; also associated with sponges, algae, hydroids, shells and seagrass	0-18
Shallow	Beady pipefish, Steep-nosed pipefish *Hippichthys penicillus*	Found in lower reaches of streams and rivers, seagrass beds in estuaries and other shallow inshore habitats	0-5
Deep	Spiny seahorse, Thorny seahorse *Hippocampus histrix*	Inhabits areas with both hard and soft bottoms, often attached to soft corals or sponges at 10-95 m, usually 15-40 m. Also found on shallower algae-rubble or rocky reef areas	5-95
Low Reef	Spotted seahorse, Yellow seahorse *Hippocampus kuda*	Inhabits coastal bays, harbours and lagoons, sandy sediments in rocky littoral zones, macroalgae and	0-55

Assemblage	Species	Habitat	Depth Range (m)
		seagrass beds, mangroves, muddy bottoms, and shallow reef flats.	
Low Reef	Flat-face seahorse *Hippocampus planifrons*	Inhabits algal and rubble reefs in shallow bays from the intertidal	0-20
Deep	Hedgehog seahorse *Hippocampus spinosissimus*	Benthic in inner reef waters on rubble substrates and in sponge and seagrass habitats near coral reefs; often attached to corals in deep current-prone channels between reefs or islands	20-70
Low Reef	Tidepool pipefish *Micrognathus micronotopterus*	Usually inhabits shallow inshore reefs and tidepools, amongst sparse seagrasses and algae-rubble, in depths from 1-5 m, although individuals have been collected from depths to 10 m	1-10
Deep	Pallid pipehorse, Hardwick's pipehorse *Solegnathus hardwickii*	Mostly known from trawled specimens captured from 12 m to 100 m depth, though it has been collected in depths of up to 180 m	12-180
Deep/ shelf	Gunther's pipehorse, Indonesian pipefish *Solegnathus lettiensis*	Benthic inhabitant of outer continental shelf waters and has been captured from depths of 42-180 m. Trawl bycatch records in 150-180 m water depths in Australia	42-180
Low Reef	Robust ghost pipefish, Blue-finned ghost pipefish *Solenostomus cyanopterus*	Reef associated	0-10
Low Reef	Double-end pipehorse, Double-ended pipehorse, Alligator Pipefish *Syngnathoides biaculeatus*	Inhabits shallow, protected waters of bays, lagoons and estuaries including mangrove areas, in association with seagrass beds and macroalgae	0-10
Low Reef	Bentstick pipefish, Bend Stick pipefish, Short-tailed pipefish *Trachyrhamphus bicoarctatus*	Inhabits sheltered coastal lagoon and reef areas on sandy and rubble habitats amongst seagrasses and macroalgae at 1–30 m. Has been recorded to 42 m	1-42
Deep	Straightstick pipefish, Long-nosed pipefish, Straight Stick pipefish	Most specimens have been trawled or dredged from muddy to sandy-bottom habitats in depths of 16-91 m, in association with sand, rubble, seagrasses, algae, sponges, sea pens and hydroids	16-91

Assemblage	Species	Habitat	Depth Range (m)
	Trachyrhamphus longirostris		
Low Reef	Reef-top pipefish *Corythoichthys flavofasciatus*	Species inhabits reef crests, slopes and on rubble patches and large coral heads with a depth range of 1-19.8 m	1-20
Low Reef	Girdled pipefish *Festucalex cinctus*	Most specimens are dredged or trawled in depths of 8-31 m. The species is also found in sponge and seagrass habitats in sheltered coastal bays with sparse low algal growth	1-31
Low Reef	Blue-speckled pipefish *Hippichthys cyanospilos*	Inhabits mangroves in tidal estuaries and creeks	0-4
Low Reef	Short-keel pipefish *Hippichthys parvicarinatus*	Restricted to estuarine and freshwater habitats within the Northern Territory	0-5
Low Reef	Western spiny seahorse *Hippocampus angustus*	Inhabits sheltered algal-covered reefs and seagrass beds to about 10 m, however the species has been recorded at depths of 30 m	1-30

DoEE (2019a); Bray and Thompson (2019); Austin and Pollom (2019); Froese and Pauly (2019

3.7 Protected Species

3.7.1 EPBC Act-listed Threatened and Migratory Species

A search of the EPBC Act Protected Matters Database was undertaken in May 2021 to identify the likelihood of occurrence of listed marine fauna within the Operational Area and EMBA. The results of the search informed the assessment of planned events in **Section 6**, as well as unplanned events in **Section 7**, associated with the Petrel Sub-Basin SW 3D MSS. It should be noted that the EPBC Protected Matters database is a general database that conservatively identifies areas in which protected species have the potential to occur.

The results of the EPBC Protected Matters Search are provided in **Table 3-10**. The search of the Operational Area identified 19 threatened species and 36 migratory species as potentially occurring. The search of the EMBA identified 59 threatened species and 85 migratory species potentially occurring. No threatened ecological communities (TECs) were identified from either search.

The full list of species identified from the PMST is provided in the EPBC Act Protected Matters Search Reports (refer to **Appendix B**). Several terrestrial species were reported to occur within the EMBA due to the PMST search area overlapping with the land; where terrestrial species are not associated with shoreline habitats within the EMBA, however, they have not been included in the EP. It is not considered credible that these terrestrial species could be impacted.

Table 3-11 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 3-11**.

Table 3-10: EPBC-Act listed threatened and migratory species that may occur within the Operational Area and EMBA

EPBC Act Status: CE = Critically Endangered, E= Endangered V= Vulnerable, M= Migratory

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
Marine Mammals						
Sei whale	*Balaenoptera borealis*	V, M	✓	Species or species habitat may occur	✓	Foraging, feeding or related behaviour likely to occur
Bryde's whale	*Balaenoptera edeni*	M	✓	Species or species habitat may occur	✓	Species or species habitat likely to occur
Blue whale	*Balaenoptera musculus*	E, M	✓	Species or species habitat likely to occur	✓	Migration route known to occur
Fin whale	*Balaenoptera physalus*	V, M	✓	Species or species habitat may occur	✓	Foraging, feeding or related behaviour likely to occur
Humpback whale	*Megaptera novaeangliae*	V, M	✓	Species or species habitat likely to occur	✓	Breeding known to occur
Killer whale	*Orcinus orca*	M	✓	Species or species habitat may occur	✓	Species or species habitat may occur
Spotted bottlenose dolphin (Arafura/Timor sea population)	*Tursiops aduncus*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat known to occur
Dugong	*Dugong dugon*	M	x	N/A	✓	Breeding known to occur
Indo-Pacific humpback dolphin	*Sousa chinensis*	M	x	N/A	✓	Breeding known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
Australian snubfin dolphin	*Orcaella heinsohni*	M	x	N/A	✓	Species or species habitat known to occur
Sperm whale	*Physeter macrocephalus*	M	x	N/A	✓	Species or species habitat may occur
Marine Reptiles						
Loggerhead turtle	*Caretta caretta*	E, M	✓	Species or species habitat likely to occur	✓	Foraging, feeding or related behaviour known to occur
Green turtle	*Chelonia mydas*	V, M	✓	Species or species habitat known to occur	✓	Breeding known to occur
Leatherback turtle	*Dermochelys coriacea*	E, M	✓	Species or species habitat likely to occur	✓	Breeding likely to occur
Hawksbill turtle	*Eretmochelys imbricata*	V, M	✓	Species or species habitat likely to occur	✓	Breeding known to occur
Olive ridley turtle	*Lepidochelys olivacea*	E, M	✓	Species or species habitat known to occur	✓	Breeding known to occur
Flatback turtle	*Natator depressus*	V, M	✓	Congregation or aggregation known to occur	✓	Breeding known to occur
Salt-water crocodile	*Crocodylus porosus*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat likely to occur
Short-nosed seasnake	*Aipysurus apraefrontalis*	CE	x	N/A	✓	Species or species habitat known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
Leaf-scaled seasnake	*Aipysurus foliosquama*	CE	x	N/A	✓	Species or species habitat known to occur
Fish, Sharks and Rays						
Great white shark	*Carcharodon carcharias*	V, M	✓	Species or species habitat may occur	✓	Species or species habitat may occur
Northern river shark	*Glyphis garricki*	E	✓	Species or species habitat may occur	✓	Breeding known to occur
Freshwater sawfish	*Pristis pristis*	V, M	✓	Species or species habitat known to occur	✓	Species or species habitat known to occur
Green sawfish	*Pristis zijsron*	V, M	✓	Species or species habitat known to occur	✓	Species or species habitat known to occur
Whale shark	*Rhincodon typus*	V, M	✓	Species or species habitat may occur	✓	Foraging, feeding or related behaviour known to occur
Shortfin mako	*Isurus oxyrinchus*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat likely to occur
Longfin mako	*Isurus paucus*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat likely to occur
Oceanic whitetip shark	*Carcharhinus longimanus*	M	✓	Species or species habitat may occur	✓	Species or species habitat may occur
Speartooth shark	*Glyphis glyphis*	CE	x	N/A	✓	Species or species habitat known to occur
Reef manta ray	*Manta alfredi*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	**Scientific Name**					
Giant manta ray	*Manta birostris*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat likely to occur
Narrow sawfish	*Anoxypristis cuspidata*	M	✓	Species or species habitat may occur	✓	Species or species habitat known to occur
Dwarf sawfish	*Pristis clavata*	V, M	✓	Species or species habitat known to occur	✓	Breeding known to occur
Seabirds and Migratory Shorebirds						
Red knot	*Calidris canutus*	E, M	✓	Species or species habitat may occur	✓	Species or species habitat known to occur
Curlew sandpiper	*Calidris ferruginea*	CE, M	✓	Species or species habitat may occur	✓	Species or species habitat known to occur
Eastern curlew	*Numenius madagascariensis*	CE, M	✓	Species or species habitat may occur	✓	Species or species habitat known to occur
Little curlew	*Numenius minutus*	M	x	N/A	✓	Roosting known to occur
Common noddy	*Anous stolidus*	M	✓	Species or species habitat may occur	✓	Breeding known to occur
Streaked shearwater	*Calonectris leucomelas*	M	✓	Species or species habitat likely to occur	✓	Species or species habitat known to occur
Lesser frigatebird	*Fregata ariel*	M	✓	Species or species habitat likely to occur	✓	Breeding known to occur within area
Great frigatebird	*Fregata minor*	M	✓	Species or species habitat may occur	✓	Breeding known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
Common sandpiper	*Actitis hypoleucos*	M	✓	Species or species habitat may occur	✓	Species or species habitat known to occur
Sharp-tailed sandpiper	*Calidris acuminata*	M	✓	Species or species habitat may occur	✓	Roosting known to occur
Pectoral sandpiper	*Calidris melanotos*	M	✓	Species or species habitat may occur	✓	Species or species habitat known to occur
Marsh sandpiper	*Tringa stagnatilis*	M	x	N/A	✓	Roosting known to occur
Terek sandpiper	*Xenus cinereus*	M	x	N/A	✓	Roosting known to occur
Osprey	*Pandion haliaetus*	M	✓	Species or species habitat may occur	✓	Breeding known to occur within area
Whimbrel	*Numenius phaeopus*	M	x	N/A	✓	Roosting known to occur
Australian lesser noddy	*Anous tenuirostris melanops*	V	x	N/A	✓	Breeding known to occur within area
Great knot	*Calidris tenuirostris*	CE	x	N/A	✓	Roosting known to occur
Red goshawk	*Erythrotriorchis radiatus*	V	x	N/A	✓	Species or species habitat known to occur
Nunivak bar-tailed godwit	*Limosa lapponica baueri*	V	x	N/A	✓	Species or species habitat known to occur
Bar-tailed godwit	*Limosa lapponica*	M	x	N/A	✓	Species or species habitat known to occur
Northern Siberian bar-tailed godwit	*Limosa lapponica menzbieri*	CE	x	N/A	✓	Species or species habitat known to occur
Black-tailed godwit	*Limosa limosa*	M	x	N/A	✓	Roosting known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
Australian painted snipe	*Rostratula australis*	E	x	N/A	✓	Species or species habitat likely to occur
Fork-tailed swift	*Apus pacificus*	M	x	N/A	✓	Species or species habitat likely to occur
Roseate tern	*Sterna dougallii*	M	x	N/A	✓	Breeding known to occur within area
Little tern	*Sternula albifrons*	M	x	N/A	✓	Breeding known to occur within area
Caspian tern	*Hydroprogne caspia*	M	x	N/A	✓	Breeding known to occur within area
Bridled tern	*Onychoprion anaethetus*	M	x	N/A	✓	Breeding known to occur within area
Greater crested tern	*Thalasseus bergii*	M	x	N/A	✓	Breeding known to occur
Abbott's booby	*Papasula abbotti*	E	x	N/A	✓	Species or species habitat may occur
Brown booby	*Sula leucogaster*	M	x	N/A	✓	Breeding known to occur within area
Masked booby	*Sula dactylatra*	M	x	N/A	✓	Breeding known to occur within area
Red-footed booby	*Sula sula*	M	x	N/A	✓	Breeding known to occur within area
Oriental reed-warbler	*Acrocephalus orientalis*	M	x	N/A	✓	Species or species habitat known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
White-tailed tropicbird	*Phaethon lepturus*	M	x	N/A	✓	Breeding known to occur within area
Red-tailed tropicbird	*Phaethon rubricauda*	M	x	N/A	✓	Breeding known to occur within area
Greater sand plover	*Charadrius leschenaultii*	V, M	x	N/A	✓	Roosting known to occur
Lesser sand plover	*Charadrius mongolus*	E, M	x	N/A	✓	Roosting known to occur
Oriental plover	*Charadrius veredus*	M	x	N/A	✓	Roosting known to occur
Little ringed plover	*Charadrius dubius*	M	x	N/A	✓	Roosting known to occur
Pacific golden plover	*Pluvialis fulva*	M	x	N/A	✓	Roosting known to occur
Grey plover	*Pluvialis squatarola*	M	x	N/A	✓	Roosting known to occur
Sanderling	*Calidris alba*	M	x	N/A	✓	Roosting known to occur
Oriental pratincole	*Glareola maldivarum*	M	x	N/A	✓	Roosting known to occur
Wedge-tailed shearwater	*Ardenna pacifica*	M	x	N/A	✓	Breeding known to occur
Red-necked stint	*Calidris ruficollis*	M	x	N/A	✓	Roosting known to occur
Long-toed stint	*Calidris subminuta*	M	x	N/A	✓	Roosting known to occur
Swinhoe's snipe	*Gallinago megala*	M	x	N/A	✓	Roosting known to occur
Pin-tailed snipe	*Gallinago stenura*	M	x	N/A	✓	Roosting known to occur
Broad-billed sandpiper	*Limicola falcinellus*	M	x	N/A	✓	Roosting known to occur
Wood sandpiper	*Tringa glareola*	M	x	N/A	✓	Roosting known to occur
Asian dowitcher	*Limnodromus semipalmatus*	M	x	N/A	✓	Roosting known to occur
Grey-tailed tattler	*Tringa brevipes*	M	x	N/A	✓	Roosting known to occur

Value/Sensitivity		EPBC Act Status	Operational Area Presence	PMST Assessment of value/sensitivity within the Operational Area	EMBA Presence	PMST Assessment of value/sensitivity within the EMBA
Common Name	Scientific Name					
Wandering tattler	*Tringa incana*	M	x	N/A	✓	Roosting known to occur
Common greenshank	*Tringa nebularia*	M	x	N/A	✓	Species or species habitat known to occur
Ruddy turnstone	*Arenaria interpres*	M	x	N/A	✓	Roosting known to occur

Santos

Table 3-11: 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

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
Marine Mammals				
Blue whale/pygmy 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.	6.3
		Habitat modification	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
		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.	7.1, 7.2, 7.4, 7.5
		Vessel strike	+ Ensure all vessel strike incidents are reported in the National Vessel Strike Database.	7.6

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
		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.	6.3
		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. + 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.	6.3
		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

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
Sei whale	Approved Conservation Advice for *Balaenoptera borealis* (sei whale) (2015a)	Pollution (persistent toxic pollutants)	+ Implement measures to manage and reduce, where possible, waste generation.	7.1, 7.2, 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.	6.3
		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
Marine Reptiles				
Green turtle Hawksbill turtle Flatback turtle Leatherback turtle Loggerhead turtle Olive ridley 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, 7.4, 7.5
		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.	6.5
		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	6.3

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
			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.	
Short-nosed seasnake	Commonwealth Conservation Advice on *Aipysurus apraefrontalis* (short-nosed seasnake) (2010)	Degradation of reef habitat	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
Leaf-scaled seasnake	Approved Conservation Advice for *Aipysurus foliosquama* (Leaf-scaled seasnake) (2010)	Degradation of reef habitat	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
Fish, Sharks and Rays				
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)	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	7.5

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
	Sawfish and River Sharks Multispecies Recovery Plan (2015)		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.	
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.	7.1, 7.2, 7.4, 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.	7.1, 7.2
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.	6.3, 6.6
		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

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
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
Speartooth shark	Approved Conservation Advice for *Glyphis glyphis* (speartooth shark) (2014c) Sawfish and River Sharks Multispecies Recovery Plan (2015)	Habitat degradation/ modification	+ Implement measures to reduce adverse impacts of habitat disruption. + 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.	7.1, 7.2, 7.4, 7.5
Seabirds and Migratory Shorebirds				
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, 7.3
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, 7.3

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
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, 7.3
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, 7.3
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, 7.3
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, 7.3
		Habitat loss and degradation	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
Great knot	Approved Conservation Advice for *Calidris tenuirostris* (Great knot) (2016)	Habitat loss and degradation	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
		Pollution/contamination impacts	+ Implement measures to manage and reduce, where possible, waste generation.	7.1, 7.2
		Disturbance	+ Manage disturbance at important sites when great knots are present.	7.1, 7.2, 7.3

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
Red goshawk	Approved Conservation Advice for *Erythrotriorchis radiates* (red goshawk) (2015)	Habitat loss and degradation	+ 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, 7.3
Lesser sand plover	Approved Conservation Advice for *Charadrius mongolus* (lesser sand plover) (2016)	Habitat loss and degradation	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
		Pollution/contamination impacts	+ Implement measures to manage and reduce, where possible, waste generation.	7.1, 7.2
		Disturbance	+ Manage disturbance at important sites when lesser sand plovers are present.	7.1, 7.2, 7.3
Greater sand plover	Approved Conservation Advice for *Charadrius leschenaultia* (greater sand plover) (2016)	Habitat loss and degradation	+ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	7.1, 7.2
		Pollution/contamination impacts	+ Implement measures to manage and reduce, where possible, waste generation.	7.1, 7.2
		Disturbance	+ Manage disturbance at important sites when greater sand plovers are present.	7.1, 7.2, 7.3
Common sandpiper, red knot, oriental plover, grey plover, little ringed plover, lesser sand plover, greater sand plover,	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, 7.3

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements / advice relevant to the Petrel Sub-Basin 3D MSS	Addressed in EP Section
Pacific golden plover, oriental pratincole, bar- tailed godwit, black-tailed godwit, pin-tailed snipe, Swinhoe's snipe, whimbrel, little curlew, terek sandpiper, common sandpiper, marsh sandpiper, wood sandpiper, common greenshank, ruddy turnstone, Asian dowditcher, great knot, sanderling, red-necked stint, long-toed stint, broad-billed sandpiper, pectoral sandpiper, sharp-tailed sandpiper				

3.7.2 Summary of Relevant Biologically Important Areas

BIAs are regions where a particular species is known or likely to display important behaviours such as aggregation, resting, breeding, foraging, nesting or migration (DAWE, n.d). BIAs have no legal status; however they provide information to help inform regulatory and management decisions.

Table 3-12 identifies the BIAs associated with threatened and/or migratory species occurring within the EMBA with potential for overlap with the Operational Area.

Table 3-12: Threatened and migratory Species BIAs within the EMBA, and potential for overlap with Operational Area

Species	BIA	Location	Occurrence in Operational Area	Distance to Operational Area
Marine Mammals				
Australian snubfin dolphin	Foraging	Ord River	No	70 km S
		Cape Londonderry and King George River	No	23 km SW
		Vansittart Bay, Anjo Peninsula	No	95 km SW
		Bougainville Peninsula	No	145 km W
		Admiralty Gulf and Parry Harbour	No	170 km W
		Maret and Biggee Island	No	264 km W
	Breeding	Ord River	No	70 km S
		Cape Londonderry and King George River.	No	23 km SW
		Darwin Harbour	No	235 km NE
		Vansittart Bay, Anjo Peninsula	No	95 km SW
		Bougainville Peninsula	No	145 km W
		Admiralty Gulf and Parry Harbour	No	170 km W
	Calving	Ord River	No	70 km S
		Cape Londonderry and King George River.	No	23 km SW
		Vansittart Bay, Anjo Peninsula	No	95 km SW
		Bougainville Peninsula	No	145 km W
		Admiralty Gulf and Parry Harbour	No	170 km W
	Resting	Ord River	No	70 km S
		Cape Londonderry and King George River	No	23 km SW

Species	BIA	Location	Occurrence in Operational Area	Distance to Operational Area
		Vansittart Bay, Anjo Peninsula	No	95 km SW
		Bougainville Peninsula	No	145 km W
		Admiralty Gulf and Parry Harbour	No	170 km W
Indo-Pacific humpback dolphin	Breeding	Darwin Harbour	No	228 km NE
	Foraging	Vansittart Bay, Anjo Peninsula	No	95 km SW
		Bougainville Peninsula	No	145 km W
		Admiralty Gulf and Parry Harbour	No	170 km W
		Maret and Biggee Island	No	264 km W
	Calving	Maret and Biggee Island	No	264 km W
Indo-Pacific spotted bottlenose dolphin	Foraging	Maret and Biggee Island	No	264 km W
	Breeding	Darwin Harbour	No	235 km NE
		Maret and Biggee Island	No	264 km W
	Calving	Maret and Biggee Island	No	264 km W
Pygmy blue whale	Migration	Augusta to Darwin	No	380 km NW
		Indonesia-Banda Sea	No	317 km NW
Dugong	Foraging	Ashmore Reef - south	No	490 km NW
		Ashmore Reef – far west	No	506 km NW
	Breeding	Ashmore Reef – far west	No	506 km NW
	Calving	Ashmore Reef – far west	No	506 km NW
	Nursing	Ashmore Reef – far west	No	506 km NW
Marine Reptiles				
Loggerhead turtle	Foraging	Western Joseph Bonaparte Depression	Yes	N/A
Flatback turtle	Foraging	Western Joseph Bonaparte Depression	Yes	N/A
	Internesting	Cape Domett	No	<1 km S
		Melville Island, Coburg Peninsula	No	105 km NE
Olive Ridley	Foraging	Western Joseph Bonaparte Depression	Yes	N/A
		JBG	Yes	N/A
		Western JBG - banks	Yes	N/A

Species	BIA	Location	Occurrence in Operational Area	Distance to Operational Area
		Northern JBG	No	115 km N
		Fog Bay	No	160 km E
	Internesting	Fog Bay to Cox Peninsula	No	178 km NE
		Bathurst Island/Melville Island	No	260 km NE
Green	Foraging	JBG	Yes	N/A
		Ashmore Reef	No	485 km NW
	Internesting	North-west of Melville Island	No	285 km NE
		Cassini Island	No	175 km W
		Cartier Island	No	411 km NW
		Ashmore Reef	No	480 km NW
	Nesting	Cassini Island	No	190 km W
	Mating	Ashmore Reef	No	500 km NW
Hawksbill	Internesting	Ashmore Reef	No	480 km NW
	Foraging	Ashmore Reef	No	500 km NW
Fish, Sharks and Rays				
Whale shark	Foraging	Northward from Ningaloo along 200 m isobaths	No	185 km W
Seabirds and Migratory Shorebirds				
Lesser crested tern	Breeding	Kimberley	Yes	N/A
		Ashmore Reef	No	465 km NW
Roseate tern	Breeding	Kimberley	No	63 km W
		Low Rocks and Stern Island in Admiralty Gulf	No	143 km SW
		Ashmore Reef	No	465 km NW
Lesser frigatebird	Breeding	Kimberley coast	No	63 km W
		Ashmore Reef	No	395 km NW
Greater frigatebird	Breeding	Ashmore Reef	No	395 km NW
		Kimberley	No	408 km W
Wedge-tailed shearwater	Breeding	Ashmore Reef	No	390 km NW
White-tailed tropicbird	Breeding	Ashmore Reef	No	395 km NW
Red-footed booby	Breeding	Ashmore Reef	No	390 km NW
		North west Kimberley	No	408 km W

Species	BIA	Location	Occurrence in Operational Area	Distance to Operational Area
Brown booby	Breeding	Ashmore Reef	No	455 km W
Greater crested tern	Breeding	Seagull Island	No	285 km NE
Little tern	Breeding	Kimberley	No	173 km W
	Resting	Ashmore Reef	No	480 km NW

3.7.3 Marine Mammals

Several species of marine mammals are known to occur in the region and have wide distributions that are associated with feeding and migration patterns linked to reproductive cycles. There are nine species known to occur regularly in the NMR, including three species of whale and six species of dolphin (DSEWPAC 2012b). In the NWMR, 27 species occur regularly including 16 species of whale and at least 11 species of dolphin (DSEWPAC 2012a).

Four threatened and migratory and three migratory marine mammal species were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the Operational Area. Four threatened and migratory and seven migratory species were identified as potentially occurring in the EMBA (refer to **Table 3-10**). No BIAs for marine mammals are located within the Operational Area. The following BIAs are located within the EMBA (refer to **Table 3-12** and **Figure 3-8**):

+ The closest Australian snubfin dolphin breeding/calving/resting and foraging BIAs are located near Cape Londonderry and King George River, approximately 23 km south-west of the Operational Area at the closest point. Other breeding/calving/resting and foraging BIAs are located further west along the north Kimberley coastline, as well as around Ord River and Cambridge Gulf approximately 70 km south from the Operational Area.
+ Indo-Pacific humpback dolphin foraging BIAs are located along the Kimberley coastline, with the closest approximately 95 km west of the Operational Area. Breeding and foraging BIAs for the species are also located near Darwin Harbour (approximately 228 km north-east of the Operational Area).
+ Indo-Pacific spotted bottlenose dolphin breeding/calving and foraging BIAs are located approximately 264 km west of the Operational Area. A breeding BIA for the species is also located near Darwin Harbour (approximately 235 km north-east of the Operational Area).
+ Pygmy blue whale migration BIAs (Augusta to Derby and Indonesia-Banda Sea) are located approximately 380 km north-west and 317 km north-west of the Operational Area, respectively.
+ Dugong foraging and breeding/calving/nursing BIAs are located approximately 490 km west and 506 km west of the Operational Area, respectively, around Ashmore Reef.

A description of the distribution, migration movements, preferred habitat and life stages of the identified marine mammal species is provided in **Table 3-13**, including commentary on their likely presence in the Operational Area and EMBA.

Table 3-13: Threatened and migratory marine mammals potentially cccurring within the Operational Area and EMBA

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Australian snubfin dolphin	Migratory	+ Records indicate that the Australian snubfin dolphin only occurs in waters off the northern half of Australia from Broome on the west coast to Brisbane River on the east coast. + The Australian snubfin dolphin occurs mostly in protected shallow waters close to the coast and close to river and creek mouths. They prefer shallow waters, less than 20 m deep (DoEE 2019a).	Breeding/calving/resting and foraging BIAs are located within the EMBA, with the closest near Cape Londonderry and King George River, approximately 23 km south-west of the Operational Area at the closest point (refer to **Figure 3-8**). Other breeding/calving/resting and foraging BIAs are located further west along the north Kimberley coastline, as well as around Ord River and Cambridge Gulf approximately 70 km south from the Operational Area (refer to **Figure 3-8**). Given the species preference for shallow waters with a maximum depth of 20 m, the presence of the species within the Operational Area and EMBA is likely to be limited.
Indo-Pacific humpback dolphin	Migratory	+ Indo-Pacific humpback dolphins occur in coastal lagoons and enclosed bays with mangrove forests and seagrass beds, but are also found in open coastal waters around islands and coastal cliffs in association with rock or coral reefs. The species usually occurs close to the coast, generally at depths of up to 20 m, but the species has been seen 55 km offshore in shallow water. + The species does not appear to undergo large-scale seasonal migrations, although seasonal shifts in abundance have been observed (DoEE 2019a).	A breeding BIA for Indo-Pacific humpback dolphins' is located in Darwin Harbour, with its northern boundary approximately 228 km away from the Operational Area (see **Figure 3-8**). The closest foraging BIA for this species is located in Vansittart Bay on the Anjo Peninsula, which is approximately 95 km west of the Operational Area (see **Figure 3-8**).

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ Indo-Pacific humpback dolphins eat a wide variety of coastal and estuarine-associated fishes, as well as reef, littoral and demersal fish species.	Given the location of the BIAs relative to the Operational Area, the species may be encountered within the Operational Area.
Spotted bottlenose dolphin (Arafura/Timor Sea populations)	Migratory	+ Bottlenose dolphins have been recorded within the Oceanic Shoals Marine Park (10 km from the Operational Area). + The spotted bottlenose dolphin occurs in tropical and subtropical coastal and shallow offshore waters of the Indian Ocean, Indo-Pacific region and the western Pacific Ocean (DoEE 2019a). + The species is typically found close to shore, within approximately 1 km from the nearest land or oceanic islands, or in water depths of less than 30 m. + Knowledge of the species seasonal migration and breeding is largely unknown, however it is inferred that only the Arafura-Timor Sea population is migratory.	BIAs identified for foraging and breeding from April to November, include Darwin Harbour (approximately 235 km away from the Operational Area) and near Camden Sound (approximately 385 km south-west of the Operational Area) (see **Figure 3-8**). Given the species preference for shallow water and close proximity to shore, the presence of the species within the Operational Area is likely to be limited. The species may occasionally be present in the coastal region of the EMBA. Given foraging and breeding occurs from April to November, the proposed December to March survey timing also avoids the time when this population is most likely to be present in the region.
Sei whale	Vulnerable	+ The movements and distributions of sei whales are unpredictable and not well documented with information suggesting that they have the same general pattern of migration as most other baleen whales, although it is timed a little later and they do not move to such high latitudes (DoEE 2019a). + There are no known mating or calving areas in Australia. + Sei whales feed intensively between the Antarctic and subtropical convergences and mature animals may also feed in higher latitudes.	Given the wide ranging nature of this species, lack of nearby important habitat and a preference for deeper offshore waters, the presence of the species within the Operational Area and EMBA is likely to be limited.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ Sei whales feed on planktonic crustaceans, in particular copepods and amphipods.	
Blue whale / pygmy blue whale	Endangered	+ In Australia, there are two recognised sub-species of blue whale; the Antarctic or true blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*) (DoEE 2019a). As true blue whales feed primarily in polar waters, it is considered that all blue whales sighted in Australian waters are pygmy blue whales. + The nearest aggregation area for the pygmy blue whale in Australian waters occurs at the Perth Canyon, approximately 2,425 km south-west of the Operational Area (DoEE 2019a). The nearest aggregation area to the Operational Area lies in Indonesian waters, in the Banda and Molucca seas, approximately 750 km north of the Operational Area. This area is used by pygmy blue whales between May and September (Double et al. 2014). The timing of this aggregation suggests that the Banda and Molucca seas are feeding and calving grounds for pygmy blue whales. + Pygmy blue whales feed in Antarctic waters between December and April and may also feed opportunistically while migrating (DoEE 2019a). + Pygmy blue whales migrate from Antarctic summer feeding grounds to lower temperate and/or tropical latitudes for mating and calving (Bannister et al. 1996). The waters off Australia are used by the species to migrate from feeding grounds to calving grounds and are recognised as a BIA. + The following information is known about the pygmy blue whale migration along the western coast of Australia: – The population around southern Australia commence heading north along the WA coast towards Indonesian waters from April to May (McCauley 2011).	The EMBA partially overlaps with a pygmy blue whale migration BIA (Augusta to Derby), approximately 380 km north-west of the Operational Area (refer to **Figure 3-7**). Whales tend to pass along the shelf edge at depths of 500 m to 1000 m, and appear close to the coast in the Exmouth-Montebello Island areas on their southern migration. The EMBA also partially overlaps with a pygmy blue whale migration BIA (Indonesia-Banda Sea), approximately 317 km north-west of the Operational Area (**Figure 3-7**). Given, the absence of known foraging, resting and calving habitat, presence within the Operational Area and EMBA is likely to be infrequent and consist of transitory individuals during migration months.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		– Individuals have been recorded by satellite tags to travel along the shelf break along the WA coast up to North West Cape, after which they continued in a north-east directional route to Indonesia, west of the Operational Area (Double et al. 2014). – They are expected to pass the latitude of the Operational Area between April and August on their northerly migration and between late October and December on their southerly migration (McCauley 2011). Based on recent satellite tracking data (Double et al. 2014), five tagged whales on their northern migration passed the latitude of the Operational Area during April and May (Double et al 2014). – The migration extends to the Banda and Molucca Seas near Indonesia, where calving is understood to occur (Double et al. 2014). + Pygmy blue whales prefer to travel alone or in small groups (McCauley 2011; Gilmour et al. 2013).	
Fin whale	Vulnerable	+ Fin whales occur from polar to tropical waters, but rarely in inshore waters (DoEE 2019a). Fin whales are widely distributed in both hemispheres between latitudes 20–75° S (Mackintosh 1965). This species is also common in temperate waters, the Arctic Ocean and Southern Ocean. + There is insufficient data to prescribe migration times and routes for fin whales; however recent sightings in Australian waters include summer and autumn months. Fin whale calls have been detected in Antarctic waters from February to July (DoEE 2019a). + Fin whales feed intensively in high latitudes and may feed to some extent in lower latitudes, depending upon prey availability and locality. Fin whales feed on planktonic crustaceans, some fish and cephalopods (crustaceans).	Given the wide ranging nature of this species, lack of nearby important habitat and a preference for deeper offshore waters, the presence of the species within the Operational Area and EMBA is likely to be limited.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The fin whale is the second-largest whale species, after the blue whale. + Fin whales are killed by ship strikes more than any other whale, which may be due to surface feeding (DoEE 2019a).	
Humpback whale	Vulnerable, Migratory	+ Camden Sound forms the northern extent of the humpback whale migration, breeding, calving and resting BIAs, but these are not located within the EMBA (refer to **Figure 3-7**). The numbers of humpback whales at Camden Sound peak between June and September each year (DoEE 2019a). The migration corridor tends to be within the 200 m isobath (Jenner et al. 2001). + The humpback whale annual migration from the summer feeding grounds in Antarctica to the breeding and calving grounds in Camden Sound (approximately 385 km southwest of the Operational Area) occurs between May and October. + Humpback whales occur globally and throughout Australian waters with their distribution being influenced by migratory pathways and aggregation areas for resting, breeding and calving. There are two genetically distinct populations of humpback whales in Australia (west coast and east coast) (DoEE 2019a). + The west coast population of the humpback whale is thought to be increasing in size by about 9% per year (DoEE 2019a; Bejder et al. 2015); estimates conducted suggest that in 2008 the population migrating up the WA coast was at 21,750 individuals (Hedley et al. 2011).	Given, the absence of known foraging, resting and calving habitat, presence within the Operational Area and EMBA is unlikely. Given migration, breeding and calving occurs from May to October, the proposed December to March survey timing also avoids the time when this population is most likely to be present in the Kimberley region.
Bryde's whale	Migratory	+ The nearest known area of aggregation area for Bryde's whales is Ningaloo Reef (approximately 1,800 km away from the Operational Area) (DOE 2015). Aerial surveys carried out in 2009, between mainland Australia and Scott Reef recorded Bryde's whales in low numbers (RPS 2010). Between September 2006 and June 2009 sea	No specific feeding or breeding grounds have been discovered off Australia and given the distance to the closest known aggregation area at Ningaloo Reef (approximately 1,800 km away), the

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		noise loggers deployed within Scott Reef also recorded Bryde's whales calls year round (McCauley 2011; RPS 2010). + Bryde's whales are distributed throughout oceanic and inshore, tropical and warm temperate waters, between 40˚N and 40˚S year-round (DOE 2015). They have been recorded off all states of Australia, with the exception of the NT (DOE 2015). + The inshore form of the Bryde's whale is typically limited to the 200 m depth contour and breeds / calves year-round, whilst the offshore form is found in deeper waters (500 to 1,000 m) and breeds and calves over several months during winter (Best et al. 1984; Kato 2002).	presence of the species within the Operational Area and EMBA is likely to be infrequent.
Sperm whale	Migratory	+ Sperm whales have been recorded in all Australian states, however their distribution is primarily assumed from incidental sightings and beach-cast animals. + Sperm whales tend to inhabit offshore areas with a water depth of 600 m or more and are uncommon in waters less than 300 m (DoEE 2019a).	Given that sperm whales are typically found in deeper, colder waters, along the south coast of Western Australia, interactions with the species in the Operational Area and EMBA is likely to be infrequent.
Killer whale	Migratory	+ The killer whale is found in all of the world's oceans, from the Arctic and Antarctic regions to tropical seas (DoEE 2019). The species has been recorded in all the coastal waters of Australia, with concentrations reported in Tasmania, and common sightings in South Australia and Victoria. + Sightings of killer whale around the Australian coast are typically recorded along the continental slope and shelf, and predominantly in the vicinity of seal colonies, which are not known to exist in the region (DEWHA 2008b). + No areas of significance and no determined migration routes have been identified for this species within waters off WA (DoEE 2019a).	There are no BIA for killer whales near the Operational Area; however they have been reported within the Oceanic Shoals Marine Park (approximately 10 km north of the Operational Area). Given the wide ranging nature of this species, presence within the Operational Area is possible however expected to be infrequent due to the lack of nearby important habitat and a preference for coastal waters.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The specific diet of killer whales in Australian waters is not known, but there are reports of attacks on dolphins, young humpback whales, blue whales, sperm whales, dugongs and Australian sea lions.	
Dugong	Migratory	+ Dugongs have been reported to occur along the coastline in the JBG from Cape Hay to Point Pearce, with the main populations concentrated around Dorcherty Island (Woodside 2004), approximately 133 km south-east of the Operational Area. + Some of the coastal waters adjacent to the region support significant populations of dugongs, including Shark Bay, which has an estimated population of around 10,000 individuals (DSEWPaC 2012c). Dugongs are also known to occur along the coast throughout the Kimberley to the WA-NT border; however, population estimates for these areas are not available (DSEWPaC 2012c). + Dugongs inhabit protected shallow coastal areas, such as wide shallow bays and mangrove channels. Although the patterns of dugong movement in Western Australia are not well understood, it is thought that dugongs move in response to seagrass and water temperature. + Dugongs feed primarily on seagrass in shallow waters less than 10 m deep and mostly above 3 m depth (Burbidge et al. 2014). A survey carried out in northern Australia between 1994 and 2001 using time-depth recorders deployed on 15 dugongs logged 39,507 dives. The survey identified that dugongs spend the majority of their time in water depths of less than 3 m (Chilvers et al. 2004).	The PMST search identified the species as potentially occurring within the EMBA but not within the Operational Area. The closest dugong foraging BIA is located south of Ashmore Reef (approximately 490 km north-west of the Operational Area, within the EMBA). Ashmore Reef supports a population of less than 50 individuals that are genetically distinct from other Australian populations. The reef provides breeding and feeding habitats, with seagrass beds of the reef flats and lagoon their preferred food source. Breeding occurs year round at Ashmore Reef (DoEE 2019a). Due to the species' foraging BIA being located 580 km from the Operational Area, absence of suitable habitat and preference for shallow waters, presence of the species within the EMBA is likely to be limited.

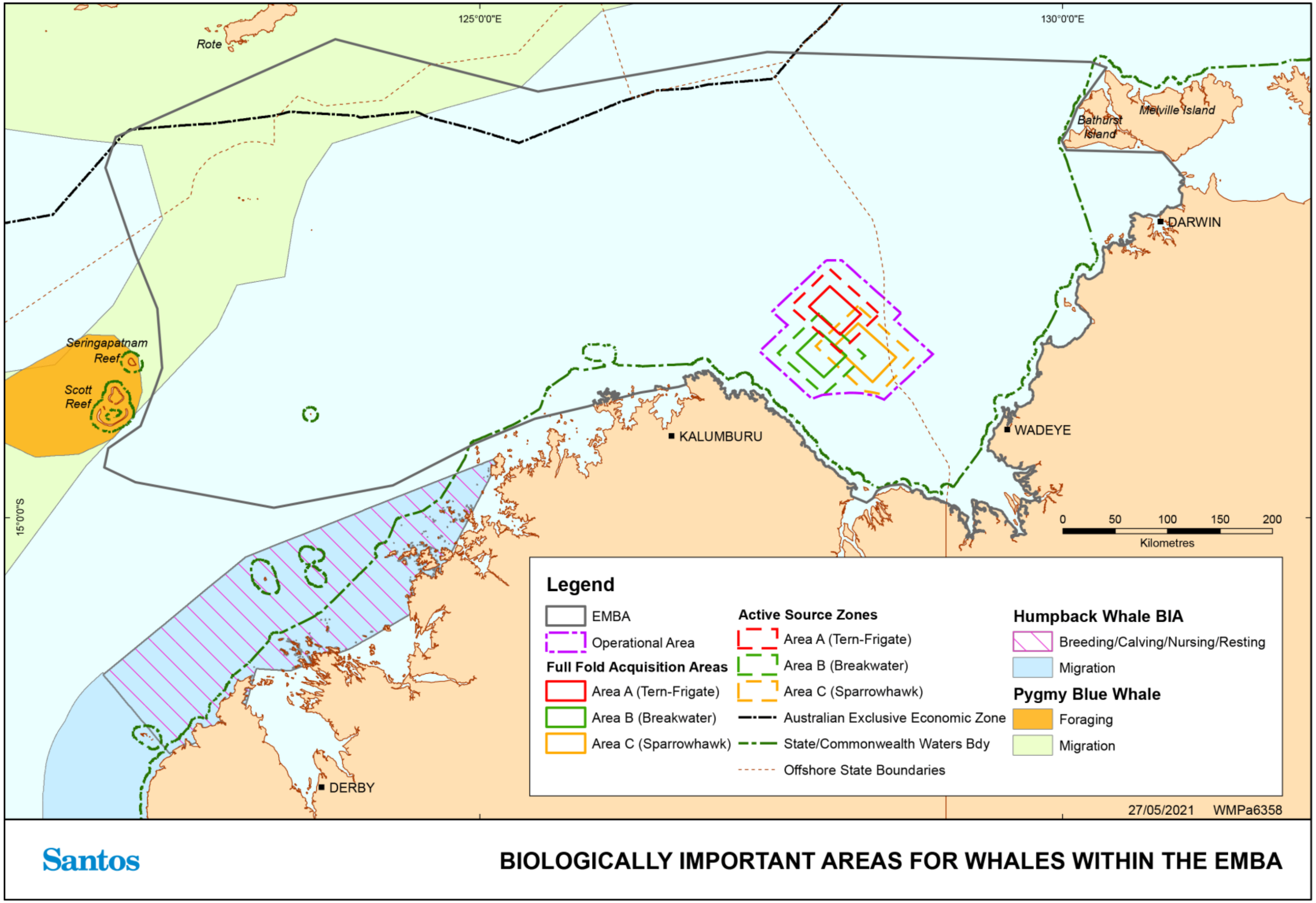


Figure 3-7: Biologically Important Areas for pygmy blue whales and humpback whales

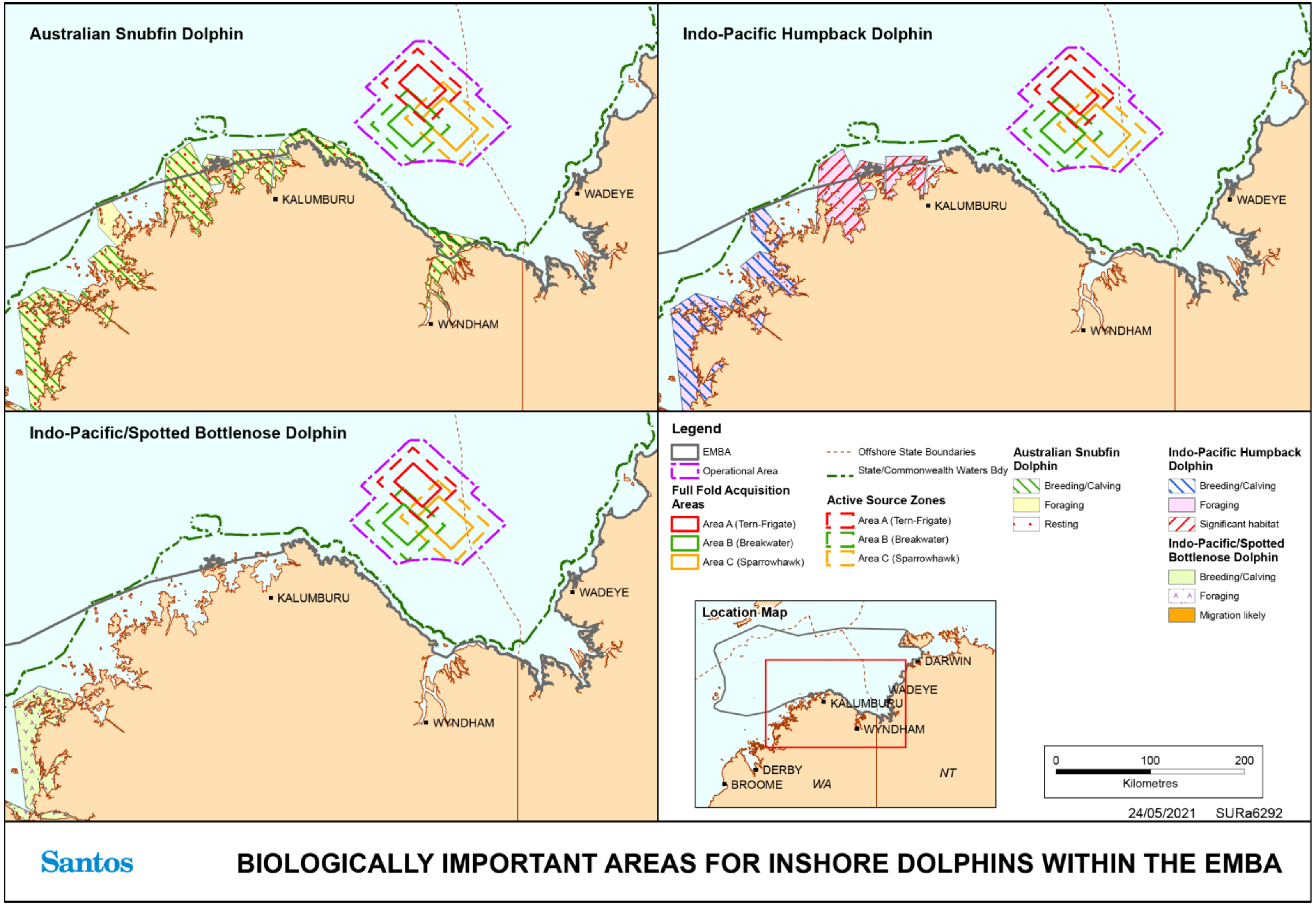


Figure 3-8: Breeding and foraging Biologically Important Areas for inshore dolphins

3.7.4 Marine Reptiles

3.7.4.1 Marine Turtles

Marine turtles are known to migrate from foraging areas to mating and nesting areas. All species with the exception of flatback turtles have an oceanic pelagic stage before moving to nearshore waters to breed. The NWMR and NMR are considered to be significant for supporting large feeding and nesting turtle populations.

The Recovery Plan for Marine Turtles in Australia (DoEE 2017) identifies areas 'habitat critical to the survival of a species' ('habitat critical') for marine turtle stocks under the EPBC Act. 'Habitat critical' is defined by the EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance as areas necessary:

+ For activities such as foraging, breeding or dispersal;
+ For the long-term maintenance of the species (including the maintenance of species essential to the survival of the species);
+ To maintain genetic diversity and long term evolutionary development; and
+ For the reintroduction of populations or recovery of the species.

It is noted that 'habitat critical' differs from 'Critical Habitat' as defined under Section 207A of the EPBC Act (Register of Critical Habitat). No 'Critical Habitat' has been identified and listed for marine turtles.

No habitat critical to the survival of a marine turtle species occurs within the Operational Area, however there are 11 habitat critical areas within the EMBA. The nearest habitat critical area is for the flatback turtle, 24 km from the Operational Area (refer to **Figure 3-10**), located at Cape Domett.

Six threatened and migratory marine turtle species were identified in the EPBC Act Protected Matters Database search as having the potential to occur in the Operational Area and EMBA. A description of their distribution, habitats, life stages and likely presence within and around the Operational Area during the survey is provided in **Table 3-14**.

There are several BIAs for turtle species in the region, including along the coastline and offshore islands adjacent to the Operational Area, within the EMBA (**Figure 3-9** and **Figure 3-10**). These include:

+ Foraging BIAs for loggerhead, flatback, olive ridley and green turtles which overlap with the Operational Area;
+ Internesting BIA for the flatback turtle (Cape Domett) which is located adjacent (south) to the Operational Area (but not overlapping);
+ Internesting BIA for the flatback turtle (Melville Island, Coburg Peninsula) located approximately 105 km north-east of the Operational Area.
+ Internesting BIAs for the olive ridley turtle located approximately 178 km north-east of the Operational Area
+ Foraging BIAs for the olive ridley turtle, with the nearest located 115 km north of the Operational Area.
+ Internesting BIAs for the green turtle, with the nearest located 175 km west of the Operational Area.

+ Nesting BIA for the green turtle (Cassini Island) located 190 km west of the Operational Area.
+ Mating BIA for the green turtle (Ashmore Reef) located 500 km north-west of the Operational Area.
+ Internesting and foraging BIAs for the hawksbill turtle, located approximately 459 km north-west and 500 km north-west, respectively, around Ashmore Reef.

3.7.4.2 Seasnakes

Seasnakes 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). Some species have extensive distributions and individuals may cover large distances, while other species have limited home ranges (Heatwole and Cogger 1993). Most seasnake species tend to be found in the shallower parts of the region to allow for increased benthic foraging time (DEWHA 2008b).

Seasnakes that inhabit coral reefs in the region (e.g. Ashmore Reef, located approximately 445 km to the west of the Operational Area) live out their lives within a few hectares, with little movement between the reefs (Guinea 2013; PTTEP 2013). The distance between reefs in the region and the deep water between reefs inhibits migration and supports the concept that seasnakes at each reef form a discrete 'management unit' for each species and prevents species from occupying all reefs (PTTEP 2013).

More than 20 species of seasnake occur within the region (DEWHA 2008b) with 21 listed marine seasnake species identified by the PMST search as potentially occurring in the Operational Area and EMBA, however only two of these species are threatened, namely the short-nosed seasnake and leaf-scaled seasnake.

No coral reefs occur within the Operational Area and therefore seasnakes are expected to occur only in low numbers. It is noted however that the pinnacles of the Bonaparte Basin KEF, can support high-order pelagic animals including seasnakes (DoEE 2019b).

A description of the distribution, migration movements, preferred habitat and life stages of the identified seasnake species is provided in **Table 3-14**, including commentary on their likely presence in the Operational Area and EMBA.

3.7.4.3 Crocodiles

One migratory crocodile species, the salt-water crocodile was identified in the EPBC Act Protected Matters Database search as potentially occurring in the both the Operational Area and EMBA. The salt-water crocodile is found in Australian coastal waters, estuaries, lakes, inland swamps and marshes. The species has a tropical distribution that extends across the northern coastline of Australia (Webb et al. 1987). The salt-water crocodile has been known to inhabit the Daly and Moyle rivers (approximately 197 km and 110 km, respectively, south-east of the Operational Area).

A description of the distribution, migration movements, preferred habitat and life stages of the crocodile is provided in **Table 3-14**, including commentary on its likely presence in the Operational Area and EMBA.

Table 3-14: Threatened and migratory marine reptiles potentially cccurring within the Operational Area and EMBA

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Flatback turtle	Vulnerable, Migratory	+ The flatback turtle is found in the tropical waters of northern Australia, Papua New Guinea and Irian Jaya, and nesting is only known to occur in Australia (Limpus 2007). + Breeding occurs all year round, however, in northern Australia most nesting occurs between June and August (DoEE 2019a). The nearest nesting beach for flatback turtles to the Operational Area is at Cape Domett (approximately 105 km south). The Cape Domett nesting population appears to be one of the largest known nesting populations of this species, with an estimated yearly population in the order of several thousand turtles. Flatback turtles nest at Cape Domett throughout the year and peak nesting occurs during July, August and September (Whiting et al. 2008). + The 60 km internesting buffer for flatback turtles in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017) is based primarily on the movements of tagged internesting flatback turtles along the NWS reported by Whittock et al. (2014), which found that flatback turtles may demonstrate internesting displacement distances up to 62 km from nesting beaches. However, these movements were confined to longshore movements in nearshore coastal waters or travel between island rookeries and the adjacent mainland (Whittock et al. 2014). There is no evidence to date to indicate flatback turtles swim out into deep offshore waters during the internesting period. + 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). Flatback turtle hatchlings do not undertake oceanic migrations like the	The Operational Area overlaps with a foraging BIA for the species (refer to **Figure 3-9**). Therefore, foraging and transient turtles may occur within the Operational Area and EMBA. The nearest internesting BIA is located adjacent to the Operational Area (but does not overlap) (refer to **Figure 3-10**). A 'habitat critical to the survival of a marine species' is located 24 km south of Operational Area (refer to **Figure 3-10**).

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		juveniles of other turtle species do, but spend their juvenile life phase within continental shelf waters (Limpus 2009). + Although turtles remain close to nesting beaches during the internesting period, there is evidence that 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). + More recent tagging studies further identified waters utilised by flatback turtles during post-nesting migration and foraging (Whittock et al. 2016a, 2016b; Thums et al. 2017). The studies found that turtles from the Pilbara region migrated north-east along the inner continental shelf, foraging in waters around Broome and James Price Point, Quondong Point, the Lacepede Islands, Lynher Bank, and at the Holothuria Banks in the Timor Sea (Whittock et al. 2016a, 2016b). Foraging areas were typically located in less than 50 m water depth (36.5 m mean depth) and 66 km from shore. + Thums et al. (2017) studied flatback turtles during their post-nesting migration from the Lacepede Islands and during foraging. The study found that flatback turtles migrated along the coast in water depths of 63 ± 5 m, passing near Adele Island on the way to foraging grounds on the Sahul Shelf in the Timor Sea. + Adult flatback turtles are primarily carnivorous, feeding on soft-bodied invertebrates. Juveniles eat gastropod molluscs, squid, siphonophores, and limited data indicate that cuttlefish, hydroids, soft corals, crinoids, molluscs and jellyfish are also eaten (DoEE 2019a).	

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The species has been recorded foraging in depths less than 10 m to over 40 m on the carbonate bank and terrace system of the Sahul Shelf KEF and around the pinnacles of the Bonaparte Basin KEF.	
Loggerhead turtle	Endangered, Migratory	+ The loggerhead turtle has a global distribution and occurs in eastern, northern and western parts of Australia (Limpus 2008). Loggerhead turtles are known to show fidelity to both their foraging and breeding areas and can make reproductive migrations of over 2,600 km between foraging and nesting areas (DoEE 2019a). The species are known to forage nearshore, in water depths up to approximately 50 to 60 m (DoEE 2019a). + In WA, the species is known to nest between October and February, with a peak in December (DoEE 2019a). + Juveniles feed on algae, pelagic crustaceans, molluscs and flotsam, whilst as an adult it feeds on gastropod molluscs, clams, jellyfish, starfish, coral, crabs and fish (DoEE 2019a). + Loggerhead turtles are known to forage around the pinnacles of the Bonaparte Basin and the carbonate bank and terrace system of the Sahul Shelf KEFs.	The northern portion of the Operational Area overlaps with a foraging BIA for loggerhead turtles (refer to **Figure 3-9**). Therefore, foraging and transient turtles are likely to occur within the Operational Area and EMBA.
Green turtle	Vulnerable, Migratory	+ Ashmore Reef and Cartier Island (approximately 445 km away) support a genetically distinct population in the region and provide critical nesting and internesting habitats (DoEE 2019a). Green turtles have been recorded to nest mainly on West Island at Ashmore Reef. They mainly nest at Ashmore Reef and Cartier Island during the mid-summer months (December to February) occasionally occurring year round, while the peak hatching period is March to April (DEWHA 2008a; Guinea 1995; Guinea 2013). + Distributed globally throughout tropical and subtropical waters, with WA supporting one of the largest green turtle populations in the	The Operational Area overlaps with a foraging BIA for the species. Therefore, foraging and transient turtles may occur within the Operational Area and EMBA. The closet biologically important internesting area is in the north of Mitchell Plateau (approximately 195 km west of the Operational Area) (refer to **Figure 3-10**).

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		world. Green turtles nest, forage and migrate across tropical northern Australia (DoEE 2019a). + Female green turtles go into an internesting cycle after each nesting occurrence. The internesting cycle takes approximately two weeks once nesting starts. The females spend this period in shallow waters beyond the reef edge, where they visit different substrates, occupy different depths and move up to tens of kilometres from the nesting beach. + The species undertakes extensive post-nesting migrations from foraging areas to traditional breeding areas, with individuals recorded migrating up to 2,600 km from nesting beaches (DoEE 2019a). One tagged female made a post-breeding migration through the Operational Area from Ashmore Reef to the Cobourg Peninsula in north-western NT (Limpus 2008). + The species primarily forages in shallow benthic habitats (<10 m) such as tropical tidal and subtidal coral and rocky reef habitat or inshore seagrass beds, feeding on seagrass beds or algae mats (Hazel et al. 2009; DoEE 2019a). Large feeding aggregations of green turtles are present at Ashmore Reef. It is the only reef recorded on the Sahul Shelf, where such large numbers of green turtles gather to feed (Guinea 2013). + Adult green turtles feed on seagrass, sponges and algae. + The pinnacles of the Bonaparte Basin are thought to be a KEF where green turtles transverse between foraging and nesting grounds. Further, a large portion of the Operational Area overlap a foraging BIA for this turtle species (refer to **Figure 3-9**).	
Leatherback turtle	Endangered, Migratory	+ Leatherback turtles are pelagic feeders, spending extended periods in tropical, subtropical and temperate open ocean waters (Limpus	The closest confirmed internesting site for the leatherback turtle is at the Cobourg Peninsula (DoEE 2019a),

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		2009). The species has been recorded feeding in the coastal waters of all Australian States and Territories in low densities. + Nesting occurs on tropical beaches and subtropical beaches (Marquez 1990) but no major centres of nesting activity have been recorded in Australia. The species is understood to migrate from Australian waters to breed at larger rookeries in neighbouring countries such as Indonesia, Papua New Guinea and Solomon Islands between December and January (DoE 2015b). + Leatherback turtle forage on pelagic soft bodied creatures (such as jellyfish, squid, salps, siphonophores and tunicates) all year round in Australian waters (DoEE 2019a).	approximately 430 km northeast of the Operational Area. Given the species distribution, and low density population in Australian waters, the presence of the species within the Operational Area and EMBA is expected to be low.
Hawksbill turtle	Vulnerable, Migratory	+ Hawksbill turtles are found in tropical, subtropical and temperate waters, with nesting mainly confined to tropical beaches (Limpus and Miller 2008). The hawksbill turtle is commonly found in the NWMR and NMR, nesting extensively along the coasts and foraging in the region. However, no hawksbill turtle nesting stocks are known to occur within the JBG (DoEE 2017). + The species is highly migratory and is known to migrate long distances between nesting and foraging areas (ranging from 35 to 2,400 km) (DoEE 2019a). + Australia has the largest breeding population of hawksbill turtles in the world (Limpus 2008). + Hawksbill turtles nest year round, with a peak between October and December (DSEWPaC 2012d). Internesting females are known to stay within approximately 20 km of nesting beaches. + The north-east subpopulation breeds throughout the year with a peak nesting period during July to October (DoEE 2019a), whilst breeding in the WA population peaks around October to January.	The closest internesting area to the Operational Area for hawksbill turtles is located at the Cobourg Peninsula (within the NMR), approximately 430 km north-east. Given the species wide distribution in Australian waters, transient turtles may occur within the Operational Area and EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ As a juvenile, the hawksbill turtle feeds on plankton in the open ocean and then feeds on sponges, hydroids, cephalopods, gastropods, jellyfish, seagrass and algae as an adult (DoEE 2019a).	
Olive ridley turtle	Endangered, Migratory	+ The olive ridley turtle has a worldwide tropical and subtropical distribution and is known to occur in both WA and NT (DSEWPaC 2012d). Whilst nesting has been recorded in WA, it is far more common in the NT (DoEE 2019a). + Although olive ridley turtles nest all year round nesting activity peaks around April to November, with the majority of nesting occurring from the Arnhem Land coast (including Bathurst Island, a biologically important internesting area) to the north-western coast of Cape York Peninsula (DoEE 2019a). After nesting, olive ridley turtles are known to migrate up to 1,050 km to various foraging areas (DoEE 2019a) including the pinnacles of the Bonaparte Basin and the carbonate bank and terrace system of the Sahul Shelf KEFs (DEWHA 2008a). + The olive ridley turtle is known to primarily forage in soft-bottom habitats ranging in depths from 6 – 35 m. They are also known to forage in pelagic waters (DEWHA 2008a). + The olive ridley turtle is known to forage in the western Joseph Bonaparte Depression and Gulf. + Adult turtles forage for crabs, shrimp, tunicates, jellyfish, salps and algae in depths ranging from several metres to over 100 m (DoEE 2019a).	The Operational Area overlaps with a foraging BIA for this turtle species (refer to **Figure 3-9**). Therefore, foraging and transient turtles may occur within the Operational Area and EMBA. The closest internesting area is off the coast of Fog Bay; approximately 178 km east from the Operational Area (refer to **Figure 3-10**).
Salt-water crocodile	Migratory	+ The salt-water crocodile is found in Australian coastal waters, estuaries, lakes, inland swamps and marshes. The species' distribution ranges from Rockhampton in QLD throughout coastal NT to King Sound (near Broome) in WA (DoEE 2019a).	Given that the nearest salt-water crocodile habitats are in the Daly and Moyle rivers, approximately 197 km and 110 km from the Operational Area

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The salt-water crocodile has been found in most major river systems in WA and the NT. The species mostly occurs in tidal rivers, coastal floodplains and channels, billabongs and swamps up to 150 km inland from the coast (DoEE 2019a). + The salt-water crocodile's primary food sources are crustaceans, insects and mammals; however, only larger individuals eat mammals. In areas of higher salinity (mangroves), the salt-water crocodile eats larger volumes of crab and a smaller volume of shrimp and insects. + Preferred nesting habitat of the salt-water crocodile includes elevated, isolated freshwater swamps that do not experience the influence of tidal movements. Floating rafts of vegetation also provide important nesting habitat. In the NT, most nest sites are found on the north-west banks of rivers. The species nest during the wet season with peak nesting during January and February.	respectively, the presence of the species within the Operational Area and EMBA is likely to be infrequent.
Short-nosed seasnake	Critically Endangered	+ The short-nosed seasnake is an aquatic seasnake. It is endemic to WA and has been recorded from Exmouth Gulf to the reefs of the Sahul Shelf. + It inhabits reef flats or shallow waters along the outer reef edge in water depths to 10 m (DoEE 2019a).	Given the preferred water habitat and depth the presence of the species within the Operational Area and EMBA is likely to be infrequent.
Leaf-scaled seasnake	Critically Endangered	+ The leaf-nosed seasnake is an aquatic seasnake found at the Ashmore and Hibernia Reefs, off the north-west coast of WA. An additional sighting of a single snake was reported in the Arafura Sea, off the northern coast of the NT. + It inhabits reef flats of shallow waters along the outer reef edge in water depths of 10 m (DSEWPaC 2011).	Given the preferred water habitat and depth the presence of the species within the Operational Area and EMBA is likely to be infrequent.

Santos

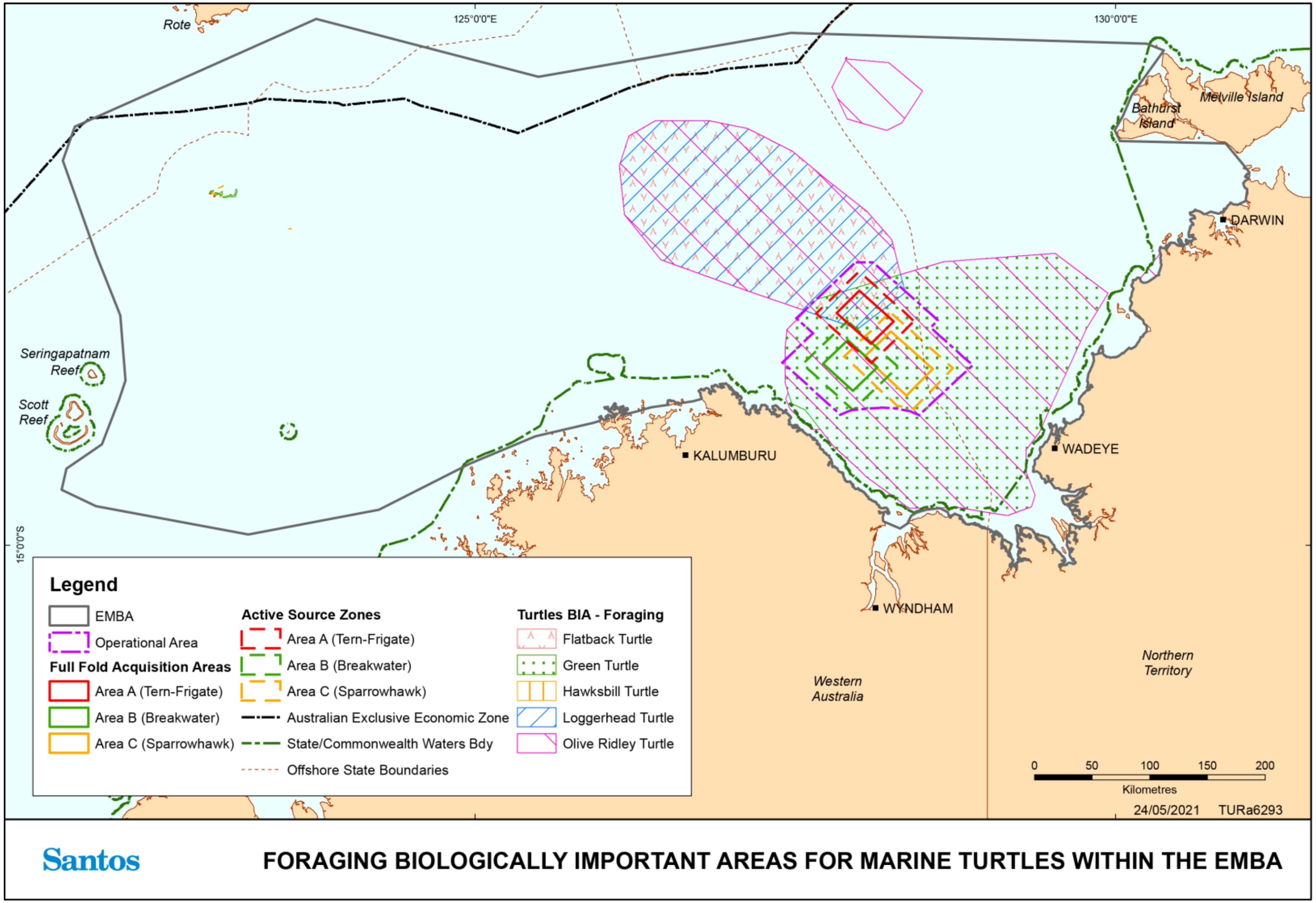


Figure 3-9: Foraging Biologically Important Areas for marine turtles within the EMBA

Santos

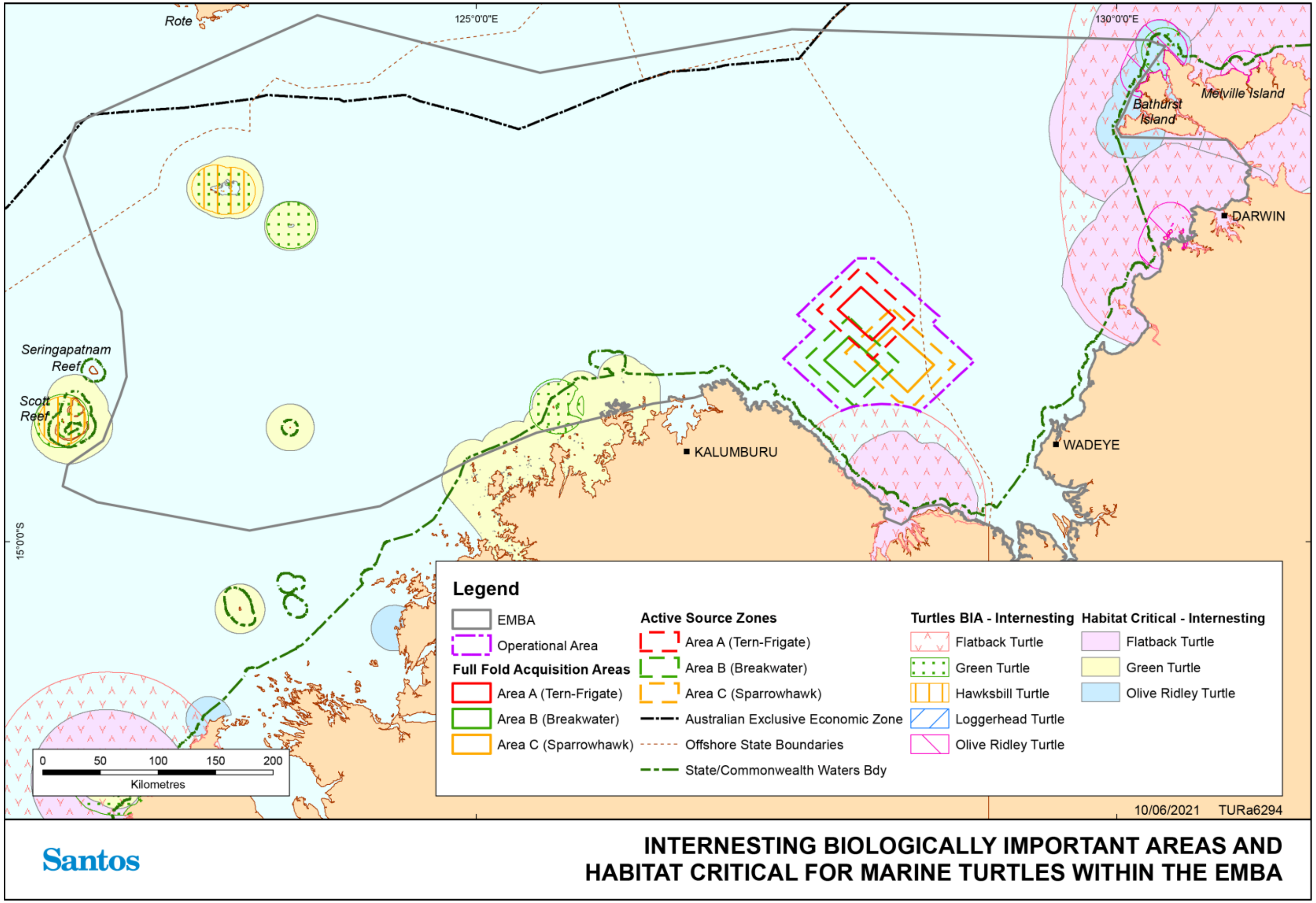


Figure 3-10: Marine turtle internesting Biologically Important Areas and Habitat Critical within the EMBA

3.7.5 Sharks and Rays

The NWMR and NMR experiences high species richness of shark, sawfish and rays stemming from the diversity of marine environments (DEWHA 2008a). There are approximately 500 shark and sawfish species globally, with 94 of these found in the region (i.e. 19% of the world's shark species) (DEWHA 2008b).

Two threatened, four threatened and migratory, and seven migratory shark and ray species were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the Operational Area.

No BIAs for sharks or rays were identified to occur within the Operational Area. A whale shark foraging BIA overlaps with the western portion of the EMBA, approximately 185 km west of the Operational Area (**Figure 3-11**). This migration and foraging route follows the continental shelf within the 200 m isobath and extends from Ningaloo to waters in the north Kimberley region. 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). The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November).

A description of the distribution, migration movements, preferred habitat and life stages of the identified sharks and rays species is provided in **Table 3-15**, including commentary on their likely presence in the Operational Area and EMBA.

Table 3-15: Threatened and migratory sharks and rays potentially occurring within the Operational Area and EMBA

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Whale shark	Vulnerable, Migratory	+ The whale shark occurs in both tropical and temperate waters with a typically oceanic and cosmopolitan distribution (Colman 1997). They are most commonly recorded in WA, the Northern Territory and Queensland, although they have been sighted occasionally in New South Wales and Victoria. + According to the DoEE's Conservation Advice on whale sharks, the species is known to aggregate at Christmas Island (approximately 2,400 km away) between December and January and at Ningaloo Reef (approximately 1,800 km away) between March and July to feed on krill and baitfish associated with coral spawning events (DoEE 2019a). + The whale shark migration between Christmas Island and Ningaloo Reef is expected to occur in deep waters away from the Operational Area between January and March (Colman 1997). + The population participating in the Ningaloo aggregation is estimated to comprise between 300 and 500 individuals, although the total population size in the region is unknown (Meekan et al. 2006).	The eastern boundary of the whale shark BIA for foraging (the northern WA coastline along the 200 m isobath) is approximately 185 km west of the Operational Area (**Figure 3-11**). Whale sharks are known to forage within the BIA during spring. Due to the species widespread distribution and highly migratory nature, individuals may transit through the Operational Area. Given the recorded migratory routes in the region, the cosmopolitan distribution of the species and location of the foraging BIA, whale sharks may be encountered in the Operational Area and EMBA in low numbers.
Green sawfish	Vulnerable, Migratory	+ The carbonate bank and terrace system of the Sahul Shelf KEF is known to support green sawfish (Donovan et al. 2008). A portion of this KEF overlaps with the eastern portion of the Operational Area. + The green sawfish occurs in both inshore and offshore marine coastal waters of northern Australia. Its current known distribution stretches from Broome in Western Australia around northern Australia and down the east coast as far as Jervis Bay, NSW (DoEE 2019a). + The green sawfish has been recorded in inshore marine waters, estuaries, river mouths, embankments and along sandy and muddy beaches (Peverell et al. 2004). They have also been recorded from	The closest foraging BIA for green sawfish in the area is located along the eastern shore of Camden Sound, over 385 km away from the Operational Area and outside of the EMBA. Given green sawfish are known to occur in the JBG (both adults and juveniles), the species may be encountered in low numbers in the Operational Area. The species may be present in higher numbers in the coastal region of the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		very shallow water (<1 m) to offshore trawl grounds in over 70 m of water (Stevens et al. 2005).	
Reef manta ray	Migratory	+ The reef manta ray is found around the northern coast of Australia between south-western Australia, and central New South Wales (DoEE 2019a). + This species is often resident in or along productive near-shore environments, such as island groups, atolls or continental coastlines. This species tends to inhabit warm tropical or sub-tropical waters (Marshall et al. 2018a). The species is commonly sighted inshore, however is also found around offshore coral reefs, rocky reefs and seamounts (Marshall et al. 2018a). + Movement patterns are likely site-specific and correlated with cycles in productivity. Individuals have been documented to make seasonal migrations of several hundred kilometres as well as daily migrations of almost 70 km (Marshall et al. 2018a).	Given the species is generally associated with nearshore environments, the presence of the species within the Operational Area is expected to be limited. The species may be present in higher numbers within the coastal region of the EMBA.
Giant manta ray	Migratory	+ The giant manta ray has a widespread distribution along the coast of Australia and is also known to seasonally migrate between aggregation sites (Marshall et al. 2018b). + The giant manta ray is commonly sighted along productive coastlines with regular upwelling, oceanic island groups and particularly offshore pinnacles and seamounts (Marshall et al. 2018b). This species has been recorded within the Oceanic Shoals Marine Park (Nichol et al. 2013). + The giant manta ray lives in tropical, marine waters worldwide, and occasionally in temperate seas between latitudes 30°N and 35°S (Australian Museum 2014). + The year-round population of giant manta rays present at Ningaloo Reef extends to Exmouth from mid- May through to mid-September.	Given the species wide-distribution, the presence of the species within the Operational Area is expected to be low. The species may be present in higher numbers in the coastal region of the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Narrow sawfish	Migratory	+ The exact distribution of the narrow sawfish is uncertain, but it is highly likely that its full range extended from Indo-Australian Archipelago to Japan and South Korea. + The narrow sawfish is a benthic-pelagic species that inhabits estuarine, inshore and offshore waters to at least 40 m depth (Last and Stevens 2009). Inshore and estuarine waters are critical habitats for juveniles and pupping females, whilst adults predominantly occur offshore (Peverell 2005).	Given the species wide-distribution, the presence of the species within the Operational Area is expected to be low. The species may be present in higher numbers in the coastal region of the EMBA.
Northern river shark	Endangered	+ The northern river shark is known to occur in WA and the NT, occupying both marine and freshwater environments including the JBG, Daly River, Adelaide River and the South and East Alligator rivers. + Northern river sharks are elasmobranchs capable of living and moving between freshwater and seawater. The species utilises rivers, tidal sections of large tropical estuarine systems, macro tidal embayments, inshore and offshore marine habitats. + Northern river sharks are thought to be endemic to Australia and southern New Guinea.	Given the species preferred estuarine habitat, the presence of the species within the Operational Area is expected to be low. The species may be present in the coastal region of the EMBA.
Dwarf sawfish	Vulnerable, Migratory	+ The dwarf sawfish usually inhabits shallow (2–3 m deep) coastal waters and estuarine habitats. Its distribution is thought to extend north from Cairns around the Cape York Peninsula in Queensland, across northern Australian waters to the Pilbara coast in WA (DoEE 2019a). + The dwarf sawfish uses its rostrum to stun schooling fish by sideswiping or threshing while swimming through a school. The main prey species is popeye mullet (*Rhinomugil nasutus*).	The closest foraging BIA for dwarf sawfish in the area is located along the eastern shore of Camden Sound, approximately 385 km away from the Operational Area and outside of the EMBA. Given the species preferred coastal habitat, and the location of the foraging BIA, the presence of the species within the Operational Area is expected to be low. The

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
			species may be present in the coastal region of the EMBA.
Freshwater sawfish	Vulnerable, Migratory	+ The freshwater sawfish is a marine/estuarine species that spends its first three–four years in freshwater growing to about half its adult size (4 m+) (Allen 2000 pers. comm.). Juveniles and sub-adult freshwater sawfish predominantly occur in rivers and estuaries, while large mature animals tend to occur more often in coastal and offshore waters up to 25 m depth (DoEE 2019a). + In northern Australia, this species appears to be confined to freshwater drainages and the upper reaches of estuaries, occasionally being found as far as 400 km from the sea. It is likely to occur within the carbonate bank and terrace system of the Sahul Shelf KEF. + The freshwater sawfish feeds on fishes and benthic invertebrates. The saw is used to stun schooling fish, such as mullet, and for extracting molluscs and small crustaceans from the benthic sediment.	The nearest freshwater sawfish foraging BIA is at King Sound, approximately 560 km away from the Operational Area. Given the species preferred estuarine habitat, and the location of the foraging BIA, the presence of the species within the Operational Area is expected to be low. The species may be present in the coastal region of the EMBA.
Speartooth shark	Critically Endangered	+ Speartooth sharks occur in geographically distinct locations across northern Australia in the NT and Queensland, and have been recorded in tidal rivers and estuaries with turbid waters, fine muddy substrates and temperatures ranging from 27-33°C (DoE 2014). + In the NT, they are found in the Van Diemen Gulf drainage, including the Adelaide River, South, East and West Alligator rivers and Murganella Creek (Field et al. 2008; Pillans et al. 2009). + Due to their similarity to bull sharks, it is thought that adult speartooth sharks may live outside of rivers in the coastal marine environment (Stevens et al. 2005; Pillans et al. 2008).	Due to the species preference for estuarine and coastal waters, the presence of the speartooth sharks within the Operational Area is expected to be low. The species may be present in the coastal region of the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Great white shark	Vulnerable, Migratory	+ Great white sharks have been recorded from central Queensland around the south coast to north-west WA, with movements occurring between the mainland coast and the 100 m depth contour (DoEE 2019a). + They are known to undertake migrations along the WA Coast, with some individuals travelling as far north as North West Cape during spring, before returning south for summer (DoEE 2019a). + Great white sharks are frequently recorded in waters around fur seal and sea lion colonies (DoEE 2019a).	Due to the species preference for cold temperate waters and feeding grounds in waters around seal colonies further south, the presence of the species within the Operational Area and EMBA is likely to be infrequent.
Shortfin mako shark	Migratory	+ The shortfin mako is a pelagic species with a circumglobal, wide-ranging oceanic distribution in tropical and temperate seas (Mollet et al. 2000). The shortfin mako is found in tropical and warm-temperate seas in water depths up to 500 m. The species is rarely found in waters cooler than 16 °C, and is occasionally found close inshore where the continental shelf is narrow (Cailliet et al. 2009). + It is widespread in Australian waters having been recorded in offshore waters all around the continent's coastline with exception of the Arafura Sea, the Gulf of Carpentaria and Torres Strait (Last and Stevens 2009). + Shortfin makos are also highly migratory and travel large distances.	Given the species distribution in deep offshore waters, the presence of the species within the Operational Area and EMBA is expected to be low.
Longfin mako shark	Migratory	+ In Australian waters, longfin mako sharks are found from Geraldton, in WA, and north to Port Stephens in New South Wales (Last and Stevens 2009). + Longfin makos inhabit oceanic and pelagic habits, typically in tropical regions. They are a highly mobile species and have a wide-ranging distribution (DEWHA 2008b) but are rarely encountered.	Given the species distribution in deep offshore waters, the presence of the species within the Operational Area and EMBA is expected to be low.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ Whilst assumed to be a deep-water shark, sightings on the ocean surface, and the species' diet, suggest a broader depth range (Rigby et al. 2019).	
Oceanic whitetip shark	Migratory	+ Within Australian waters, the oceanic whitetip shark is found from Cape Leeuwin, WA, through parts of the northern territory and down the east coast of Queensland and New South Wales to Sydney (Last and Stevens 2009). It has not been recorded within the Gulf of Carpentaria or the Arafura Sea. + The oceanic whitetip shark is a circumglobal deep-water pelagic species inhabiting tropical to warm-temperate waters (Compagno 1984). + Oceanic whitetip sharks prefer water temperatures above 20°C and can reach depths of >180 m (Castro et al. 1999).	Given the species distribution in deep offshore waters, the presence of the species within the Operational Area and EMBA is expected to be low.

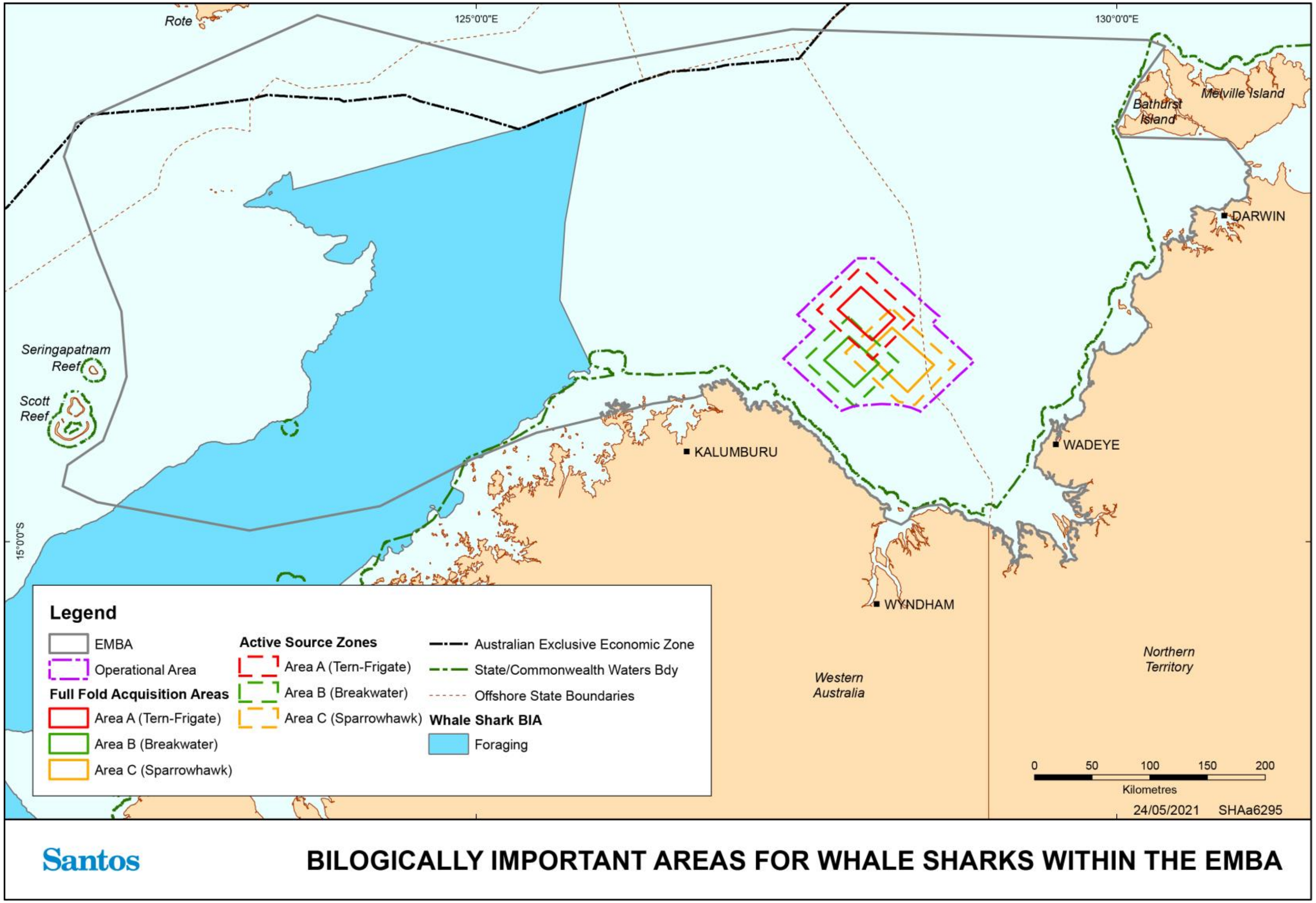


Figure 3-11: Foraging Biologically Important Area for whale sharks within the EMBA

3.7.6 Seabirds and Migratory Shorebirds

Many migratory shorebirds (including those frequenting offshore islands) and seabird species are known to occur in the NWMR and NMR. Migratory shorebird species forage and rest in the region on their way between Northern Hemisphere breeding grounds and Northern Australian feeding grounds, known as the East Asian–Australasian Flyway. Seabird species spend the majority of their lives foraging across large distances over the open ocean and many also breed within the region (DSEWPaC 2012f).

There is no emergent land within the Operational Area to support breeding colonies of seabirds. The closest known breeding sites occur at the three estuaries at the head of the JBG (located approximately 150 km away from the Operational Area) (the Keep, Victoria and Fitzmaurice rivers), which support seabird and shorebird colonies of 10,000–15,000 birds. Extensive areas of shorebird and waterbird feeding habitat are associated with the mangroves and mudflats in this region. The Anson Bay to Fog Bay area, on the eastern side of the JBG, is one of the most important areas for colonial waterbird breeding in the NT. There is extensive shorebird feeding and roosting habitat in Fog Bay, Anson Bay and the Little Moyle River (DEWHA 2008b). Additionally, the Cartier Island and Ashmore Reef, within the EMBA, support breeding colonies of seabirds and migratory shorebirds. Given coastal habitats support large migratory populations, seabirds may fly over the Operational Area during migrations.

There are 23 bird species considered to be ecologically significant to the NWMR; that is, they are either endemic to the region, have a high number of interactions with the region (nesting, foraging, roosting or migrating) or have life history characteristics that make them susceptible to population decline. In addition, there are 11 bird species considered to be ecologically significant to the NMR, due to the presence of important feeding sites in the NMR.

Results from the EPBC Act Protected Matters Database revealed that there are three threatened and migratory, and eight migratory seabird species within the Operational Area, and six threatened, six threatened and migratory, and 36 migratory seabird species within the EMBA.

There are several BIAs for marine bird species in the region, including along the coastline and offshore islands adjacent to the Operational Area, within the EMBA (**Figure 3-12**). These include:

+ Lesser crested tern breeding BIAs overlap with the south-west portion of the Operational Area and further locations;
+ Roseate tern breeding BIAs, with the nearest located approximately 63 km west of the Operational Area.
+ Lesser frigatebird breeding BIAs, with the nearest located approximately 63 km west of the Operational Area.
+ Greater frigatebird breeding BIAs, with the nearest located 395 km north-west of the Operational Area.
+ Wedge-tailed shearwater breeding BIAs, with the nearest located 390 km north-west of the Operational Area.
+ White-tailed tropicbird breeding BIA, located 395 km north-west of the Operational Area;
+ Red-footed booby breeding BIA, located 390 km north-west of the Operational Area.
+ Brown booby breeding BIA, located 455 km west of the Operational Area.
+ Greater crested tern breeding BIA, located 285 km north-east of the Operational Area, within the EMBA.

+ Little tern breeding BIAs, with the nearest located approximately 173 km west of the Operational Area.
+ Little tern resting BIA (Ashmore Reef) located approximately 480 km north-west of the Operational Area.

A description of the distribution, migration movements, preferred habitat and life stages of the identified marine bird species in provided in **Table 3-16**, including commentary on their likely presence in the Operational Area and EMBA.

Table 3-16: Threatened and migratory seabirds potentially occurring within the Operational Area and EMBA

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Lesser crested tern	N/A	+ The lesser crested tern inhabits tropical and sub-tropical dandy and coral coasts and estuaries (DSEWPaC 2012e). + In Australia, lesser crested terns are found on coasts and in coastal waters, primarily in the north. The species occurs around most of the NT, with the highest density of confirmed sightings along the coast to the south-west of Darwin (DSEWPaC 2012e). + The species breeds on low-lying islands, coral flats, sandbanks and flat sandy beaches, and may move nesting sites from one year to the next (DSEWPaC 2012e). + Lesser crested terns forage for small pelagic fish and shrimp in the surf and over offshore waters in areas of reef and deeper shelf waters (DSEWPaC 2012e). + The lesser crested tern is not listed as threatened or migratory under the EPBC Act 1999.	The Operational Area partially overlaps with a lesser crested tern breeding BIA (refer to **Figure 3-12**). Given the preference for breeding grounds nearby to the Operational Area and overlap with a breeding BIA, this species is likely to be present in the Operational Area and EMBA.
Red knot	Endangered, Migratory	+ The red knot is common in all the main suitable habitats around the coast of Australia, very large numbers are regularly recorded in northern Australia. + In Australasia, the red knot mainly inhabits intertidal mudflats, sandflats and sandy beaches of sheltered coasts or shallows pools on exposed wave-cut rock platforms or coral reefs. + The red knot usually forages in soft substrate near the edge of water on intertidal mudflats or sandflats exposed by low tide. At high tide, they may feed at nearby lakes, sewage ponds or floodwaters. They have also been observed foraging on thick algal mats in shallow water and in shallow pools on crests of coral reefs. + The red knot is diurnal and nocturnal. In non-breeding areas, feeding activity is regulated by tide; they feed less just before and after high	Red knots were recorded in large numbers along the coastal strip from Fog Bay to Peron Island North (170 km from the Operational Area). Given the range and distribution of this species, the survey is likely to encounter low numbers of this species in the Operational Area during October. Higher population densities may be encountered in the nearshore waters of the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		tide. The red knot is omnivorous and eats mostly worms, bivalves, gastropods, crustaceans and echinoderms. + The red knot lays eggs in June and nests on open vegetated tundra or stone ridge, often close to a clump of vegetation. The red knot is migratory, breeding in the high Artic and moving south to non-breeding between 58° N and 50 °S. + Peak numbers of this species in the NWMR and NMR are usually between September and October.	
Curlew sandpiper	Critically Endangered, Migratory	+ The curlew sandpiper's breeding areas are mainly restricted to the Arctic (DoEE 2019a). This species does not breed in Australia. + Within Australia, curlew sandpipers occur around the coasts while also being widespread inland, though in smaller numbers (DoEE 2019a). + This species forages mainly on invertebrates, including worms, molluscs, crustaceans, and insects, as well as seeds. Outside Australia, they also forage on shrimp, crabs and small fish. Curlew sandpipers usually forage in water, near the shore or on bare wet mud at the edge of wetlands (DoEE 2019a). + The species move into certain areas in Australia during northward migration in April, fatten up, and migrate out of Australia during May. They start returning to the area in August and throughout September (Chatto 2003).	Given the distribution of this coastal wetland bird species, the survey is likely to encounter low numbers of this species in the Operational Area, during the April/May period. Higher population densities may be encountered in the coastal waters of the EMBA.
Little tern	Migratory	+ The closest breeding site to the Operational Area for the non-Asian migrants of the little tern is on the coastline of the Kimberley (approximately 150 km away). Breeding is thought to occur in June, July and October (DoEE 2019a). + The little tern is widespread in Australia, with breeding sites widely distributed. The species has three separate populations in Australia; the northern subpopulation breeds across northern Australia, the	The closest breeding site to the Operational Area for the non-Asian migrants of the little tern is on the coastline of the Kimberley (approximately 150 km away). Breeding is thought to occur in June, July and October (DoEE 2019a).

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		eastern subpopulation breeds in the eastern and south-eastern coast of Australia; and the third subpopulation comprises of Asian migrants that migrate to spend their non-breeding season in Australia. The species has a widespread and continuous distribution from north-western Australia, around the north and east coast to south eastern Australia (DoEE 2019a). + The little tern is a coastal seabird, which usually forages in very shallow water, more often in brackish lagoons and saltmarsh creeks. The little tern usually forages close to breeding colonies (Commonwealth of Australia 2012). + The Asian migrants' non-breeding season is between spring and summer (September to May). The Asian migrants leave for their northern Hemisphere Breeding grounds between March and April (DoEE 2019a).	Given the wide distribution and migration pattern, this species may be present in the Operational Area and EMBA in low numbers or isolated individuals/groups.
Sharp-tailed sandpiper	Migratory	+ The sharp-tailed sandpiper spends the non-breeding season in Australia with small numbers occurring regularly in New Zealand (NZ). Most of the population migrates to Australia, mostly to the south-east and are widespread in both inland and coastal locations. In WA, they are widely distributed from Cape Arid to Carnarvon, around coastal plains of the Pilbara Region to south-west and east Kimberly Division. In NT, the most important area is the area from Darwin to Murgenella Creek and the Port McArthur. + In Australasia, the sharp-tailed sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emerged grass or low vegetation. + The sharp-tailed sandpiper forages on seeds, worms, molluscs, crustaceans and insects.	Given the wide distribution of this species and the migratory pattern, it is likely this species will be encountered in low numbers within the Operational Area and EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The sharp-tailed sandpiper migrates to Australia in late June, early July, departing the breeding grounds. The species then departs the non-breeding grounds in Australia by April/March (DoEE 2019a).	
Eastern curlew	Critically Endangered, Migratory	+ Within Australia, the eastern curlew has a primarily coastal distribution. They have a continuous distribution from Barrow Island and Dampier Archipelago, WA, through the Kimberley and along the NT, QLD, and NSW coasts and the islands of Torres Strait. Elsewhere they are patchily distributed (DoEE 2019a). + This species does not breed in Australia, rather in the Northern Hemisphere during summer, between early May and late June (DoEE 2019a). They start to depart early March and begin to arrive back in late July. + During the non-breeding season in Australia, the eastern curlew is most commonly associated with sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons, with large intertidal mudflats or sandflats, often with beds of seagrass (Zosteraceae) (DoEE 2019a).	Given the distribution of this coastal wetland bird species, the survey is likely to encounter low numbers of this species in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA.
Common noddy	Migratory	+ In Australia, the common noddy occurs mainly in the ocean off the QLD coast, but the species also occurs off the north-west and central WA coast. + During the breeding season, the common noddy usually occurs on or near islands, on rocky islets and stacks with precipitous cliffs, or on shoals or cays of coral or sand. When not at the nest, individuals will remain close to the nest, foraging in the surrounding waters. During the non-breeding period, the species occurs in groups throughout the pelagic zone. Birds may nest in bushes, saltbush, or other low vegetation. The seasonality of breeding varies greatly between sites. Depending on locations, birds breed annually or twice a year (spring to early summer and again at autumn).	The closest breeding BIA for this species is located at East Arnhem approximately 875 km east of the Operational Area. Given the wide distribution of the species and preferred habitat, the species may be present in low numbers in the Operational Area and in the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The common noddy feeds mainly on fish, although they are known to also take squid, pelagic molluscs, medusa and aquatic insects.	
Streaked shearwater	Migratory	+ The streaked shearwater occurs frequently in northern Australia from October to March, with some records as early as August and as late as May (Marchant and Higgins 1990). Whilst the species does not breed in Australia, it is known to forage in the NMR, in particular north-west of the Wellesley Islands (1,195 km from the Operational Area). + The streaked shearwater feeds mainly on fish and squid. + The streaked shearwater is a colonial breeder that lays a single egg in a burrow. Colonies are usually in a well-forested area (Birdlife 2019a).	Given the distribution of the species and preferred habitat, the species may be present in low numbers in the Operational Area and EMBA during the October - May period.
Lesser frigatebird	Migratory	+ The lesser frigatebird is usually seen in tropical or warmer waters off northern WA, NT, QLD and northern NSW. The species forages in the NMR and breeds in areas adjacent to the region (Marchant and Higgins 1990). + The species is usually pelagic and often found far from land, but is also found over shelf waters, in inshore areas, and inland over continental coastlines (Marchant and Higgins 1990). + The lesser frigatebird breeds in mangroves or bushes, and even on bare ground. It feeds mainly on fish (especially flying-fish) and squid, but also on seabird eggs and chicks, carrion and fish scraps (Birdlife 2019b).	The closest biologically important breeding area of this species is at Kimberley and Pilbara coasts approximately 60 km west of the Operational Area (**Figure 3-12**). Given the distribution of the species and preferred habitat, this species may be present in the Operational Area and EMBA in low numbers.
Great frigatebird	Migratory	+ Great frigatebirds are found in tropical waters globally. The species breeds on small, remote tropical and sub-tropical islands, in mangroves or bushes and occasionally on bare ground. + Great frigatebird feeds on fish, squid and chicks of other bird species.	A BIA has been identified at Ashmore Reef and Cartier Island for the species to highlight breeding and foraging behaviours in the area (approximately 445 km northwest from the Operational Area) (**Figure 3-12**).

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ Breeding is known to occur between May to June and in August (DoEE 2019a).	Given the distribution of the species and preferred habitat, this species may be present in the Operational Area in low numbers. Higher population densities may be encountered in the coastal waters of the EMBA.
Common sandpiper	Migratory	+ Distributed along all coastlines of Australia and many areas inland, the common sandpiper is widespread in small numbers. + Generally, the species forages in shallow water and on bare soft mud at the edges of wetlands. Birds sometimes venture into grassy adjoining wetlands and mangroves. + Typically, the common sandpiper eats molluscs such as bivalves, crustaceans such as amphipods and crabs and a variety of insects (DoEE 2019a). + The common sandpiper breeds in Eurasia and moves south for the boreal winter, with most of the western breeding populations wintering in Africa, and eastern breeding populations wintering in South Africa and Australia. Individuals usually arrive in Western Australia from July onwards.	Given the distribution of the species and preferred habitat, this species may be present in the Operational Area in low numbers. Higher population densities may be encountered in the coastal waters of the EMBA.
Pectoral sandpiper	Migratory	+ In Australasia, the species is found at coastal lagoons, estuaries, bays, swamps, lakes, inundated grasslands, saltmarshes, river pools, creeks, floodplains and artificial wetlands. + The pectoral sandpiper is omnivorous, consuming algae, seeds, crustaceans, arachnids and insects. While feeding, they move slowly, probing with rapid strokes. They walk slowly on grass fringing water. + In WA, the species is rarely recorded. It has been observed at the Nullarbor Plain, Reid, Stoke's Inlet, Grassmere Lake, Warden Lake, Dalyup and Yellilup Swamp, Swan River, Benger Swamp, Guraga	Given the wide distribution and migration pattern, this species may be present in the Operational Area and EMBA in low numbers or isolated individuals/groups.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		Lake, Wittecarra, Harding River, coastal Gascoyne, the Pilbara and the Kimberley. In NT, the species habitat likely occurs along the coast of Darwin, which is 260 km away from the Operational Area (DoEE 2019a).	
Greater crested tern	Migratory	+ The greater crested tern is widespread and numerous along the NT coastline, with 20 breeding colonies reported (DSEWPaC 2012a). + The species shows a preference for nesting on offshore islands, low-lying coral reefs, sandy or rocky coastal islets, coastal spits and lagoon mudflats (DSEWPaC 2012e). + The colony on Seagull Island, off the north-west tip of Melville Island supports a BIA of approximately 60,000 greater crested terns (Woinarski et al. 2003), which is thought to be the largest breeding colony of this species and of international significance. + The species forages in a range of habitats including shallow waters of lagoons, coral reefs, bays, harbours, inlets and estuaries, along shorelines, rocky outcrops and in open sea, in mangrove swamps and in offshore and pelagic waters (DSEWPaC 2012e). + The breeding period for the greater crested term is March to July, with most eggs being laid during late April to early June (Chatto 2001).	Given the widespread distribution, this species may be present in the Operational Area in low numbers or isolated individuals/groups. Higher population densities may be encountered in the coastal waters of the EMBA.
Bridled tern	Migratory	+ In Western Australia, breeding is widespread from islands off Cape Leeuwin (extending round the southern coast to Seal Rocks) north to Shark Bay and in Pilbara region and Kimberley Division. At sea, distribution extends from Cape Leeuwin north to Dirk Hartog Island, with isolated mainland coastal records at Point Maud and Ningaloo, and from Barrow Island to the Dampier Archipelago, and at sea off the Kimberley coast from waters west of the Dampier Peninsula to Ashmore Reef and JBG.	Given the wide distribution and migration pattern, this species may be present in the Operational Area and EMBA in low numbers or isolated individuals/groups.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The species occupies tropical and subtropical seas, breeding on islands, including vegetated coral cays, rocky continental islands and rock stacks. + In WA, birds breed late spring to summer, with eggs recorded from mid-October to late January, and young from mid-December to early March (DoEE 2019a).	
Osprey	Migratory	+ The osprey is most abundant in northern Australia, where high population densities occur in remote areas. The breeding range of the osprey extends around the northern coast of Australia (including many offshore islands) from Albany in WA to Lake Macquarie in NSW. + Ospreys occur in littoral and coastal habitats and terrestrial wetlands of tropical and temperate Australia and offshore islands. + Ospreys mainly feed on fish, especially mullet where available, and rarely take molluscs, crustaceans, insects, reptiles, birds and mammals. The species usually forage diurnally, but have also been observed hunting prey at night. + Osprey breed from April to February in Australia.	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA.
Australian lesser noddy	Vulnerable	• The Australian lesser noddy is endemic to Australia and nests on the Houtman Abrolhos Islands and, possibly, Ashmore Reef. The species remain near breeding islands throughout the year, however, gales may displace birds many hundreds of kilometres (DoEE 2019a). + The species usually occupies coral-limestone islands that are densely fringed with white mangrove *Avicennia marina* and occasionally occurs on shingle or sandy beaches (Higgins and Davies 1996). + The breeding season is protracted, extending from mid-August to early April; however this can vary year to year (Higgins and Davies 1996).	Given the preferred habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The Australian lesser noddy may forage out at sea or in seas close to breeding islands and fringing reefs (Johnstone and Storr 1998; Storr et al. 1986; Whittell 1942).	
Bar-tailed godwit	Vulnerable	+ The bar-tailed godwit has been recorded in the coastal areas of all Australian states. It is widespread in the Torres Strait and along the east and south-east coasts of Queensland, NSW and Victoria, including the offshore islands. + The bar-tailed godwit is found mainly in coastal habitats such as large intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays. + The species typically roosts on sandy beaches, sandbars, spits and also in near-coastal saltmarsh. + Roebuck Bay and Eighty Mile Beach are internationally important sites for the species, supporting over 50,000 individuals. + At the subspecies level, *Limosa lapponica baueri* is listed as Vulnerable and *Limosa lapponica menzbieri* is listed as Critically Endangered under the Wildlife Conservation Act 1950.	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA.
Australian painted-snipe	Endangered	+ The Australian painted snipe has been recorded at wetlands in all states of Australia, however the species has been recorded less frequently at a smaller number of more scattered locations farther west in South Australia, the Northern Territory and Western Australia. + The species generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. + The species may breed in response to wetland conditions rather than during a particular season (DoEE 2019a).	Given the preferred habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the EMBA.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
Fork-tailed swift	Migratory	+ In Western Australia, the fork-tailed swift is scattered along the coast from south-west Pilbara to the north and east Kimberley region, near Wyndham. + The Fork-tailed Swift is almost exclusively aerial, flying from less than 1 m to at least 300 m above ground. + The Fork-tailed Swift does not breed in Australia (DoEE 2019a).	Given the distribution of this species and habitat, it is unlikely this species will be encountered within the Operational Area, however may be present in low numbers within the EMBA.
Roseate tern	Migratory	+ In WA, the subspecies is regularly recorded north from Mandurah to Eighty Mile Beach, in the Pilbara Region. Along the Kimberley coastline, the subspecies occurs at scattered sites, north to the Bonaparte Archipelago and possibly further. In the NT, the subspecies has a scattered occurrence along the north coast, mainly from Darwin to Grove Peninsula, though birds have been recorded west to North Peron Island and east to the Sir Edward Pellow Islands. + The roseate tern occurs in coastal and marine areas in subtropical and tropical seas. The species inhabits rocky and sandy beaches, coral reefs, sand cays and offshore habitats. + Breeding in WA occurs from Second Rock, near Penguin Island, to Lacepede Island (approximately 680 km from the Operational Area), whilst breeding occurs in the NT at Haul Round Island, 605 km from the Operation Area. + Breeding in WA occurs in two quite distinct periods, within peak months for laying April to November. At the same sites, breeding occurs during both late spring-summer and late autumn-winter. Most colonies in the NT nests between September and January/ February (DoEE 2019a).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA.
Brown booby	Migratory	+ The brown booby occurs throughout all tropical oceans, bounded by latitudes 30°N and 30°S (DSEWPaC 2012e).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ In Australia, the brown booby is found from Bedout Island in WA, around the coast of the NT to the Bunker Group of islands in Queensland with occasional reports further south in New South Wales and Victoria. + The Brown Booby uses both marine and terrestrial habitat. Off north-west Western Australia, Brown Boobies are most abundant 18–36 km from land, but also occur inside and outside these limits (DoEE 2019a). + The species nests on rugged rocky terrain such as cliffs and steep slopes, on larger islands, beaches, and coral rubble and guano flats on cays. The species typically leaves breeding islands when not breeding, in search of better foraging grounds (DoEE 2019a).	densities may be encountered in the coastal waters of the EMBA.
Red-footed booby	Migratory	+ The red-footed booby is found worldwide, essentially confined to tropical waters between 30°N and 30°S in the Atlantic, Indian and Pacific Oceans (DoEE 2019a). + In Australia, a recent or recently re-established breeding colonies of red-footed boobys is found at Ashmore Reef (Clarke 2010). + Adult red-footed boobys have been detected up to 125 km from the nearest breeding islands during foraging, with females found to feed mostly at the extremity of their foraging trip (Clarke 2010).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA, particularly in waters surrounding Ashmore Reef.
Oriental reed warbler	Migratory	+ The species has been recorded off the Dampier Peninsula in WA and off the coast of Darwin in the NT. + It is a non-breeding species in Australia. + Habitat mainly includes beds of reed beside lakes, coastal marshes, estuaries and along rivers (DoEE 2019a).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA.
Oriental plover	Migratory	+ The oriental plover is a non-breeding visitor to Australia, where the species occurs in both coastal and inland areas, mostly in northern Australia.	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The oriental plover is a migratory species, breeding in the Northern Hemisphere and flying south for the boreal winter (Dement'ev and Gladkov 1951; Lane 1987; Marchant and Higgins 1993; Wiersma 1996). + Internationally important sites in Australia includes Roebuck Bay, approximately 750 km southeast of the Operational Area (DoEE 2019a). + Oriental plovers usually forage among short grass or on hard stony bare ground, but also on mudflats or among beachcast seaweed on beaches. + In Australia, the species typically inhabits coastal habitats such as estuarine mudflats and sandbanks, on sandy or rocky ocean beaches or nearby reefs, or in near-coastal grasslands.	densities may be encountered in the coastal waters of the EMBA.
Oriental pratincole	Migratory	+ Within Australia, the oriental pratincole is widespread in northern areas, especially along the coasts of the Pilbara Region and the Kimberley Division in WA, the Top End of the NT, and parts of the Gulf of Carpentaria. + In non-breeding grounds in Australia, the species usually inhabits open plains, floodplains or short grassland (including farmland or airstrips), often with extensive bare areas. + The species does not breed in Australia (DoEE 2019a).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA.
Wedge-tailed shearwater	Migratory	+ The wedge-tailed shearwater is widespread across the Indian and Pacific Oceans. + In Australia, the species breeds on the east and west coasts of Australia and on offshore islands, including the Ashmore Reef. + The West Island, Ashmore Reef supports a small colony of breeding wedge-tailed shearwaters, with an estimated 30 active burrows in 2002 (Swan 2005).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA, particularly in waters surrounding Ashmore Reef.

Species	Protection Status	Distribution, Habitat and Life Stages	Presence in the Operational Area and EMBA
		+ The foraging areas of wedge-tailed shearwaters that breed at Ashmore Reef are unknown.	
White-tailed tropicbird	Migratory	+ The white-tailed tropicbird breeds on islands throughout the tropics of the northern Indian Ocean, including Ashmore Reef and Rowley Shoals off the northern coast of WA (Johnstone and Storr 1998; Marchant and Higgins 1993). + The white-tailed tropicbird is a rather scarce breeding species at Ashmore Reef, and it is estimated that up to two pairs nest within the reserve each year (Clarke 2010). + The species forages up to 89 km from the nest site when breeding, and further when not breeding, and are surface foragers that occasionally take shallow dives (Marchant and Higgins 1990).	Given the preferred coastal habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the coastal waters of the EMBA, particularly in waters surrounding Ashmore Reef.

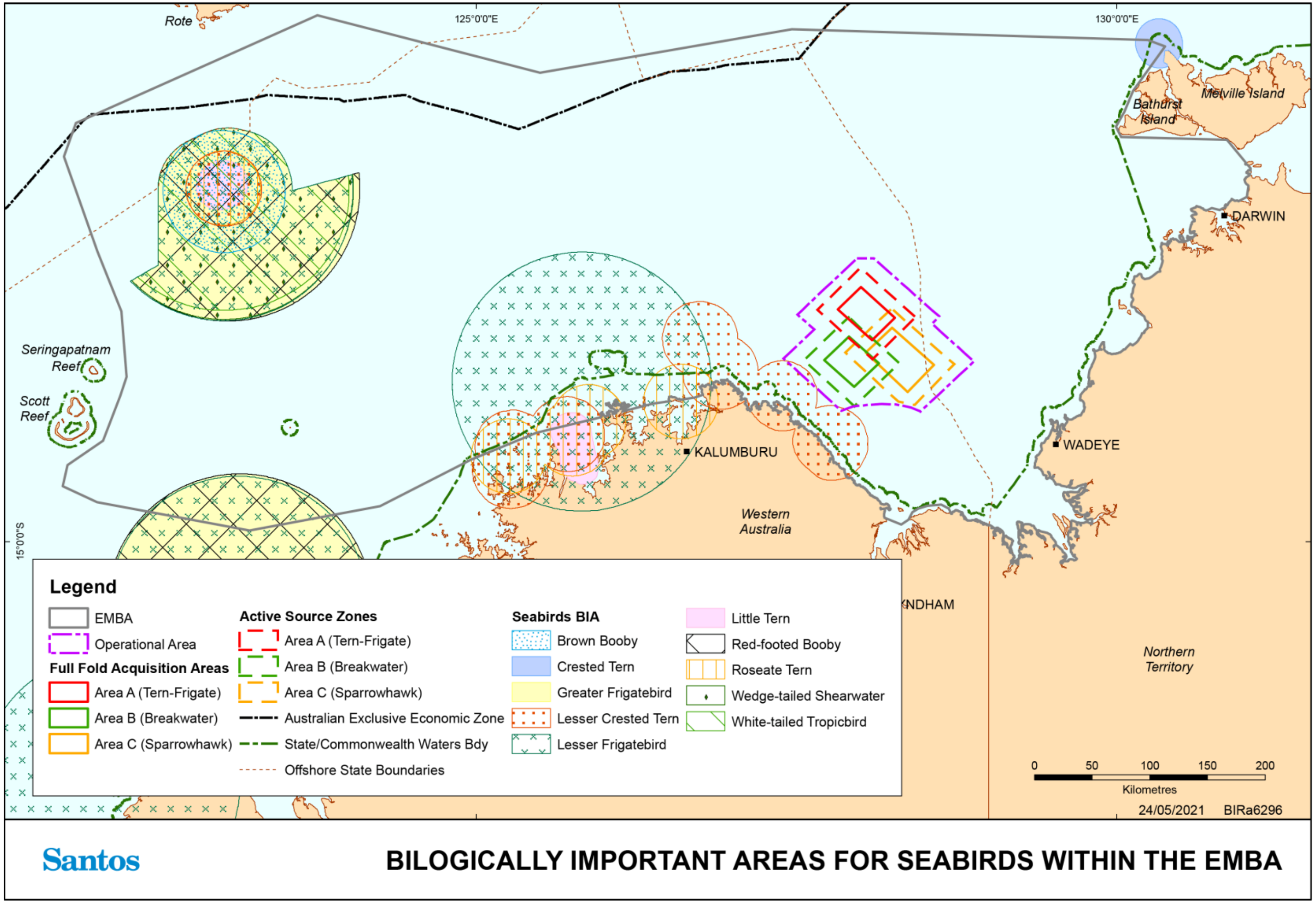


Figure 3-12: Breeding Biologically Important Areas for seabirds and migratory shorebirds in the EMBA

3.8 Socio-economic and Cultural Features

The section describes the socio-economic values within the EMBA including commercial fisheries, shipping, recreational fishing, oil and gas industry, tourism, cultural heritage, and defence activities. Particular focus is however given to commercial fishers as active and socio-economically important co-users of the marine environment within the operational area and surrounds.

3.8.1 Commercial Fisheries

3.8.1.1 Commonwealth Managed Fisheries

The Australian Fisheries Management Authority (AFMA) manages Australian fisheries on behalf of the Commonwealth Government from 3 nm to the edge of the Australian fishing Zone (AFZ). AFMA carry out objectives that are listed in the Fisheries Administration Act 1991 and the Fisheries Management Act 1991. Commonwealth-managed fisheries with management boundaries that overlap with the Operational Area and EMBA include:

+ Northern Prawn Fishery;
+ Western Tuna and Billfish Fishery;
+ Southern Bluefin Tuna Fishery; and
+ Western Skipjack Fishery.

These fisheries are further described in **Table 3-17**.

Table 3-17: Relevant Commonwealth-managed fisheries

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Northern Prawn Fishery (NPF)	✓	✓	**Extent**: Operates from the JBG across to the Gulf of Carpentaria (AFMA 2018d). **Effort:** In 1981, fishing effort peaked at 40,000 fishing days and more than 250 vessels. Three decades later, it has reduced to around 8,000 days of effort and 52 vessels. The majority of fishing is conducted in coastal waters. The main fishing area for the NPF is the Gulf of Carpentaria, with relatively low intensity within the JBG. The NPF operates during two seasons. The first season is from 1 April to 15 June, and during this time banana prawns are mainly caught. In the second season (1 August – 1 December) tiger prawns are predominantly caught. Either season has the potential to end early if catch rates fall below pre-set trigger levels. Annual catches tend to vary year to year because of natural variability in the banana prawn component of the fishery. During the 2019 season, a total of 5,640 tonnes of banana prawns, 2,086 tonnes of tiger prawns and 656 tonnes of endeavour prawns were caught. During the 2018	✓	The JBG comprises about 60,000 km^2 of the western portion of the NPF. The Operational Area overlaps with less than 1% of the total fishery. Fishing takes place in waters 35–70 m deep, with most fishing effort between 50 and 60 m. Water depths within the Acquisition Area range between 59 -103 m (generally outside of the main fishing depths). The fishery is known to fish at a low (<0.1 days/km^2) to medium (0.1-0.25 days/km^2) intensity within the JBG. The JBG fishery comprises less than 5% of the area of the NPF, however it contributes about 65% of the NPF's red-legged banana prawn catch and around 20% of

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			season, a total 6,778 tonnes of prawns were caught (Parsa et al. 2020). **Resource**: Banana prawns, tiger prawns, endeavour prawns, others (squid, bugs and scampi). **Method:** Otter trawl gear, a quad rig comprising four trawl nets.		the NPF's total banana prawn catch. The main fishing area in the JBG is understood to overlap with the Full Fold Acquisition Area B and Area C. Therefore, there is potential for interaction with the Petrel Sub-Basin SW 3D MSS.
Western Skipjack Tuna Fishery (STF)	✓	✓	**Extent**: Covers the AFZ and extends westward from the South Australian/ Victorian border around the coast of Australia to Cape York Peninsula in QLD (AFMA 2018c). **Resource**: Skipjack tuna (AFMA 2018c). Skipjack tuna are known to spawn throughout the continental shelf and slope waters of the Indian Ocean. **Effort:** There has been no fishing effort since the STF since the 2008-09 season (Patterson et al. 2020). **Method**: Predominantly purse-seine gear is used. A small amount of pole and line effort (Patterson et al. 2020).	X	The fishery is currently not in operation. There is no potential for interaction with the Activity and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Southern Bluefin Tuna Fishery (SBTF)	✓	✓	**Extent**: Fishery includes all waters of Australia, out to 200 nm from the coast (AFMA, 2018b). Juvenile 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. 2020). **Effort**: No current effort in the JBG, fishing activity is concentrated in the Great Australian Bight and off South-east Australia (Patterson et al. 2020). **Resource**: Key species is the Southern Bluefin tuna (*Thunnus maccoyii).* Migration and spawning locations outside of the Operational Area and EMBA. **Method**: 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. 2020).	X	There is no effort currently reported in WA or the NT. There is no potential for interaction with the Activity and therefore, the fishery is not considered further in this EP.
Western Tuna and Billfish Fishery (WTBF)	✓	✓	**Extent**: The WTBF operates in Australia's Exclusive Economic Zone and high seas of the Indian Ocean. In recent years, fishing effort has been concentrated off south-west Western Australia, with occasional activity off South Australia (AFMA 2018a). **Effort**: Since 2005, there has been fewer than five vessels active in the fishery, down	X	There is no potential for interaction with the Petrel Sub-Basin SW 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			from 50 active vessels in 2000. In recent years, fishing effort has concentrated off south-west WA and South Australia with no current effort on the NWS (Patterson *et al.* 2020). The fishery caught 218 t of fish in the 2019 season. **Resource**: Key species include Bigeye tuna (*Thunnus obesus*), yellowfin tuna (*T. albacares*), striped marlin (*Tetrapturus audux*) and swordfish (*X. gladius)* (Patterson et al. 2020). These species are known to spawn throughout the continental shelf and slope waters of the Indian Ocean. **Method:** The main fishing gear in the WTBF is pelagic longline, with low levels of minor-line fishing (Patterson et al. 2020).		

As presented in **Table 3-17**, the NPF is the only Commonwealth managed fishery that actively fishes within the Operational Area and EMBA. Further information on the NPF is provided below.

Northern Prawn Fishery

The NPF operates off Australia's northern coast from Cape York (QLD) to Cape Londonderry (WA) (AFMA 2018d). The NPF is restricted to 52 vessels. The overlap of the NPF with the Operational Area is shown in **Figure 3-13**. The main fishing area for the NPF is the Gulf of Carpentaria, with low intensity within the JBG (**Figure 3-14**).

Figure 3-15 shows the main areas of fishing activity in the JBG for 2013-2019, based on fishing intensity data presented in the annual ABARES Fishery Status Reports.

The following information in regards to the NPF in general is sourced from the ABARES 2020 Fishery Status Report (Patterson et al. 2020) except where noted. Information relating to the activities of the NPF within the JBG has been sourced from:

+ Loneragan et al. (2002);
+ AFMA (2021a);
+ Laird (2018);
+ Jarrett et al. (2015); and
+ Information obtained from NPFI during stakeholder consultation for this EP and previous seismic surveys in the JBG.

The NPF is managed through a combination of input controls (limited entry, seasonal closures, permanent area closures, gear restrictions and operational controls) that are implemented under the Northern Prawn Fishery Management Plan 1995.

The NPF uses otter trawl gear to target a range of tropical prawn species. White banana prawn and two species of tiger prawn (brown and grooved) account for around 80% of the landed catch. In recent years, many vessels have transitioned from using twin gear to mostly using a quad rig comprising four trawl nets—a configuration that is more efficient.

Advice from the NPFI during the development of the Santos Fishburn EP is that prawn species reach a commercial size at six months, and can live for up to two years. Larger sized prawns have a higher price tag. Growth rates vary considerably between species and sexes, with females generally growing faster and to a larger size than males.

The NPF operates during two seasons. The first season is from 1 April to 15 June, and during this time banana prawns are mainly caught. Conversely, during the second season (1 August – 1 December) tiger prawns are predominantly caught. Either season has the potential to end early depending on the total catch.

The total catch in 2019 for the NPF was 8,581 t at a value of $117.7 million, and in 2018 it was 6,778 t at a value of $98.2 million. Annual catches tend to be quite variable from year to year because of natural variability in the banana prawn component of the fishery.

White banana prawn (*Penaeus merguiensis*) is mainly caught during the day on the eastern side of the Gulf of Carpentaria, whereas redleg banana prawn (*P. indicus*) is caught during both day and night, mainly in the JBG. Tiger prawns (*P. esculentus* and *P. semisulcatus*) are caught at night (daytime trawling has been prohibited in all areas during the tiger prawn fishing season). Most tiger prawn catches come from the southern and western Gulf of Carpentaria, and along the Arnhem Land coast. Tiger prawn fishing grounds may be close to those of banana prawns, but the highest catches come from areas near coastal seagrass beds, the nursery habitat for tiger prawns (Patterson et al. 2020).

By-product species include endeavour prawns (*Metapenaeus* spp.), scampi (*Metanephrops spp*.), bugs (*Thenus spp*.) and saucer scallops (*Amusium spp*.). Scampi is taken from a deepwater area on the edge of the Australian Fishing Zone (AFZ) north of Melville Island (Tiwi Islands) and is targeted during the NPF prawn trawling closure periods (AFMA 2021a). The scampi fishing grounds are located outside of the EMBA for this Activity.

The JBG comprises approximately 60,000 km^2 of the westernmost portion of the NPF (**Figure 3-13**). Catch in the JBG is comprised primarily of banana prawns (mainly *P. indicus* and *some P. merguiensis*), with a very minor catch of tiger and endeavour prawns (Laird 2017). This is consistent with confidential fishing data provided by NPFI during consultation in 2019 and 2021, which shows that tiger prawns typically make up a significantly smaller proportion of catch and effort in the JBG than banana prawns. The confidential data cannot be presented here, but are included in the Sensitive Information Report submitted to NOPSEMA with this EP.

Fishing for the banana prawns is permitted day and night in both NPF fishing seasons. Fishing takes place in waters 35 – 70 m deep, with most fishing effort between 50 and 60 m. The trawling regime for this species is similar to the tiger prawn sub-fishery in other regions of the NPF, where the total duration of individual trawls are usually long (~3 h). Although the JBG fishery comprises less than 5% of the area of the NPF, it contributes about 65% of the NPF's red-legged banana prawn catch and around 20% of the NPF's total banana prawn catch (combined *P. merguensis* and *P. indicus*) (Loneragan et al. 2002).

Due to the large tidal range (6–8 m) in the JBG and its reputed influence on prawn abundance in the region, *P. indicus* are fished on the neap tides, when tidal range and currents are minimal (Tonks et al. 2008). Thus, over a tide cycle, fishing effort is high on the late spring-neap, neap and early neap-spring tides, and low to non-existent at other times when the fleet moves to fishing grounds north of Melville Island and Port Essington, outside the JBG. The extra steaming time that this fishing pattern generates, together with the remoteness of the JBG and the lower price of *P. indicus* in comparison to other species of prawns, makes the JBG a less attractive area to fish than other parts of the NPF. As a result, the annual fishing effort in the JBG fishery is mostly dependent on the catch levels elsewhere in the NPF; if catches are good elsewhere, effort in JBG is low (Loneragan et al. 2002).

Prior to 2021, a seasonal closure area for the NPF in the JBG existed which excluded fishing from nearshore banana prawn nursery habitats the southern part of the JBG to protect small juvenile banana prawns as they migrate offshore to deeper waters in the south-western JBG, where the adults are targeted during the trawling operations. The southern portion of the Operational Area partially overlaps with this former seasonal closure area (**Figure 3-16**). The closure area applied during the 1 April to 15 June fishing season each year, which, in combination with the closure periods across the fishery, protected the juvenile migration. Any catch south of the seasonal closure line was taken in the second fishing season only (1 August – 1 December) when the less-fished tiger prawns in the JBG were targeted, whereas catch taken north of the closure line was taken during both the first and second seasons.

However, in 2021, the NPF Resource Assessment Group (NPRAG) recommended adopting a new closure area (**Figure 3-16**) to apply to the whole of the JBG south of latitude 13°S. The closure area excludes fishing in the JBG during the first 1 April to 15 June fishing season for better management of the redleg banana prawn stock of the JBG. The new closure area effectively means that fishing during the 1 April to 15 June banana prawn fishing season will no longer occur in the JBG. Only fishing during the 1 August to 1 December tiger prawn season is now permitted in the JBG. The new closure area will be reviewed in five years (2026) to determine its effectiveness on improving the JBG stock (AFMA 2021b).

Santos

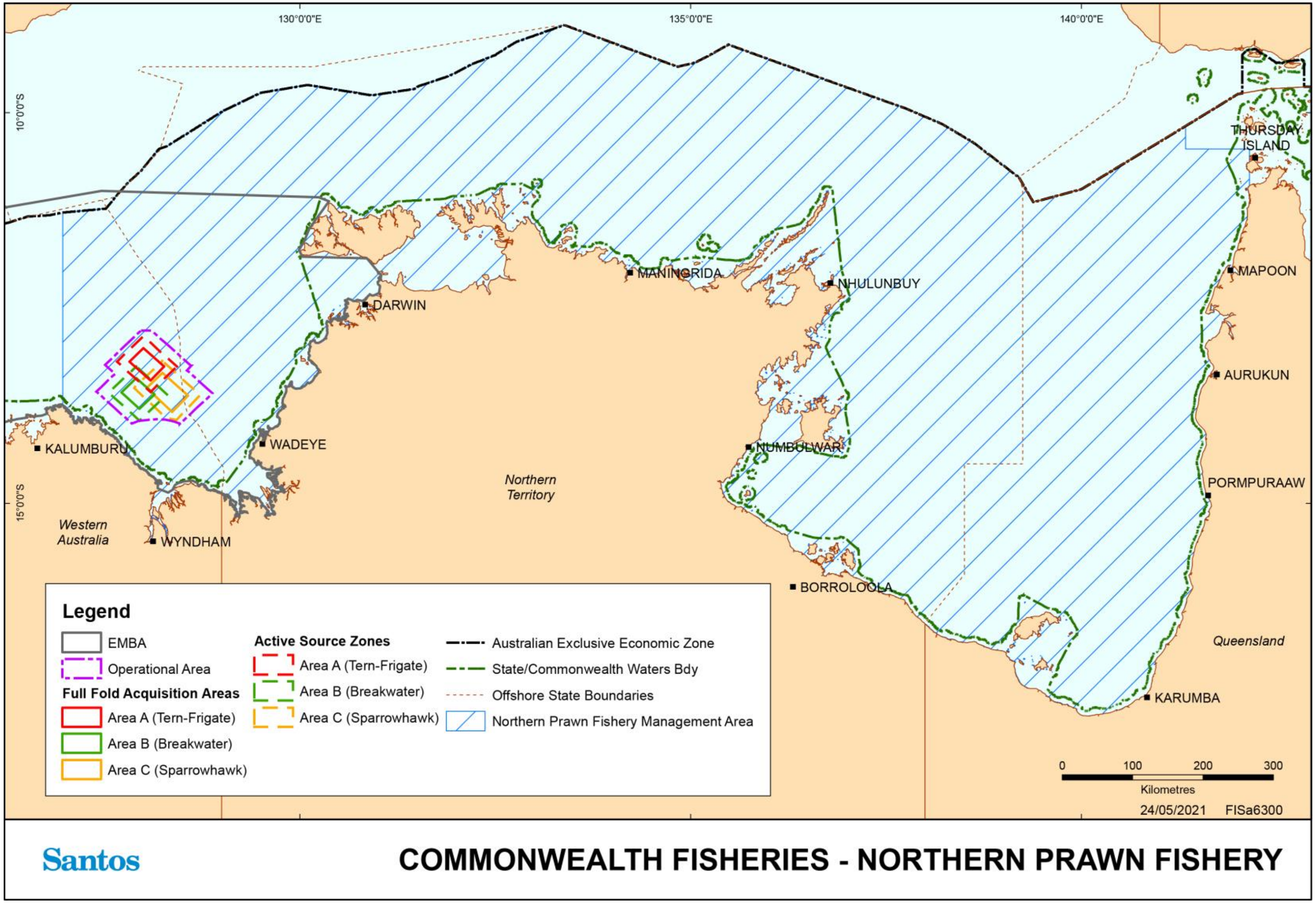


Figure 3-13: Northern Prawn Fishery management area

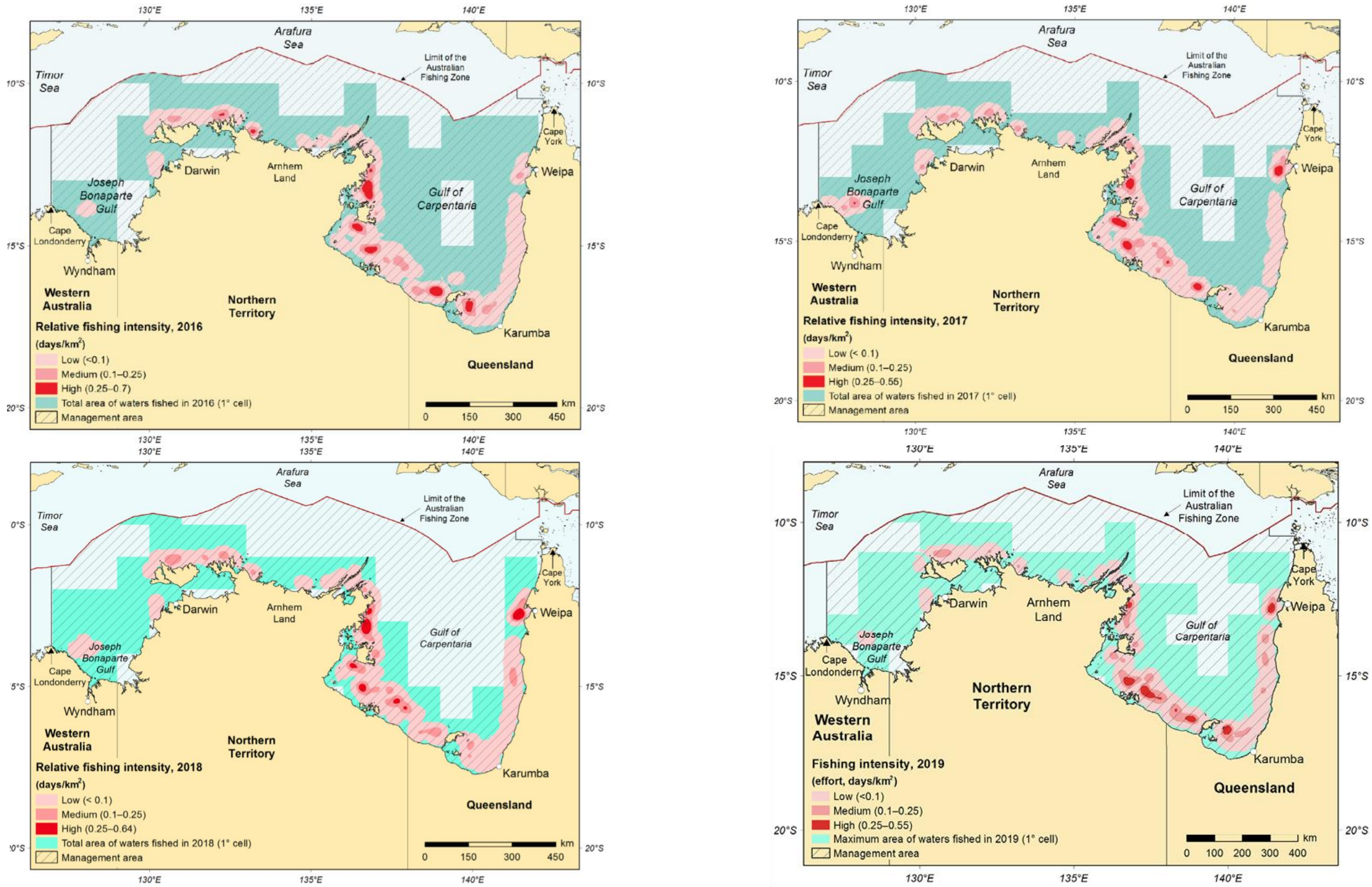


Figure 3-14: The area fished and relative fishing intensity in the Northern Prawn Fishery (2016 – 2019)

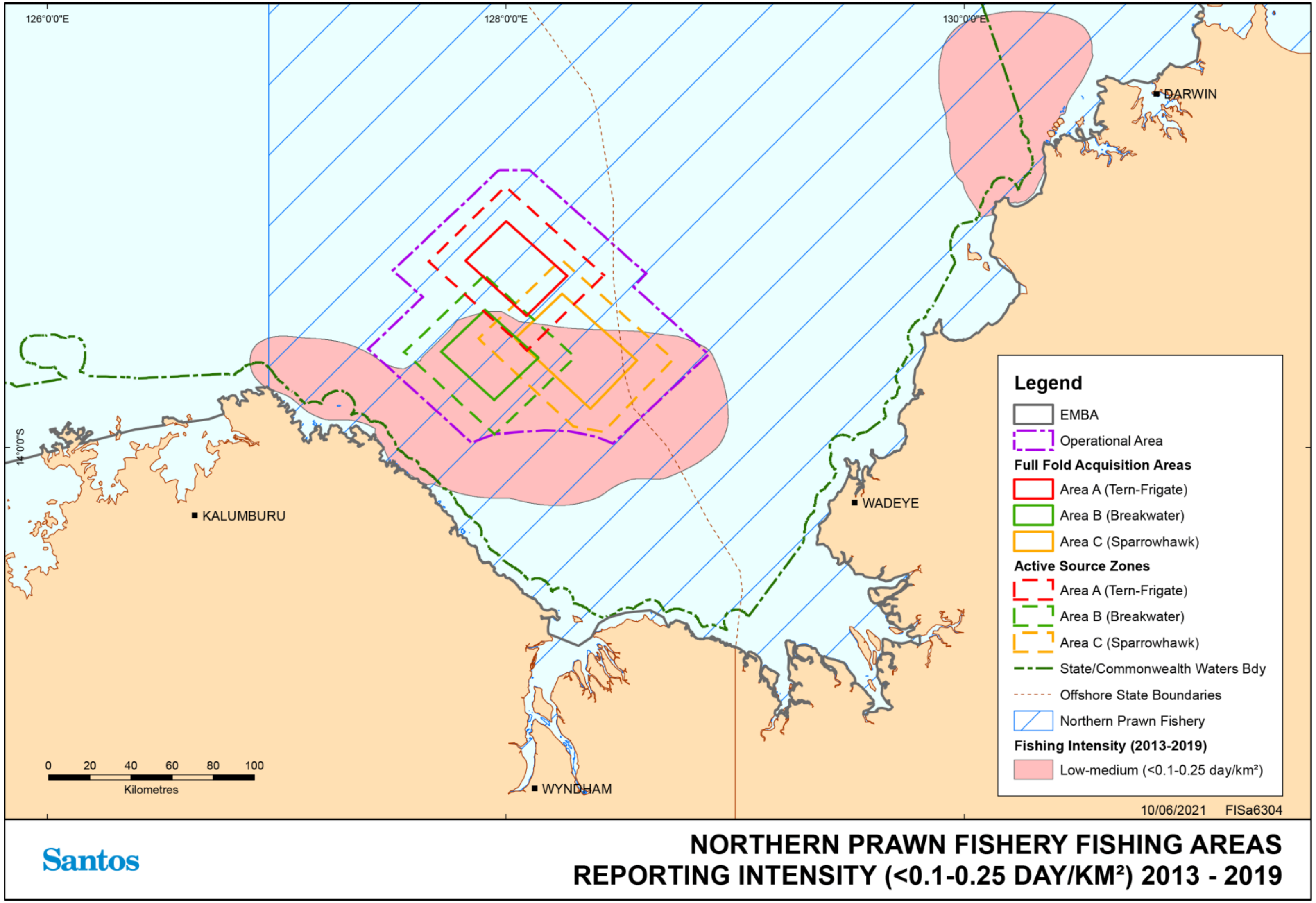


Figure 3-15: NPF fishing areas reporting low-medium intensity (<0.1-0.25 day/km^2) fishing in the JBG between 2013 and 2019 (adapted from ABARES annual fishing reports)

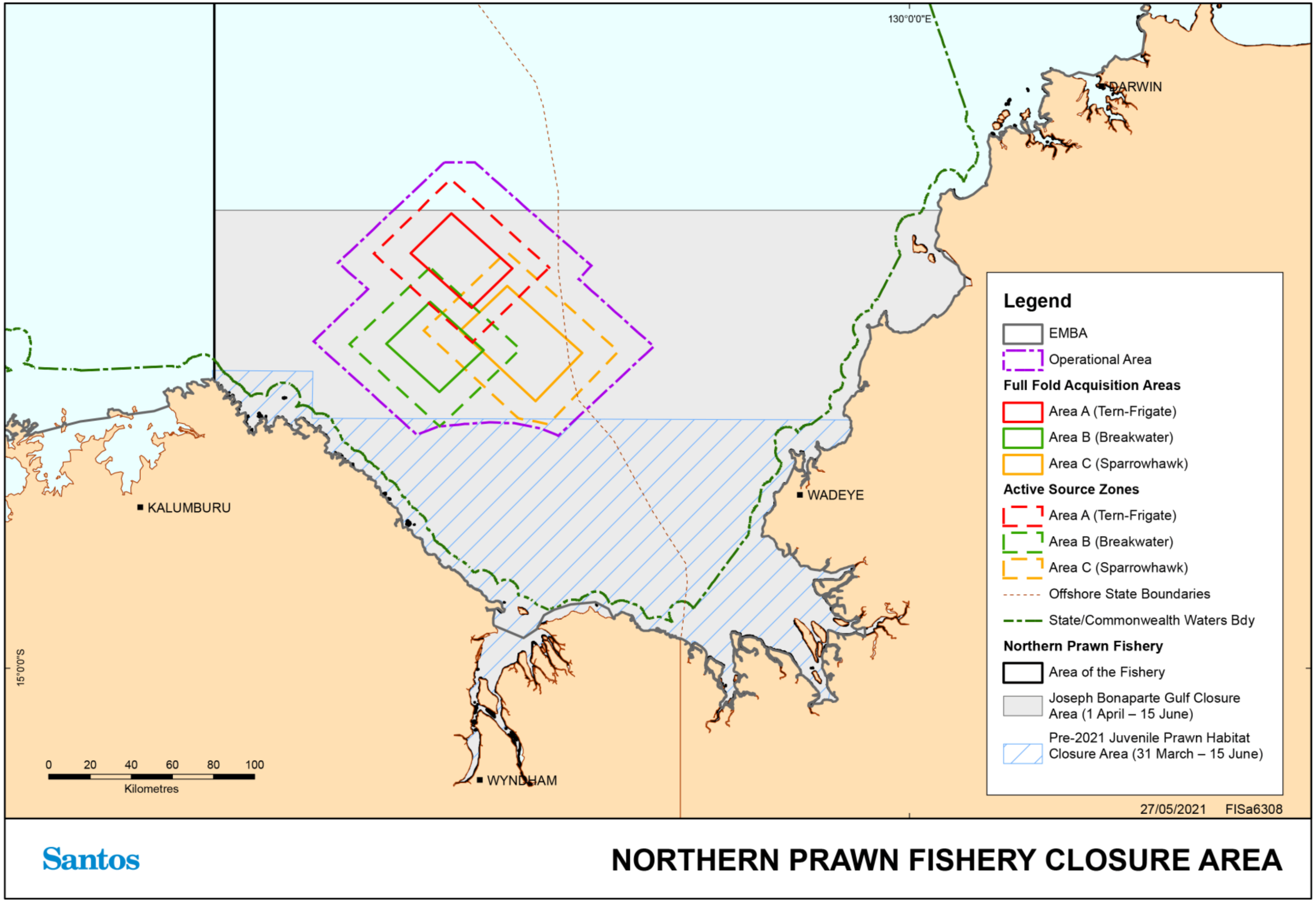


Figure 3-16: Northern Prawn Fishery seasonal closure area

3.8.1.2 Western Australian Managed Fisheries

WA State commercial fisheries are managed by the WA Department of Primary Industries and Regional Development (DPIRD) under the Fish Resources Management Act 1994, Fisheries Resources Management Regulations 1995, relevant gazetted notices and licence conditions and applicable Fishery Management Plans. WA managed fisheries with management boundaries that overlap with the Operational Area and EMBA include:

+ Northern Demersal Scalefish Managed Fishery (NDSMF);
+ Mackerel Managed Fishery (MMF);
+ North Shark Fisheries (Joint Authority Northern Shark Fishery and WA North Coast Shark Fishery) (NSF);
+ Pearl Oyster Managed Fishery (POMF);
+ Marine Aquarium Fish Managed Fishery (MAFMF);
+ Beche-de-Mer Managed Fishery (BMF); and
+ Specimen Shell Managed Fishery (SSMF).

These fisheries are further described in **Table 3-17**.

Catch and Effort Data

Santos requested annual catch and effort data (FishCube data) from WA 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 11 years (2009-2019, aggregated); and
+ Annual catch and effort data for each of the most recent 5 years (2015, 2016, 2017, 2018, 2019).

Data for 2020 is not yet available.

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.

Santos acknowledges that the State of Western Australia is the owner of the copyright of this information.

As presented in **Table 3-18**, the NDSMF and MMF are the only WA-managed commercial fisheries that have actively fish within the Operational Area. The following sub-sections provide additional information and presents the FishCube data that has been mapped for the two fisheries.

Table 3-18: **Relevant Western Australian managed fisheries**

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Northern Demersal Scalefish Managed Fishery (NDSMF)	✓	✓	**Extent:** North-west coast of WA in the waters east of longitude 120°E to the edge of the AFZ. The fishery is divided into two fishing areas; an inshore sector (Area 1) and an offshore section (Area 2). Area 2 is further divided into 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 area representing waters deeper than 200 m (Newman et al. 2020). **Catch and Effort:** Total catch in 2018 was 1,297 tonnes (Newman et al. 2020). **Resource:** Demersal scale fish (red emperor, goldband snapper, cod species) (Newman et al. 2020). **Method:** Primarily trap, some line	✓	The Operational Area is located in Zone A of Area 2 of the NDSMF, noting that the NDSMF primarily targets deeper waters in Zone B of Area 2 of the fishery (over 100 km north-west of the Operational Area). A review of historic fishing catch data indicates that effort was reported in the north of the Operational Area from 2009-2019. The area of overlap represents fishing by less than 3 vessels during the entire 11-year (2009-2019) period and during many years, no fishing has occurred in the Operational Area at all. While there is potential for interaction between the fishery and the Petrel Sub-Basin SW 3D MSS is

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
					unlikely or expected to be infrequent.
Mackerel Managed Fishery (MMF)	✓	✓	**Extent:** The Mackerel Managed Fishery mainly operates between Geraldton and the WA-NT border. It comprises of three areas: Area 1 – Kimberley, Area 2 – Pilbara and Area 3 – Gascoyne/West Coast (Fletcher et al. 2017). The fishery encompasses the entire coastline of Western Australia from the North Territory border to Cape Leeuwin in the south-west. However, the fishery mainly operates between Geraldton and the WA-NT border (Lewis and Blay 2020). **Catch and Effort:** Fishing effort occurs year round but typically takes place between May and November and is concentrated in waters less than 70 m. The total catch of Spanish mackerel in the 2018/19 season was the lowest on record at 213 tonnes, below the target commercial catch range of 246-430 tonnes (Lewis and Bray 2020). **Resource:** Target species comprise Spanish and grey mackerel. Spanish mackerel are an offshore, pelagic (surface-dwelling) fish, which inhabit offshore and coastal reefs. **Method**: Trolling or handline. Near-surface trolling gear from vessels in coastal areas	X	The Operational Area overlaps with less than 1% of Area 1 (Kimberley) of the fishery. FishCube data for the period 2009-2019 indicates that the two 10 nm blocks overlapped by the Operational Area have been subject to relatively low fishing effort, compared with other areas that are more regularly and intensively fished to the north and west of Kalumburu (over 90 km west of the Operational Area). Peak fishing effort between May and November will be avoided by the proposed December to March survey window. While there is potential for interaction between the fishery and the Petrel

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			around reefs, shoals and headlands (Lewis and Blay 2020).		Sub-Basin SW 3D MSS, such interactions are expected to be infrequent.
North Shark Fisheries (Joint Authority Northern Shark Fishery and WA North Coast Shark Fishery)	✓	✓	**Extent:** Covers the Pilbara and eastern and western Kimberley. **Catch and Effort:** Limited to no fishing activity has been recorded in both fisheries since 2008/09 as they do not have a Wildlife Trade Operation (WTO) accreditation that allows export of product from the fishery thus making the fishery unprofitable. **Resource:** Sandbar shark, blacktip shark **Method:** Line fishing	X	The fishery is currently inactive. If fishing does recommence, there is the potential for interaction with the Petrel Sub-Basin SW 3D MSS. However, given the range of target species, fishing effort in the Operational Area is expected to be low, and interactions infrequent.
Pearl Oyster Managed Fishery (POMF)	✓	✓	**Extent**: Quota based dive fishery operating in shallow coastal waters of the North West Shelf (Fletcher et al. 2017). The fishery is split into 4 zones: + Zone 1 – North West Cape to longitude 119°30´ E; + Zone 2 – East of Cape Thouin and south of latitude 18°14´ S; + Zone 3 – West of longitude 125°20´ E and north of latitude 18°14´ S; and	X	The Operational Area is located within the actively fished Zone 3. However, the Operational Area is located away from the Kimberley coastline where pearling leases are located, and where pearl fishing/diving occurs (<50 m depth).

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			+ Zone 4 - East of longitude 125°20´ E to the WA/Northern Territory border. **Catch and Effort:** Pearl oyster shell fishing has not been reported in Zone 1 since 2008 (Fletcher and Santoro 2014). In 2018, catch was only taken in Zone 2/3 (Gaughan and Santoro 2020). 614,002 individuals were caught in 2018 (Gaughan and Santoro 2020). Diving activities start in January and are typically conducted for 6 months of the year. Diving occurs in depths of less than 23 m during 6-12 days over the neap tidal cycle, with dives lasting no more than 40 minutes. **Resource**: Indo-Pacific, silver-lipped pearl oysters. **Method**: Drift diving, harvesting oysters by hand.		Historic catch data obtained from FishCube data for the period 2009-2019 confirms that there has been no fishing activity within the Operational Area or the JBG in the last 11 years. Therefore, there is no potential for interaction with the Petrel Sub-Basin SW 3D MSS.
Marine Aquarium Fish Managed Fishery (MAFMF)	✓	✓	**Extent:** The MAFMF operates in WA state waters from the Northern Territory border in the north through to the South Australian border in the south. The effort is spread over a total gazetted area of 20,781 km^2 (Gaughan and Santoro 2020). **Catch and Effort:** There were 12 licences in the fishery all of which were in operation in 2018 (Gaughan and Santoro 2020). While the MAFMF operates throughout all Western Australian waters, catches are relatively low in volume due to the special	X	The fishery occurs in WA State waters and is typically more active in waters between Esperance and Broome with higher levels of effort around the Capes region, Perth, Geraldton, Exmouth and Dampier (Fletcher et al. 2017).

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			handling requirements of live fish (Gaughan and Santoro 2020). **Resource:** This fishery has the capacity to target more than 950 species of marine aquarium fish. Coral, live rock, algae, seagrass and invertebrates under the Prohibition on Fishing (Coral, 'Live Rock' and Algae) Order 2007 are also permitted. **Method:** Dive based, hand net operating from small boats.		FishCube data for the period 2009-2019 confirms that there has been no fishing activity within the Operational Area in the last 11 years. Therefore, there is no potential for interaction with the Petrel Sub-Basin SW 3D MSS.
Beche de Mer Managed Fishery (BMF)	✓	✓	**Extent:** Primarily based in the northern half of WA from Exmouth Gulf to the Northern Territory border, although fishers have access to all 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) (Gaughan and Santoro 2020). **Catch and Effort:** Catch and effort occurs in shallow, inshore waters along the coastline and surrounding islands. Total catch in 2018 was 0 tonnes (Gaughan and Santoro 2020). Maximum total catch during 2009-2019 (based on FishCube data) was 252 tonnes. **Resource:** Sea cucumbers, 99% of the catch being sandfish *(Holothuria scabra).*	X	FishCube data for the period 2009-2019 confirms that there has been no fishing activity within the Operational Area in the last 11 years. Therefore, there is no potential for interaction with the Petrel Sub-Basin SW 3D MSS.

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			Method: Collected by hand by divers and waders throughout the Kimberly region (WAFIC 2019)		
Specimen Shell Managed Fishery (SSMF)	✓	✓	**Extent**: The fishing area includes all Western Australian waters between the high water mark and the 200 m isobath, with some concentration of effort in areas adjacent to population centres such as Broome, Karratha, Shark Bay, metropolitan Perth, Mandurah, the Capes area and Albany (Gaughan and Santoro 2020). **Effort:** This is a limited entry fishery with 31 licences in the fishery, 20 of them fished in 2018. A maximum of four divers are allowed in the water per licence at any one time (Gaughan and Santoro 2020). Effort in 2018 was 636 days, which is 38 days less than that reported in 2017 (674 days). Over the last five years, there was an annual average of around 630 days fished (Gaughan and Santoro 2020). **Resource:** There is some focus of effort on mollusc families most popular with shell collectors, such as cowries, cones, murexes and volutes. Cypraeidae or cowries are noted for their localised variations in both shape and colour, making them attractive to collectors. Habitat and ecosystem impacts are considered negligible. This is due to the	X	Collection typically occurs in shallow waters (outside of the Operational Area), however exception permits allow for the use of remote controlled underwater vehicles up to a depth of 300 m. FishCube data for the period 2009-2019 confirms that there has been no fishing activity within the Operational Area in the last 11 years. Therefore, there is no potential for interaction with the Petrel Sub-Basin SW 3D MSS.

Fishery	Overlap with Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			small scale of the fishery and the hand collection methods. While the fisheries can potentially operate over large areas catches are relatively low due to the special handling requirement. **Method:** 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.		

Northern Demersal Scalefish Managed Fishery

In the Kimberley, the NDSMF operates off the WA coast in waters east of 120° E longitude (**Figure 3-17**). The NDSMF is managed primarily through input controls in the form of an annual fishing effort capacity, with supplementary gear controls and area closures.

The fishery is permitted to use hand lines, droplines and fish traps, although the NDSMF has essentially operated as a trap based fishery since 2002. The NDSMF principally targets red emperor and goldband snapper, with a number of species of snappers (Lutjanidae), cods (Epinephelidae) and emperors (Lethrinidae) comprising the majority of the remainder of the catch (Newman et al. 2020).

The fishery is further divided into two fishing areas; an inshore sector (Area 1) and an offshore sector (Area 2). The Northern Demersal Scalefish Managed Fishery Management Plan 2000 was amended in 2013 to formalise the previous voluntary industry agreement which further divides the offshore sector (Area 2) into three zones; A, B and C. Zone B comprises the area with most of the historical fishing activity. Zone A is an inshore developmental area and Zone C is an offshore deep slope developmental area representing waters deeper than 200 m (Newman et al 2020). The Petrel Sub-Basin SW 3D MSS is located within Area 2, Zone A, where fishing effort is limited.

In 2018/19 the total catch for the NDSMF was reported at 1,297 tonnes and was within the acceptable catch range of 903 to 1,332 tonnes for the fishery (Newman et al 2020). The majority of the catch was landed from Zone B, with a catch of 1,106 tonnes in 2018. The level of catch in Zone B is the highest reported since zoning was implemented (Newman et al 2020). The total catch of goldband snapper in 2018 in the NDSMF (498 tonnes) was similar to that reported in 2017 (495 tonnes) (Newman et al 2020). Catch levels of goldband snapper have remained high since the peak catch of 523 tonnes reported in 2010. The last five years have seen high reported landings for this species, continuing an overall trend of increasing catches since 2005. The total catch of red emperor in 2018 was 147 tonnes, which is similar to the red emperor catch levels reported over the past few years including 2016 (138 tonnes) (Newman et al 2020).

Analysis of FishCube data shows that the area of fishing effort over the West Australian coast is 142,173 km^2 for the period between 2009 and 2019. The Operational Area overlaps with 1,603 km^2 (1.13%) of this fished area (refer to **Figure 3-18**). The Acquisition Areas do not overlap with the fished area.

The 10 nm blocks overlapped by the Operational Area have been fished by less than three vessels during the entire 11-year (2009-2019) period and during many years, no fishing has occurred in the Operational Area at all.

Mackerel Managed Fishery

The MMF is divided into three zones, Area 1 - Kimberley (121°E to WA-NT border), Area 2 - Pilbara (114°E to 121°E) and Area - 3 Gascoyne (27°S to 114°E), which encompass the entire coastline of WA from the Northern Territory (NT) border to Cape Leeuwin in the south-west (Fletcher and Santoro 2015) (**Figure 3-17**).

The primary target species of the MMF is the Spanish mackerel (*Scomberomorus commerson*), which is fished commercially between Geraldton and the Northern Territory border.

The MMF was made a fully managed fishery in 2012 and operates under an Individual Transferable Quota (ITQ) system, which includes the setting of Total Allowable Commercial Catches (TACCs) for each area of the fishery, allocation of the entitlement to take quota in the form of units, and establishment of minimum unit holding requirements to operate in the Fishery.

Santos

Licence holders may only fish for mackerel by trolling or hand-line. There are currently only 14 licences in the Kimberley management area. A total of 15 vessels operated across the entire MMF during the 2018/19 season (Lewis and Bray 2020).

The total catch of Spanish mackerel in the 2018/19 season was the lowest on record at 213 tonnes, below the target commercial catch range of 246-430 tonnes (Lewis and Bray 2020). Previously, the catch throughout the MMF had been relatively stable at 270-320 tonnes. The low catch can be partially attributed to a significant change in operators in the MMF but may also be due to widespread environmental changes in Northern Australia, with catches also declining in other states (Lewis and Bray 2020). The nominal catch rates in the Kimberley and Pilbara management areas of the MMF are generally decreasing suggesting that the overall spawning stock may be declining, possibly due to the effects of marine heatwaves (Lewis and Bray 2020). In the Kimberley area of the MMF, the 2018 Spanish mackerel catch of 126 tonnes was within the target range of 110 – 225 tonnes, while the catches in the Pilbara and West Coast areas were below the respective tolerance ranges (Lewis and Bray 2020).

Analysis of FishCube data shows that the area of fishing effort in the Kimberley region of the MMF (Area 1) covers 55,375 km^2 for the eleven-year period between 2009 and 2019. The two blocks overlapped by the Operational Area are located in the southern half of the Operational Area, within or adjacent to the Area C Active Source Zone, and in water depths of approximately 70 m or less (refer to **Figure 3-19**). One of the blocks has only been fished in 2019, with less than three vessels reported for the block. The other block overlapped by the Operational Area is located in the vicinity of a shallow bank feature on the southern boundary of the Operational Area. This block has reported 45 days of fishing effort during the entire 11-year period (2009-2019) and was only fished during four of the 11 years.

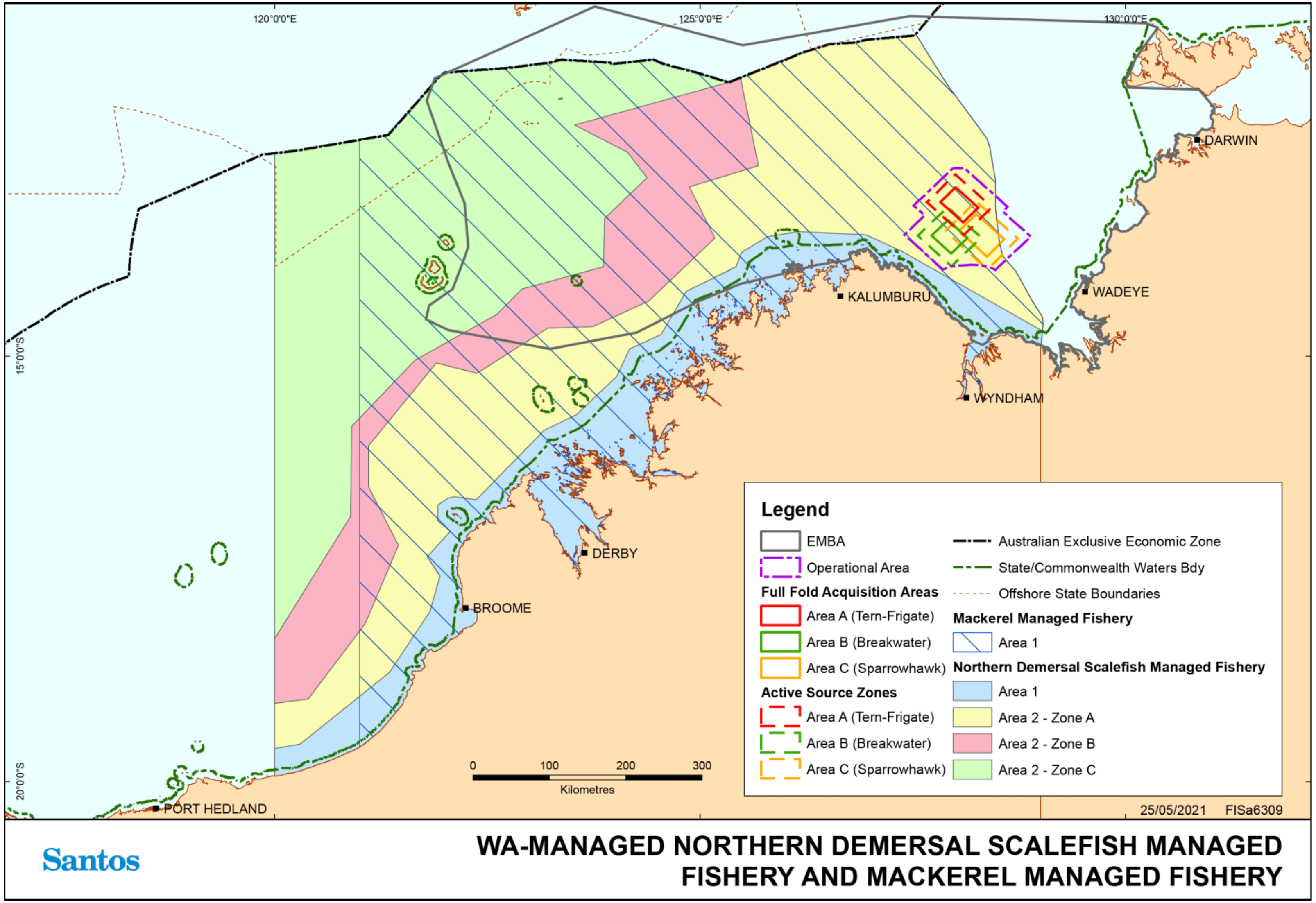


Figure 3-17: Relevant Western Australian managed fisheries

Santos

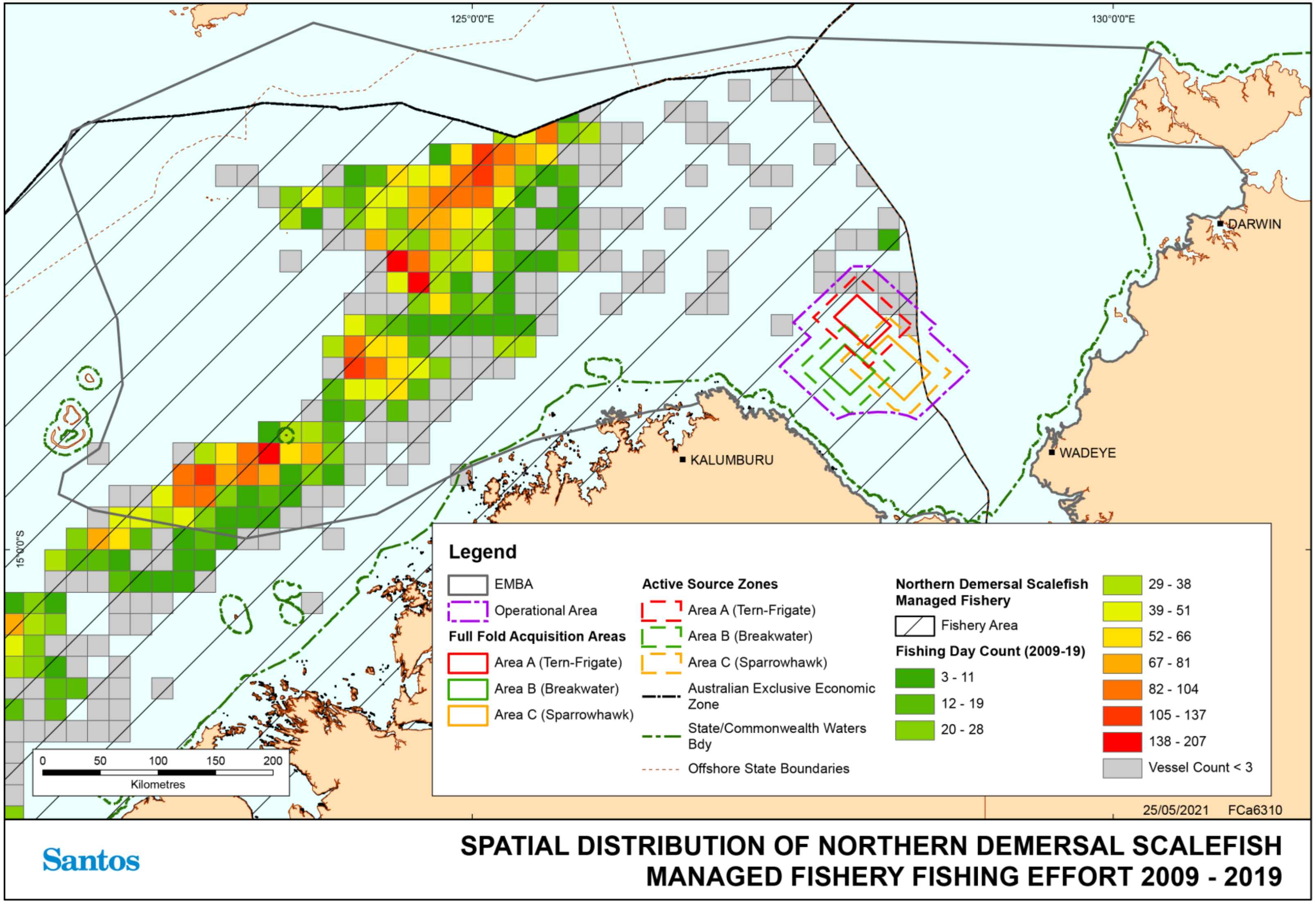


Figure 3-18: Northern Demersal Scalefish managed fishery total fishing day count (2009-2019)

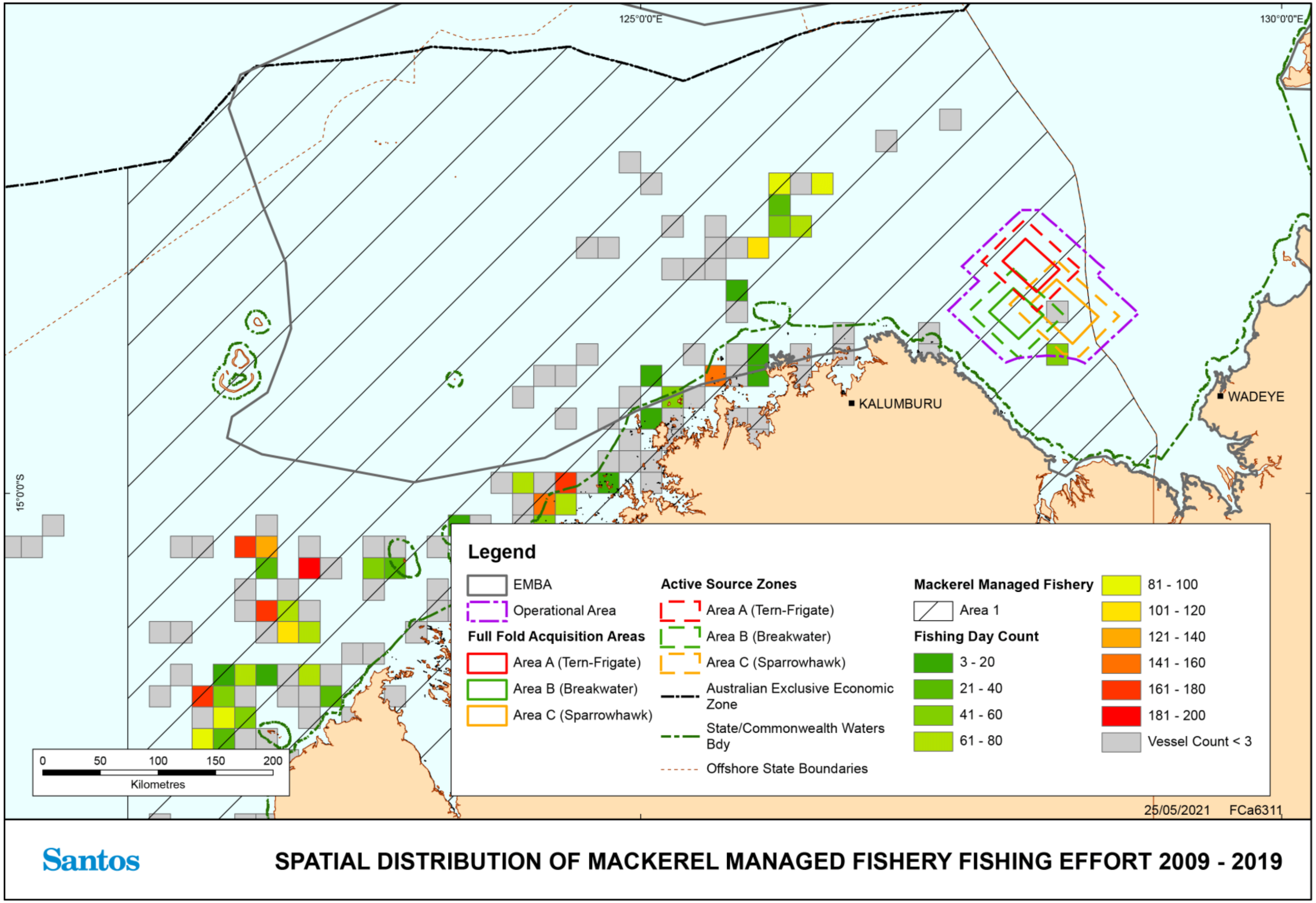


Figure 3-19: Mackerel Managed Fishery total fishing day count (2009-2019)

3.8.1.3 Northern Territory Managed Fisheries

Northern Territory fisheries are managed by the NT Department of Industry, Tourism and Trade (NT DITT), formerly known as NT Department of Primary Industry and Resources (NT DPIR). Wild harvest fisheries are managed under the Fisheries Act 1988 and Fisheries Regulations 1992 and management plans. NT managed fisheries with management boundaries that overlap with the Operational Area and EMBA include:

+ Demersal Fishery (DF);
+ Spanish Mackerel Fishery (SMF);
+ Offshore Net and Line Fishery (ONLF);
+ Pearl Oyster Managed Fishery (POMF);
+ Aquarium Fishery (AF);
+ Barramundi Fishery (BF);
+ Coastal Line Fishery (CLF); and
+ Bait Net Fishery (BNF).

These fisheries are further described in **Table 3-19**. The information presented in this section has predominantly been sourced from recent NT DITT fisheries reports.

Catch and Effort Data

Santos requested annual catch and effort data from NT DITT. Annual catch and effort data was available for each of the most recent 5 years (2015 - 2019).

Data was assessed for 60 nm x 60 nm blocks to identify where the greatest fishing effort in each fishery occurred and the relative importance of waters within the Operational Area. Block resolution finer than 60 nm x 60 nm was not available.

Data provided included:

+ Weight (kg) – a measure of fish catches per block during the period of interest;
+ Licence Count – a measure of the number of licences that fished in a CAES block during the period of interest; and
+ Sum of Hook Hours – a measure of fishing effort, represented by the number of hours fished in a block during the period of interest.

Due to confidentiality reasons, NT DITT was unable to release catch and effort data for blocks where less than five licences fished during the period of interest. 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. Blocks where no fishing is recorded do not return any data.

The following sub-sections provide additional information on the relevant NT managed fisheries and presents the fishing catch and effort data that has been mapped for the fisheries.

Santos

Table 3-19: Relevant Northern Territory managed fisheries

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Demersal Fishery (DF)	✓	✓	**Extent:** Demersal fishing is allowed from 15 nm from the low water mark to the outer boundary of the Australian fishing zone, excluding the area of the Timor Reef Fishery (DPIR 2019a). **Effort:** In 2016, seven vessels were active in the Demersal Fishery with a reported total catch of 3,463 tonnes, including 2,510 tonnes of red snappers and 318 tonnes of goldband snappers (DPIR 2016). There are currently 18 active licences (DPIR 2019a) and in 2017, the reported catch was 3,389 tonnes (DPIR 2019f), including, red snapper (70.8 %) and goldband snapper (10.1 %). **Resource:** Goldband snapper, red snapper, saddletail snapper and crimson snapper. **Method**: Vertical lines, drop lines, finfish long-lines, baited fish traps and semi-demersal trawl nets in two multi-gear areas.	✓	The Operational Area overlaps with less than 1% of the fishery. Specifically, the license boundary of the fishery overlaps with the eastern portion of the Operational Area and Full Fold Acquisition Area C. Analysis of 5 years of NT fishing effort data (2016-2020) shows that the Operational Area overlaps with approximately 0.53% of the total area of fishing effort. Therefore, there is potential for interaction with the Petrel Sub-Basin SW 3D MSS.
Spanish Mackerel Fishery (SMF)	✓	✓	**Extent:** Commercial fishing for Spanish mackerel is permitted from the high water mark to the outer boundary of the AFZ. **Effort:** The Spanish Mackerel Fishery is a limited entry fishery, with catch managed via input controls (DPIR 2019b). There are currently 15 active licences (DPIR 2019b). Total catch was 290 tonnes in 2017 (DPIR 2019f). **Resource:** Spanish mackerel	ü	The Operational Area overlaps with less than 1% of the fishery. Specifically, the license boundary overlaps with the eastern portion of the Operational Area and Full Fold Acquisition Area C.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			Method: Troll lines, floating hand lines and rods.		Analysis of 5 years of NT fishing effort data (2016-2020) shows that the Operational Area overlaps with approximately 0.49% of the total area of fishing effort The primary fishing grounds include waters near Bathurst Island, New Year Island, the Wessel Islands around to Groote Eylandt and the Sir Edward Pellew Group of islands. While there is potential for interaction between the fishery and the Petrel Sub-Basin SW 3D MSS, such interactions are expected to be infrequent.
Offshore Net and Line Fishery (ONLF)	✓	✓	**Extent:** The Offshore Net and Line Fishery is a quota managed fishery. Fishing is permitted from the low water mark to the outer boundary of the AFZ to the extent the waters are waters relevant to the Northern Territory (DPIR 2018). **Effort:** 641 tonnes in 2017 (DPIR 2019f). Including, grey mackerel (73 %) and blacktip shark (11 %).	ü	The Operational Area overlaps with less than 1% of the fishery. Specifically, the license boundary overlaps with the eastern portion of the Operational Area and Full Fold Acquisition Area C.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			There are currently 11 active licences. **Resource:** Black-tip sharks and grey mackerel. **Method**: Demersal long lines, pelagic long lines, longlines and pelagic nets.		Most fishing is done in the coastal zone within 12 nm of the coast, and immediately offshore in the Gulf of Carpentaria (approx. 1,000 km from the Operational Area). Analysis of 5 years of NT fishing effort data (2016-2020) shows that the Operational Area overlaps with approximately 0.51% of the total area of fishing effort While there is potential for interaction between the fishery and the Petrel Sub-Basin SW 3D MSS, such interactions are expected to be infrequent.
Pearl Oyster Managed Fishery (POMF)	X	✓	**Extent:** Operates from the high water mark to the outer boundary of the Australian fishing zone, 200 nautical miles offshore (DPIR 2019d). **Effort:** Maximum catch of 138,000 oysters. There are currently five active licences. **Resource:** *Pinctada maxima* **Method**: Hand harvest.	X	DPIR (Fisheries) advised during consultation with Polarcus that the harvesting of pearl culture oysters stopped in 1994, when hatchery produced oysters became readily available for culture. Since this period, there has been irregular harvest of pearl

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
					oysters from the Bonaparte Basin. Fishing efforts are generally restricted to water depths less than 35 m. No fishing has occurred in the Operational Area during the period 2016-2020. There is no potential for interactions with the Petrel Sub-Basin SW 3D MSS.
Aquarium Fishery (AF)	X	✓	**Extent:** The NT Aquarium Fishery is a small-scale, multi-species fishery. It includes freshwater, estuarine and marine habitats to the outer boundary of the AFZ, which is 200 nautical miles offshore (DPIR 2019e). **Effort:** According to the NTSC, the fishery has 11 licences and around three boats are active each year (NTSC 2017). Total catch in 2017 was 2 tonnes. **Resource:** Aquarium includes rainbowfish, catfish and scats. Invertebrates includes hermit crabs, snails, whelks and hard/soft corals. **Method**: Hand harvest.	X	Freshwater and estuarine species are generally collected between the Adelaide and Daly rivers, while most marine species are collected within 100 km of Nhulunbuy and Darwin. Information obtained from the Chair of the Aquarium Fishery Licence Committee during the consultation process for the nearby Santos Bethany 3D MSS confirmed that licence holders typically scuba dive to a maximum of 30 m. It was also confirmed that one operator

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
					operates at Evan Shoal, east of Lyndoch Shoal, Blackwood Shoal and Money Shoal in Arafura Sea and within the Timor Reef Fishery Area. The Operational Area overlaps the licence boundary of the fishery. However, given that fishing effort is restricted to waters less than 30 m deep, there is no potential for interactions with the Petrel Sub-Basin SW 3D MSS.
Barramundi Fishery (BF)	X	✓	**Extent:** Commercial fishing for barramundi is allowed from the high water mark to three nautical miles seaward of the low water mark. The fishing area is restricted to waters seaward from the coast, river mouths and legislated closed lines. **Effort:** The fishery is restricted to 14 licences which can be bought, sold and leased. **Resource:** Barramundi and king threadfin are the primary species taken in the barramundi fishery. **Method**: Commercial operators fish over tidal mud flats and inside a restricted number of rivers using monofilament gill nets (NT Government 2020a).	X	The fishery is located within the EMBA. There is no potential for interaction with the Petrel Sub-Basin SW 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Coastal Line Fishery (CLF)	X	✓	**Extent:** Coastal NT waters. **Effort:** The fishery is restricted to 52 licences. **Resource:** Black jewfish and golden snapper are the main species taken in the coastal line fishery. **Method**: Vertical lines, cast nets, scoop nets or gaffs can be used from the high water mark out to 15 nautical miles from the low water mark. Drop lines and up to five fish traps can be used from two to 15 nautical miles out from the low water mark (however not in the western zone). Up to five hooks per vertical line and up to 40 hooks per drop line are allowed (NT Government 2020b).	X	The fishery is located within the EMBA. There is no potential for interaction with the Petrel Sub-Basin SW 3D MSS and therefore, the fishery is not considered further in this EP.
Bait Net Fishery (BNF)	X	✓	**Extent:** Commercial fishing is allowed from the high water mark to three nautical miles seaward of the low water mark but foes not include Darwin Harbour **Effort:** Restricted to two licences. **Resource:** Commercial fishers are allowed to take all fish for use as bait except barramundi, threadfin salmon, Spanish mackerel or mud crabs **Method**: Commercial fisheries can use a bait net, cast net or scoop net (NT Government 2020c).	X	The fishery is located within the EMBA. There is no potential for interaction with the Petrel Sub-Basin SW 3D MSS and therefore, the fishery is not considered further in this EP.

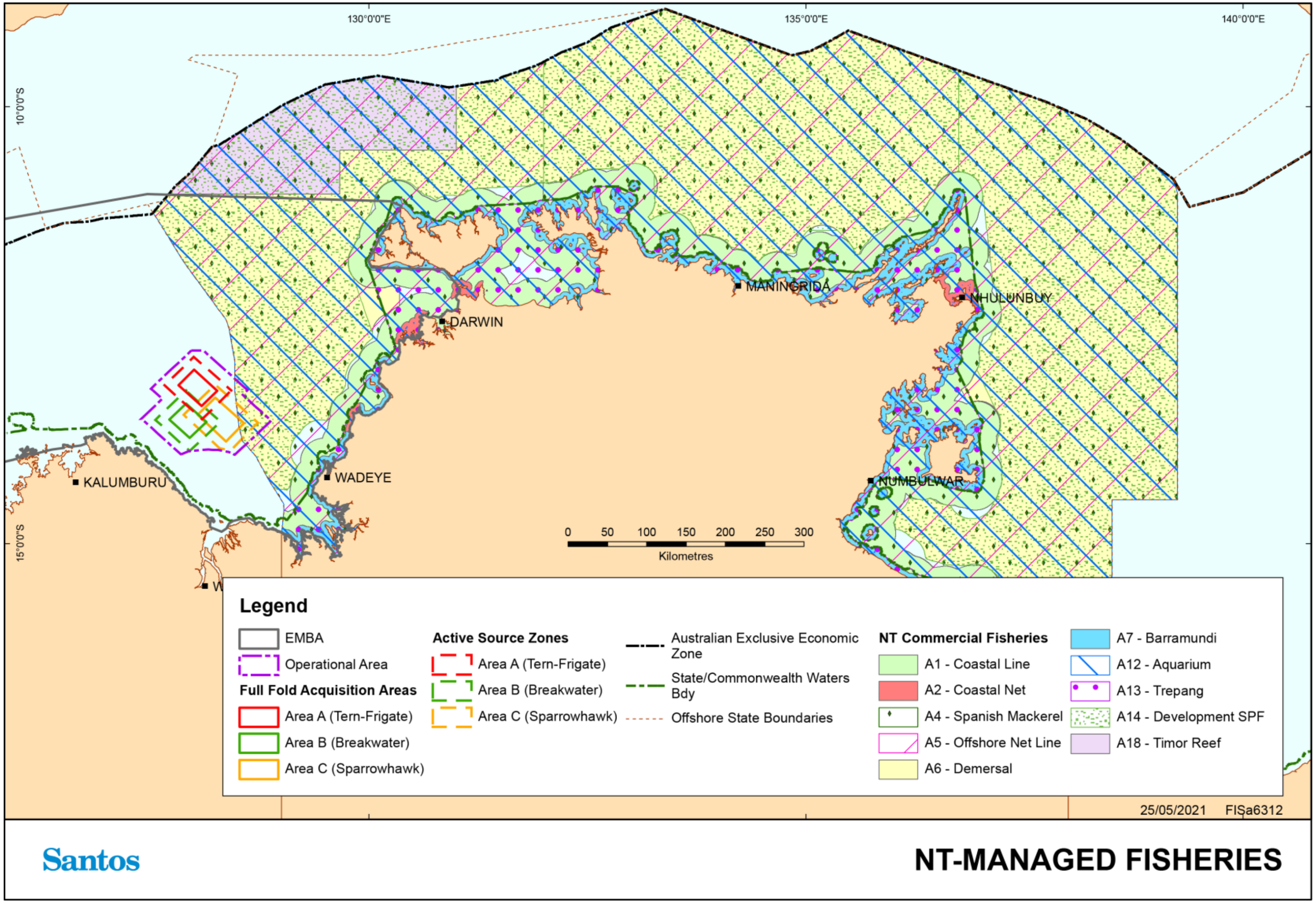


Figure 3-20: Northern Territory managed fisheries

As presented in **Table 3-19**, the DF, SMF and ONLF are the only NT managed commercial fisheries that actively fish within the Operational Area (**Figure 3-20**).

Demersal Fishery

The NT DF extends from 15 nm from the low water mark to the outer limit of the AFZ (excluding the area of the Timor Reef Fishery) and targets a range of tropical snappers (*Lutjanus spp*. and *Pristipomoides spp.*). In 2017, there was a reported total catch of 3,389 t.

The harvest by the DF is limited through a set of total allowable catches (TACs) applied to goldband snappers (*Pristipomoides spp*.) (400 t), red snappers (*L. malabaricus* and *L. erythropterus*) (2,500 t) and a “grouped fish” category (915 t). The latter group includes all fishes other than barramundi (*Lates calcarifer*), king threadfin (*Polydactylus macrochir*), Spanish mackerel, shark and mud crabs (*Scylla spp*.) (DPIR 2019a).

DF licensees harvested 3,389 t of fishes in 2017 (DPIR 2019f). Red snappers and goldband snappers formed the bulk of the harvest (70.8% and 10.1%, respectively) with painted sweetlip (*Diagramma labiosum*) being the primary by-product species (5.7%) along with redspot emperor (2.8%). Reported bycatch (by weight) during 2017 was less than 1% of the drop-line and trap harvest and the average bycatch recorded by observers for the trawl harvest in 2016 was 27.4% (DPIR 2019f).

In 2016, the total commercial catch of goldband snapper was 535.2 t, of which 340.7 t was taken by the DF. The status of goldband snapper from the Arafura and Timor seas was assessed using data up to 2016 using a stochastic Stock Reduction Analysis (SRA) model. The outputs of this model estimated egg production to be around 65 to 70% of unfished levels and the current harvest rate is below that required to achieve maximum sustainable yield. This level of fishing mortality is well above conventional target levels and is unlikely to cause the stock to be recruitment overfished (DPIR 2019a).

The fishery is split into two areas – Area 1, where line and fish-trap gear are permitted and demersal trawls nets are excluded and Area 2, where line, fish-trap and finfish trawl gear are all permitted. The eastern portion of the Operational Area and the eastern corner of Area C Active Source Zone overlaps with Area 1. Area 2 is located approximately 28 km northeast of the Operational Area.

Traps used in the fishery are set on the seabed with an identifying float on the sea surface. The fishery is monitored primarily through logbook returns, which operators are required to fill out on a daily basis during fishing operations. The logbooks provide detailed catch and effort information, as well as information on the spatial distribution of the fishing operations.

Catch and effort for trap vessels varies from year to year. The NT Government (2014) states that the substantial variability in trap effort since 2009 generally reflects movement between the DF and the nearby Timor Reef Fishery. The NT Government (2014) states that Stock Reduction Analysis evidence suggests that this is not due to changes in fish abundance or sustainability concerns that the fluctuating CPUE reflects the small number of operators and their developing knowledge of the fishery.

Analysis of fishing catch and effort data shows that the fishing effort over the NT coast is 315,310 km2 for the period between 2016 and 2020. The Operational Area overlaps with approximately 1,668 km2 (0.53%) of the area of fishing effort (refer to **Figure 3-21**).

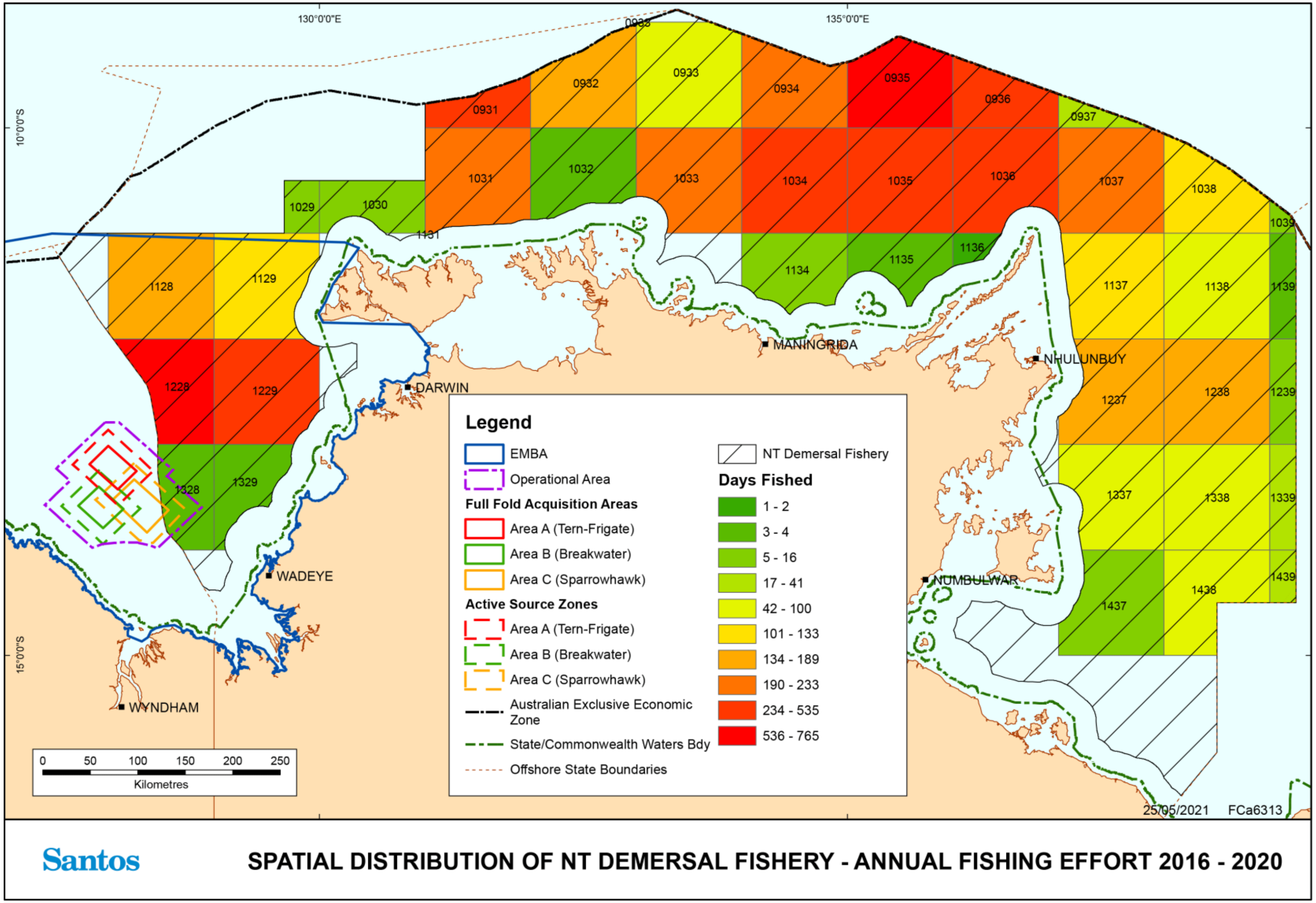


Figure 3-21: Demersal Fishery total fishing day count (2016-2020)

Spanish Mackerel Fishery

The NT SMF extends seaward from the high water mark to the outer limit of the AFZ and targets Spanish mackerel (*Scomberomorus commerson*) using trolled lures or baited lines. The primary fishing grounds include waters near Bathurst Island, New Year Island, the Wessel Islands around to Groote Eylandt and the Sir Edward Pellew Group of islands. The eastern portion of the Operational Area and eastern corner of the Full Fold Acquisition Area C overlaps the fishery (refer to **Figure 3-22**).

Licensees typically fish from a mother ship and dories, with a maximum of two dories permitted per licence. They may use any number or combination of troll lines, floating hand lines or rods. Operators generally troll two to four lines behind a dory and up to eight lines from a mother boat.

Commercial catches and catch rates of Spanish mackerel gradually increased from 1986 to 2006, before declining to an average catch of about 350 tonnes (t) per annum and a catch rate of 300 kg per day. Both commercial catches and catch rates of the commercial sector of the Spanish Mackerel Fishery have since increased to peak at their highest level of 446.5 t (2016) and 389 kg per day (2012).

A total of 390.6 t of fish were harvested by SMF licensees in 2017, with all but 0.7 t being Spanish mackerel and the remaining, reported as grey mackerel (DPIR 2019f).

Current biomass levels are well within sustainable limits and suggest that this stock is not considered to be recruitment overfished and the current level of fishing mortality is unlikely to cause the stock to become recruitment overfished. The NT Spanish Mackerel stock is classified as a sustainable stock.

Analysis of fishing catch and effort data shows that the fishing effort over the NT coast is 337,351 km2 for the period between 2016 and 2020. The Operational Area overlaps with approximately 1,668 km^2 (0.49%) of the area of fishing effort (refer to **Figure 3-22**).

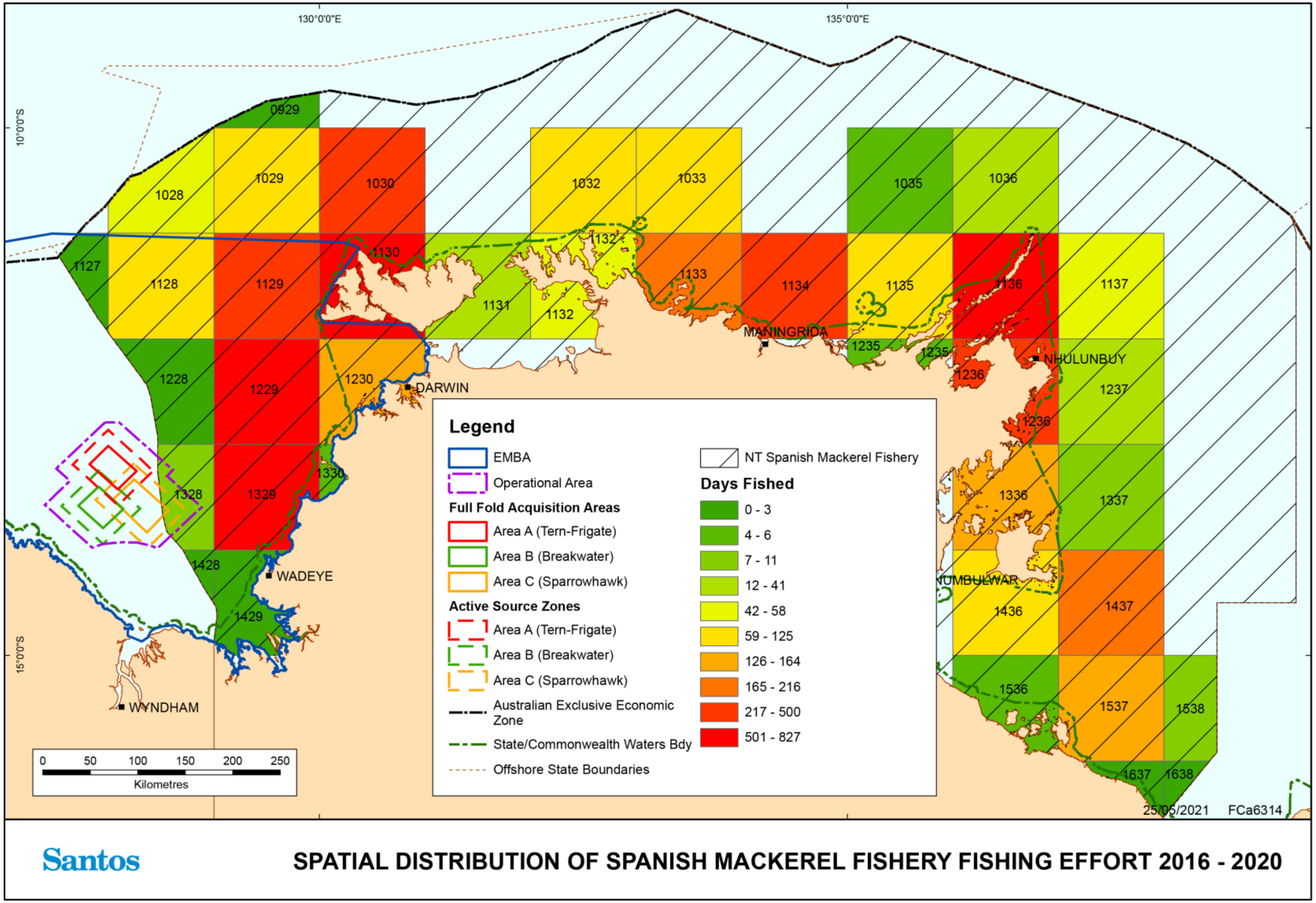


Figure 3-22: Spanish Mackerel Fishery total fishing day count (2016-2020)

Offshore Net and Line Fishery

The NT ONLF extends seaward from the high water mark to the outer limit of the AFZ and targets Australian blacktip sharks (*Carcharhinus tilstoni*), common blacktip sharks (*C. limbatus*) and grey mackerel (*Scomberomorus semifasciatus*). The eastern portion of the Operational Area and eastern corner of the Full Fold Acquisition Area C overlaps the fishery (refer to **Figure 3-23**).

Demersal long-lines can be used throughout the fishery whereas pelagic gillnets and pelagic long-lines can only be used beyond 2 nm and 3 nm of the coast, respectively. Pelagic gillnets are the primary gear used by this fishery and are generally set within 15 nm of the coast. Long-lines have not been used in the fishery since 2013, primarily as a result of the drop in the price of shark fins.

Licensees can use nets up to 2,000 m in length, but most choose to use nets in the order of 1,000 m to 1,500 m. The drop of the net must not exceed 100 meshes and the size of each mesh panel typically ranges from 160 mm to 185 mm when stretched. Pelagic gillnets are weighted and have a buoyed headline. Pelagic long-lines must not exceed 15 nm in length and cannot have more than 1,000 snoods (hooks) attached. Automated baiting gear is prohibited (DPIR 2019c).

Licensees harvested 640.8 t of fishes in 2017 (DPIR 2019f). Grey mackerel formed the bulk of the harvest (73.2%) followed by the blacktip shark group (11.8%) and Spanish mackerel (3.1%). The primary by-product species were hammerhead sharks (3%), tuna (2.1%) and queenfish (2%). Bycatch (by weight) was less than 1% of the harvest in 2017 (DPIR 2019f).

Analysis of fishing catch and effort data shows that the fishing effort over the NT coast is 326,966 km^2 for the period between 2016 and 2020. The Operational Area overlaps with approximately 1,668 km^2 (0.51%) of the area of fishing effort.

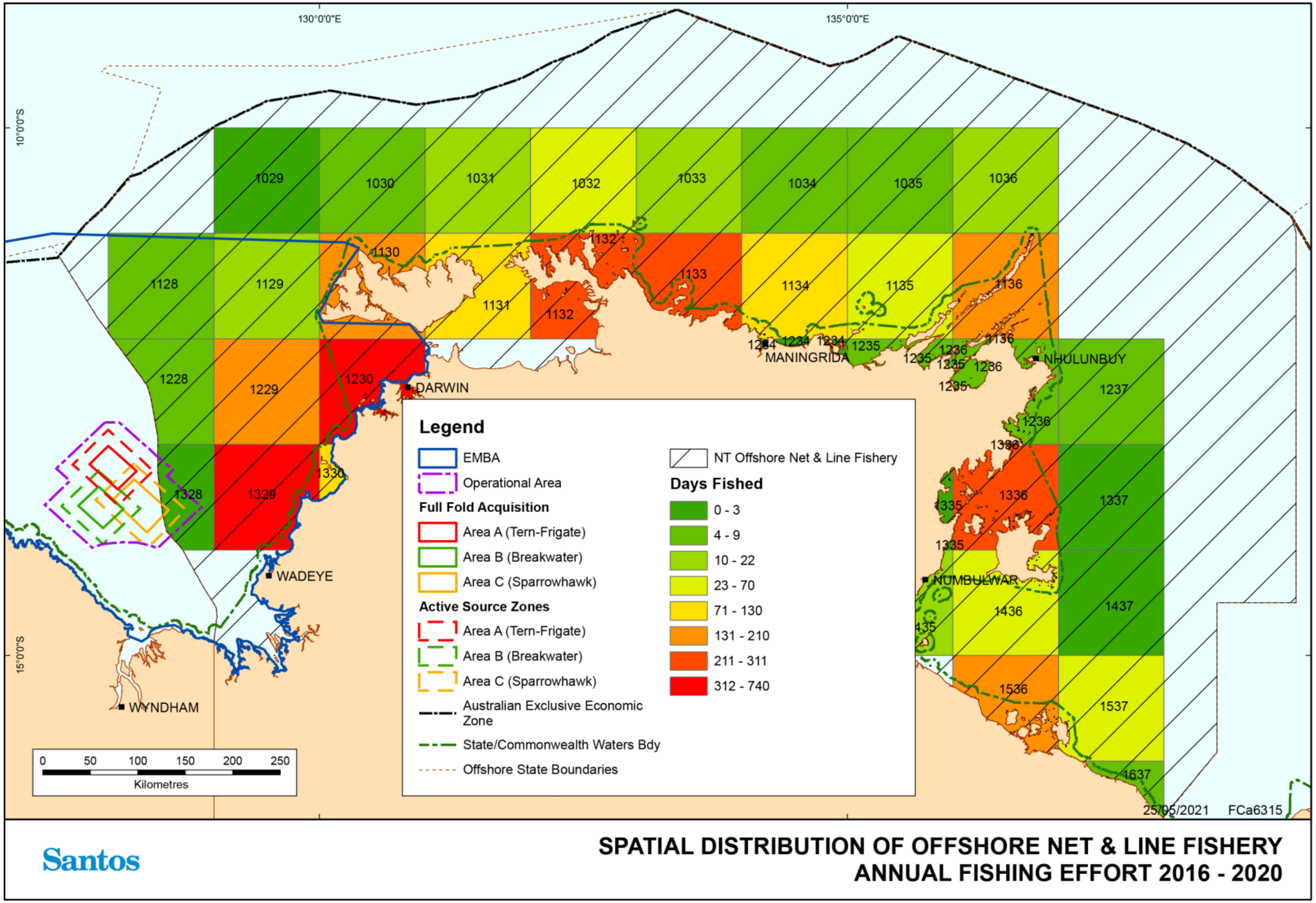


Figure 3-23: Offshore Net and Line Fishery total fishing day count (2016-2020)

3.8.1.4 Key Commercial Finfish and Shellfish Species

The Operational Area is located mainly within the Kimberley fisheries management unit. The WA DPIRD provided information on the spawning and distribution of finfish species, which was used in combination with stock information provided in the Fisheries Research and Development Corporation (FRDC) Status of Australian Fish Stocks Reports published online at https://fish.gov.au/ to provide an indication of fish stocks targeted by commercial fisheries relevant to the Operational Area.

It is noted that the Operational Area overlaps with the edge of the NT fisheries management unit (less than 0.5% of the fishery management unit). The NT DITT (Fisheries) monitors the key biological fish stocks in the NT, following the national reporting framework used in the Status of Key Australian Fish Stocks Reports 2018 (Stewardson et al., 2018).

ABARES and AFMA monitor Commonwealth-managed fisheries, including the NPF. The prawn stocks within the NPF are considered as a single stock and management unit.

The species described in the following sub-sections are referred to by the fishery management authorities as indicator species and are relevant to the management of commercial fish stocks. Indicator species are selected from the suite of commercially targeted finfish (based on their inherent vulnerability, management importance and overall risk to sustainability) for assessing the status of the overall resource.

Key Prawn Species

Based on information from the Northern Prawn Fishery Industry Pty Ltd (NPFI) and NPF fishery publications, the NPF indicator prawn species (banana prawns and tiger prawns), as well as endeavour prawns may spawn within the Operational Area. The biology of these species is described below and summarised in **Table 3-20**, as published by AFMA (2021a), Parsa et al. (2020), and the FRDC online Status of Australian Fish Stocks Reports (Butler et al. 2020).

Banana prawns inhabit tropical and subtropical coastal waters. They are found over muddy and sandy bottoms in coastal waters and estuaries. Juveniles inhabit small creeks and rivers in sheltered mangrove environments. White banana prawns can generally be found at depths of 16 - 25 m but can occur to depths of 45 m. Red-legged banana prawns are found at depths of 35 - 90 m (AFMA 2021a).

Advice provided to industry by the NPFI in relation to other marine seismic surveys in the region (i.e. Santos Fishburn 3D MSS, Santos Beehive 3D MSS and Polarcus Petrelex 3D MSS), is that *P. indicus* spawn offshore in proximity to the fishing area throughout the year. Two spawning peaks have been identified: the late dry season (September-November) and the late wet season (March-May). The larvae move inshore and then wash out as juveniles with the wet season floods. A twelve-month-old female can produce hundreds of thousands of eggs at a single spawning and may spawn more than once in a season. The eggs sink to the bottom after release, where they hatch into larvae within about 24 hours. Less than 1% of these offspring survive the 2-4 week planktonic larval phase to reach suitable coastal nursery habitats where they may settle. After one to three months on the nursery grounds, the young prawns move offshore onto the fishing grounds.

As described in Loneragan et al. (2002), the offshore fishery for red-legged banana prawns (*P. indicus*) takes place in the western offshore waters of the JBG (in water depths of 50-80 m). The juvenile phase of *P. indicus* is found in estuarine habitats up to 120 km south and 240 km east-southeast of the southern and eastern limits of the JBG *P. indicus* fishing grounds. The juvenile phase of *P. merguiensis* is found in estuarine habitats in the western JBG, about 50 km to the south-west of the offshore fishing grounds. Although these mangrove habitats are the closest inshore habitats to the fishery, they are not used by *P. indicus*. These results suggest that the larvae of *P. indicus* resulting from spawning in the fishing area of the JBG, are advected large distances to the south and east to their nursery habitats (**Figure 3-24**). They also imply that the emigrating juveniles and sub-adults migrate from the mangrove nursery habitats, north and west, across shallower sand substrates (30 – 40 m deep) to the deeper-water fishery (on mud substrates about 50 – 80 m deep).

The migration of juvenile *P. indicus* in the JBG appears to be split into two periods, with the migration of the main cohort occurring between November and March, with a possible second cohort migrating from April to June (Neil Loneragan, CSIRO Division of Marine Research, pers. comm., April 2000). The migration of juveniles is thought to be triggered by rainfall and river discharge.

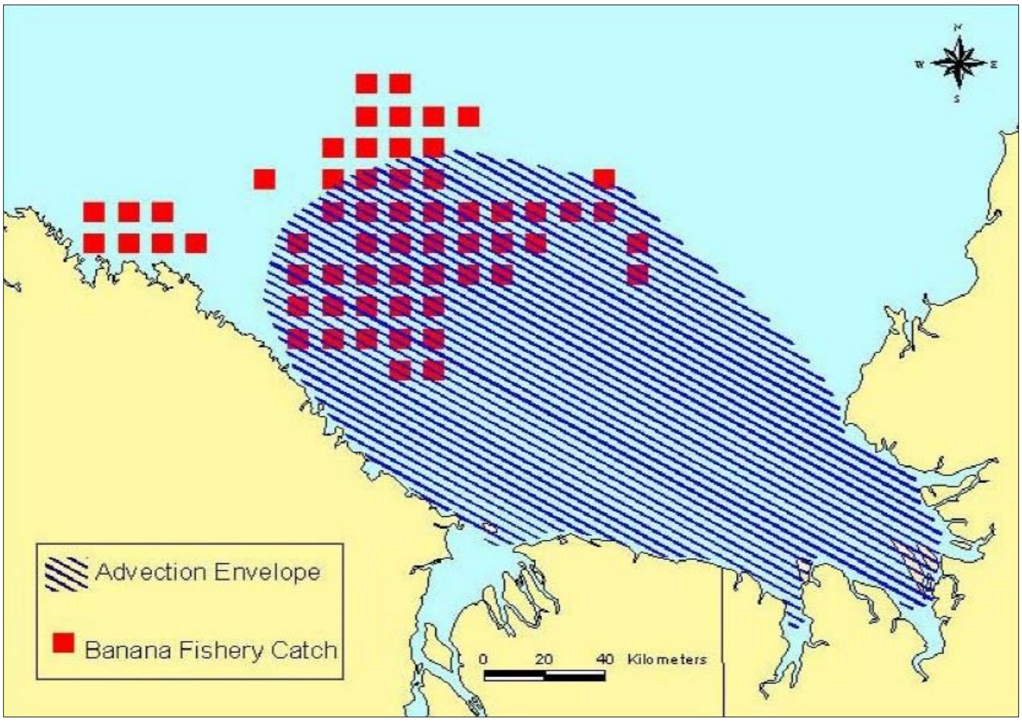


Figure 3-24: Size of the probable advection envelope for post larval P. indicus in the JBG (Loneragan et al. 2002)

Tiger prawns inhabit shelf waters to depths of 200 m. Adult brown tiger prawns are found over coarse sediments. Adult grooved tiger prawns are found in fine mud sediments. Juvenile tiger prawns are found in shallow waters, often in association with seagrass beds, and sometimes on top of coral reef platforms. Spawning occurs throughout the year, in both inshore and offshore areas for brown tiger prawns and in offshore areas for grooved tiger prawns. Brown tiger prawns have a spawning peak between July and October. Grooved tiger prawns have a spawning peak in August-September, with a secondary peak in February (AFMA 2021).

Endeavour prawns inhabit tropical coastal waters. Blue endeavour prawns can be found over sandy or mud-sand substrates to depths of about 60 m. Red endeavour prawns prefer muddy substrates and have been found to depths of 95 m. Juvenile blue endeavour prawns are commonly associated with seagrass beds in shallow estuaries, while juvenile red endeavour prawns are more widely distributed across seagrass beds, mangrove banks, mud flats and open channels. Spawning occurs throughout the year. Blue endeavour prawns have spawning peaks in March and September. Red endeavour prawns have a spawning peak in September to December (AFMA 2021a).

Table 3-20: Key Prawn Species Relevant to the Survey

Species	Habitat	Stock Structure and Distribution	Reproduction and Recruitment	Stock Assessment	Relevance to EP
Banana prawns Redleg banana prawn *P. indicus* White banana prawn *P. merguiensis*	Tropical and subtropical coastal waters. Muddy and sandy bottoms in coastal waters and estuaries. Juveniles inhabit small creeks and rivers in sheltered mangrove environments. White banana prawns can generally be found at depths of 16-25 m but can occur to depths of 45 m. Redleg banana prawns are found at depths of 35-90 m. Schooling species that sometimes form dense aggregations near the surface called 'boils'.	Banana prawns are found across northern Australia, from WA to QLD. The biological stock structure of banana prawn is uncertain. There is some evidence that there may be separate biological stocks of banana prawn within the Northern Prawn Fishery, however, the boundaries of the biological stocks are unknown. Stocks in WA and QLD are widely separated, but it is not known whether these are completely independent stocks. In the JBG, a single separate stock is assumed for stock assessment purposes, although stock status for the species is reported at the management unit level - Northern Prawn Fishery.	Spawn offshore near the fishing grounds throughout the year with two spawning peaks: the late dry season (September - November) and the late wet season (March – May). Banana prawns are serial spawners. Each female lays several egg batches each year. Females produce 100,000-450,000 eggs per year. The eggs sink to the bottom and hatch into larvae within 24 hours. Less than 1% of larvae survive the 2-4 week planktonic larval phase to reach suitable coastal nursery habitats where they may settle. After 1-3 months on the nursery grounds, the young prawns migrate offshore. Migration of the main cohort occurs November-March. A possible second cohort migrates April-June. Reach sexual maturity at ~6 months, lifespan 1-2 years. Recruitment in the NPF is highly variable due to seasonal environmental conditions, particularly rainfall. Annual recruitment (as evidenced by catches) has been maintained and continued a pattern of	**Sustainable** A stock–recruitment relationship is not established and no formal stock assessment is conducted. Status determination is instead based on a weight-of-evidence approach. The harvest strategy in the NPF is designed to ensure adequate remaining spawning biomass and prevent overfishing by controlling the timing of the fishing seasons and closure of the seasons when catch rates fall below a catch-rate trigger level. The species has shown resilience to fishing pressure, with strong subsequent recruitment following historical high levels of catch. The above evidence indicates that the stock biomass is unlikely to be depleted and that recruitment is unlikely to be impaired.	White banana prawns are likely to occur in waters shallower than 45 m (i.e. shallower than the Active Source Zones). They may occur in the shallower parts of the Operational Area and in waters shoreward of here. Redleg banana prawns may occur in the southern part of the Operational Area in water depths shallower than 90 m, as indicated by the main area of NPF fishing effort in the JBG, which targets the species here. The juvenile migration in the JBG takes place from coastal waters to the south of the Operational Area.

Species	Habitat	Stock Structure and Distribution	Reproduction and Recruitment	Stock Assessment	Relevance to EP
			high natural variability from year-to-year.		
<u>Tiger prawns</u> Brown tiger prawn, *P. esculentus* Grooved tiger prawn, *P. semisulcatus*	Tiger prawns inhabit coastal waters to depths of 200 m. Adult brown tiger prawns are found over coarse sediments. Adult grooved tiger prawns are found in fine mud sediments. Juvenile tiger prawns are found in shallow waters, often in association with seagrass beds, and sometimes on top of coral reef platforms.	Brown tiger prawns are endemic to tropical and subtropical waters of Australia, while Grooved Tiger Prawns have a wider Indo–West Pacific distribution. There is some genetic evidence of separation of brown tiger prawn stocks from the east and west coasts of Australia. Assessment of stock status is undertaken at the management unit level - Northern Prawn Fishery.	Spawning occurs throughout the year, in both inshore and offshore areas for brown tiger prawns and in offshore areas for grooved tiger prawns. Brown tiger prawns have a spawning peak between July and October. Grooved tiger prawns have a spawning peak in in August-September, with a secondary peak in February. Females produce about 186,000 eggs (brown tiger prawns) and 365,000 eggs (grooved tiger prawns) per year. Eggs hatch within 24 hours of fertilisation. Reach sexual maturity at ~6 months, lifespan 2 years.	**Sustainable** The harvest strategy in the NPF is designed to ensure adequate remaining spawning biomass and prevent overfishing by controlling the timing of the fishing seasons and closure of the seasons when catch rates fall below a catch-rate trigger level. The NPF management unit is not considered to be recruitment impaired. The brown tiger prawn and grooved tiger prawn stocks in the NPF management unit are classified as sustainable.	Tiger prawns may occur throughout the Operational Area.

Species	Habitat	Stock Structure and Distribution	Reproduction and Recruitment	Stock Assessment	Relevance to EP
Endeavour prawns Blue endeavour prawn, *M. endeavouri* Red endeavour prawn, *M. ensis*	Endeavour prawns inhabit tropical coastal waters. Blue endeavour prawns can be found over sandy or mud-sand substrates to depths of about 60 m. Red endeavour prawns prefer muddy substrates and have been found to depths of 95 m. Juvenile blue endeavour prawns are commonly associated with seagrass beds in shallow estuaries, while juvenile red endeavour prawns are more widely distributed across seagrass beds, mangrove banks, mud flats and open channels.	Little is known about the biological stock structure of the populations of blue and red endeavour prawns. Assessment of stock status is undertaken at the management unit level - Northern Prawn Fishery.	Spawning occurs throughout the year. Blue endeavour prawns have spawning peaks in March and September. Red endeavour prawns have a spawning peak in September - December. Females produce about 296,000 eggs per year.	**Sustainable** (*M. endeavouri*) **Undefined – no current stock assessment** (*M. ensis*)	Blue endeavour prawns are likely to occur in waters shallower than 60 m and, therefore, may occur in the shallower parts of the Operational Area and in waters shoreward of here. Red endeavour prawns may occur in the southern part of the Operational Area in water depths shallower than 95 m.

AFMA 2021 https://www.afma.gov.au/fisheries-management/species/prawns

Butler et al. 2018 https://fish.gov.au/report/272-BANANA-PRAWNS-2020

Parsa et al. 2020 https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/northern-prawn-fishery#51-description-of-the-fishery

Key Demersal and Pelagic Finfish Species

The two demersal indicator species for the Kimberley region of WA are red emperor (*Lutjanus sebae*) and goldband snapper (*Pristipomoides multidens*) (DPIRD 2017). Demersal indicator species for the NT DF include goldband snapper (*Pristipomoides multidens*), saddle-tail snapper (*Lutjanus malabaricus*), and crimson snapper (*L. erythropterus*) (FRDC 2018).

Spanish mackerel (*Scomberomorus commerson*) is the principal target pelagic species and single indicator species for the WA MMF (Mackie et al. 2010) and NT SMF (Grubert et al. 2013). Grey mackerel; is an indicator species of the NT ONLF (FRDC 2021).

As described for each individual key indicator fish species in the Australian Fisheries Research and Development Corporation (FRDC) Status of Australian Fish Stocks (SAFS) reports (FRDC 2019) and in DPIRD's stock structure summary (Gaughan et al. 2018), fish stock structures are considered in terms of both their genetic stocks and fishery management units. The genetic stocks refer to the geographic areas where genetic homogeneity is maintained by the dispersal of pelagic eggs and larvae within and between regions (Newman et al. 2000; Department of Fisheries 2004). The level of mixing from egg and larval dispersal is influenced by the spatial-temporal patterns of spawning relative to the prevailing oceanographic currents, the duration of the spawning period and the periodicity of spawning. For example, a species that spawns over a large portion of the continental shelf for a protracted period will very likely have a high level of egg and larval dispersal resulting in a wide spatial stock extent (Gaughan et al. 2018). This is the case with all of the key indicator fish species in northern Western Australia, which spawn throughout their ranges and on multiple occasions during protracted spawning periods (Gaughan et al. 2018).

There is considerable bidirectional mixing of pelagic eggs and larvae across northern Australia, therefore, for species that are relatively evenly distributed throughout their range and with spawning seasons that extend over several months, there is a high propensity for alongshore mixing over large distances (Gaughan et al. 2018). The eggs and larvae released by spawning adult demersal 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. 2010; Marriott et al. 2012; Berry et al. 2012; Gaughan et al. 2018). The genetic stocks, therefore, represent the area where the exchange of larvae and subsequent recruitment of juvenile fish to the stocks occurs over many years (Martin et al. 2014; Gaughan et al. 2018).

Table 3-21 summarises the indicator fish species that are relevant to the Operational Area, the spatial extent of their biological stocks, and their reproductive biology, based on information provided by DPIRD (2019c) and other published literature on the fisheries and fish species.

Note that fish stocks may also be considered in terms of smaller more discrete fisheries 'management units', which are adopted by fisheries management authorities for the purposes of fisheries management and monitoring. The management units consider the genetic stock and larval settlement, but also take into account the smaller ranges and localised movements of adult and juvenile fish, as well as the extent of the fisheries that target the stocks. Consequently, the fisheries management units are typically smaller than the extent of the genetic stocks. Application of management units provides a more conservative approach to managing the resource (Gaughan et al. 2018). The North Coast Fisheries Bioregion of WA defined by DPIRD is divided into two management units, the Pilbara and the Kimberley management units, which also inform the FRDC (2019) stock assessments.

Table 3-21: Key Indicator Finfish Species Relevant to the Survey

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
Demersal Species							
Goldband snapper (*Pristipomoides multidens*)	Goldband snapper occur around offshore reefs, shoals, and areas of hard flat bottom with occasional benthos or vertical relief. Juveniles typically occur on uniform sedimentary habitat with no relief (Newman et al. 2008). Goldband snapper are widely distributed throughout northern Australia, from the Gascoyne region of WA to SE Queensland (Newman et al. 2008, 2018a; Saunders et al. 2018).	Australian populations of goldband snapper are likely to form a single biological stock and there is gene flow among goldband snapper from the Northern Territory (Timor Sea and Arafura Sea) and between the Western Australian management units (Kimberley, Pilbara and Gascoyne) (Saunders et al. 2018). Relevant to the Operational Area is the stock belonging to the Kimberley and NT management units.	50-200 m (DPIRD 2019).	Goldband snapper are highly fecund, serial, broadcast spawners and they can produce several million eggs per season (Newman et al. 2008). They spawn throughout their range (DPIRD 2019). Goldband snapper can spawn approximately every three days / every week during the spawning period (Santos 2020). Juveniles remain in offshore waters with the adult spawning biomass, but are found in association with different habitat (Newman et al. 2008). Fish are estimated to reach maturity after approximately 4.6 years (Saunders et al. 2018).	**Sustainable (both WA and NT management units)**	October – May (extended peak spawning period) (DPIRD 2019).	Given the known distribution and habitat depths, goldband snapper are likely to occur and may spawn within the Operational Area.

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
Red emperor (*Lutjanus sebae*)	Red emperor occur from the central west coast of WA to southern Queensland (Newman et al. 2018). Red emperor are widely distributed across the continental shelf and associated with reefs, lagoons, epibenthic communities, limestone sand flats and gravel patches (Newman et al. 2008).	The reproductive biology of red emperor results in a very broad distribution of eggs and larvae, which results in genetic connectivity over a wide geographic range (Gaughan et al. 2018). There is extensive connectivity and gene flow among populations across northern Australia (Queensland to Shark Bay in WA), indicating a single genetic stock (Newman et al 2018). There is no evidence of discrete breeding populations between regions in WA (Gaughan et al 2018). Relevant to the Operational Area is the stock belonging to the Kimberley management unit.	10-180 m (DPIRD 2019).	Red emperor are highly fecund, serial, broadcast spawners. Females release numerous batches of eggs over an extended spawning period. (Newman et al. 2008; Gaughan et al 2018). They spawn throughout their range (DPIRD 2019). Juvenile fish are more common in nearshore waters and move offshore and recruit to the stock as they mature (Newman et al. 2008; van Herwerden et al. 2009). Fish are estimated to reach maturity after approximately 4 – 6 years (Newman et al. 2018).	**Sustainable (WA management unit)**	The species spawns for 10-12 months of the year on the north coast of WA (Gaughan et al. 2018). DPIRD (2019) advise that the main spawning season is September – June (with bimodal peaks September – November and January – March).	Given the known distribution and habitat depths, red emperor are likely to occur and may spawn within the Operational Area.

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
Saddle-tail snapper (*Lutjanus malabaricus*)	Saddle-tail snapper are widely distributed throughout the Indo-Pacific region from Fiji to the Persian Gulf and tropical Australian waters. In Australian waters, they are found from Shark Bay in WA, across northern Australia to the east coast of Queensland over a wide depth range, from coastal to offshore areas.	Stock status is presented at the management unit level. Relevant to the Operational Area is the stock belonging to the NT management unit.	The depth distribution for this species has not been well defined in the NT. This species is expected to be found between 5 m and 100 m (Salini et al. 2006).	Saddle-tail snapper reach reproductive maturity at about 9-years and have a lifespan of about 30-years (FRDC 2018; Fry et al. 2009). There is a distinct difference in length at first maturity between the sexes, with male saddle-tail snappers first reaching sexual maturity at around 240 mm whereas females began maturing between 250 and 300 mm. Published data available on the reproductive characteristics of tropical lutjanides indicate that most species are highly fecund, serial spawners with a protracted spawning season (Davis and West 1993; Grimes 1987; Kritzer 2004; Marriot et al. 2007; Shimose 2005). Northern Australian populations of saddle-tail snapper show a single-modal cycle in their reproductive activity (Fry et al. 2009). The species has been recorded producing up to 997,000 oocytes per batch (Fry et al. 2009). Preferred spawning	**Sustainable (NT management unit)**	Spawning occurs throughout the year, with a peak between September and March (Fry et al. 2009).	Given the known distribution and habitat depths, saddle-tail snapper may occur in the Operational Area and may spawn throughout their range, particularly during their peak spawning times.

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
				depths have not been identified for this species in the region.			
Crimson snapper (*Lutjanus erythropterus*)	Crimson snapper are widely distributed throughout the Indian Ocean and the tropical parts of the Western Pacific Ocean, ranging from India through the entire Malay Archipelago to China, the Philippines and Australia (Allen and Talbot 1985). In Australian waters, they are found from Shark Bay in WA to central NSW over a wide depth range, from coastal to offshore areas (NT Government 2018).	Stock status is presented at the management unit level. Relevant to the Operational Area is the stock belonging to the NT management unit.	The depth distribution for this species has not been well defined in the NT. This species is expected to be found between 5 m and 100 m (Salini et al. 2006).	Male crimson snapper reach reproductive maturity at about 240 mm whereas females begin maturing between 250 and 300 mm. The species has a lifespan of about 40-years (FRDC 2018; Fry et al. 2009). Published data available on the reproductive characteristics of tropical lutjanids indicate that most species are highly fecund, serial spawners with a protracted spawning season (Davis and West 1993; Grimes 1987; Kritzer 2004; Marriot et al. 2007; Shimose 2005). Northern Australian populations of crimson snapper show a single-modal cycle in their reproductive activity (Fry et al. 2009). The species has been recorded producing up to 676,100 oocytes per batch (Fry et al. 2009).	**Sustainable (NT management unit)**	Spawning occurs throughout the year, with a peak between July and December (Fry et al. 2009).	Given the known distribution and habitat depths, crimson snapper may occur in the Operational Area and may spawn throughout their range, particularly during their peak spawning times.

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
Pelagic Species							
Spanish mackerel (*Scomberomorus commerson*)	Spanish mackerel are a pelagic species that are widely distributed throughout Indo-West Pacific waters. In Australia, Spanish mackerel are found from approximately Geraldton in WA to Northern NSW (Langstreth et al. 2018). Adult movements in Australian waters occur over ranges of 100 – 300 km (Mackie et al. 2010).	Spanish mackerel in northern Australia form 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) (Langstreth et al. 2018). Consequently, the whole of the WA Mackerel Managed Fishery (spanning the Kimberley, Pilbara and Gascoyne regions) is defined as a single stock (Langstreth et al. 2018). Relevant to the Operational Area is the stock belonging to the Kimberley and NT management units.	1 – 50 m (DPIRD 2019).	Form spawning schools around inshore reefs in north coast bioregion (Mackie et al. 2010; Lewis and Jones 2018). Spanish mackerel spawning occurs in coastal waters. They are serial spawners and alongshore dispersal of eggs maintains genetic homogeneity (Mackie et al. 2010). 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 (McPherson 1993; Mackie et al. 2010). 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 (McPherson 1993; Begg et al. 2006; Mackie et al. 2010). Fish are estimated to reach maturity after	**Sustainable (both WA and NT management units)**	September – December (peak spawning) (DPIRD 2019).	Given the known distribution and habitat depths, Spanish mackerel may occur in the Acquisition Area but is unlikely to spawn in the Acquisition Area due to the species preferred water depth ranges. Spawning is limited to water depths in less than 50 m. The minimum water depth in the Acquisition Area is 50 m.

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
				approximately 2 years (Langstreth et al. 2018).			
Grey mackerel (*Scomberomorus semifasciatus*)	Grey mackerel have a restricted distribution and are confined to the waters of southern Papua New Guinea and around northern Australia from the Houtman Abrolhos Islands on the west coast to northern NSW on the east coast (NT Government, 2020). Adult grey mackerel are known to commonly occur in turbid tropical and subtropical waters at approximately 3–30 m depth. This is usually in the vicinity of bottom structure in close proximity to headlands and reefs and on sandy mud and muddy sand substrates (NT Government 2020).	Stock status is presented at the management unit level. Relevant to the Operational Area is the stock belonging to the NT management unit.	Grey mackerel are usually found in water depths of about 3–30 m (NT Government, 2020d).	Grey mackerel have a lifespan of about 14-years, with females reaching maturity at around 2-years while males reach maturity between 1-2 years (Cameron and Begg 2002; Department of Agriculture and Fisheries 2016). Grey mackerel grow rapidly and are highly fecund, producing approximately 250,000 oocytes per spawning (NT Government 2020). They form spawning schools that are predictable enough both spatially and temporally to be targeted by fisheries (NT Government 2020). Once hatched, larvae of this species move to the inner margins of coastal bays and also into estuaries (Jenkins et al. 1985). Juveniles grow rapidly in estuarine habitats and move into coastal environments as they mature.	**Sustainable (NT management unit)**	August – January, though this is thought to be temperature dependent and potentially extended in northern regions (Welch et al. 2009)	Given the known distribution and habitat depths, grey mackerel are unlikely to occur in the Operational Area in significant numbers and are therefore unlikely to spawn within the Operational Area.

3.8.2 Shipping

The proximity of the Darwin Port to South East Asia makes the surrounding area a key shipping region. Vessel traffic data (provided by Australian Maritime Safety Authority (AMSA)) within and surrounding the Operational Area between January and December 2020 is illustrated in **Figure 3-25**. The figure shows high traffic shipping volumes in close proximity to Darwin Harbour, around operating petroleum fields (i.e. Blacktip platform) and along key shipping routes to and from South-east Asia. There is also vessel traffic that passes through the northern part of the Operational Area between Darwin and Kalumburu, and also between Darwin and the INPEX Ichthys and Shell Prelude offshore LNG facilities.

It is important to note that an area of high traffic volume directly north-east of the Operational Area is a result of the Polarcus Petrelex 3D MSS, which was completed between November 2019 and January 2020.

Traffic within the Operational Area is relatively low. The number of vessels passing through the Operational Area each month is provided in **Table 3-22**. The highest number of vessels (24) was recorded in October and the lowest (8) in December. These numbers are equivalent to a single vessel being present in the Operational Area every 1 – 4 days. It is noted that some vessels my transit through the Operational Area while some may remain within the Operational Area for a number of days (e.g. fishing vessels).

Table 3-22: Number of vessels per month within the Operational Area (2020)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Vessels	9	9	12	13	15	19	15	19	20	24	18	8

Santos

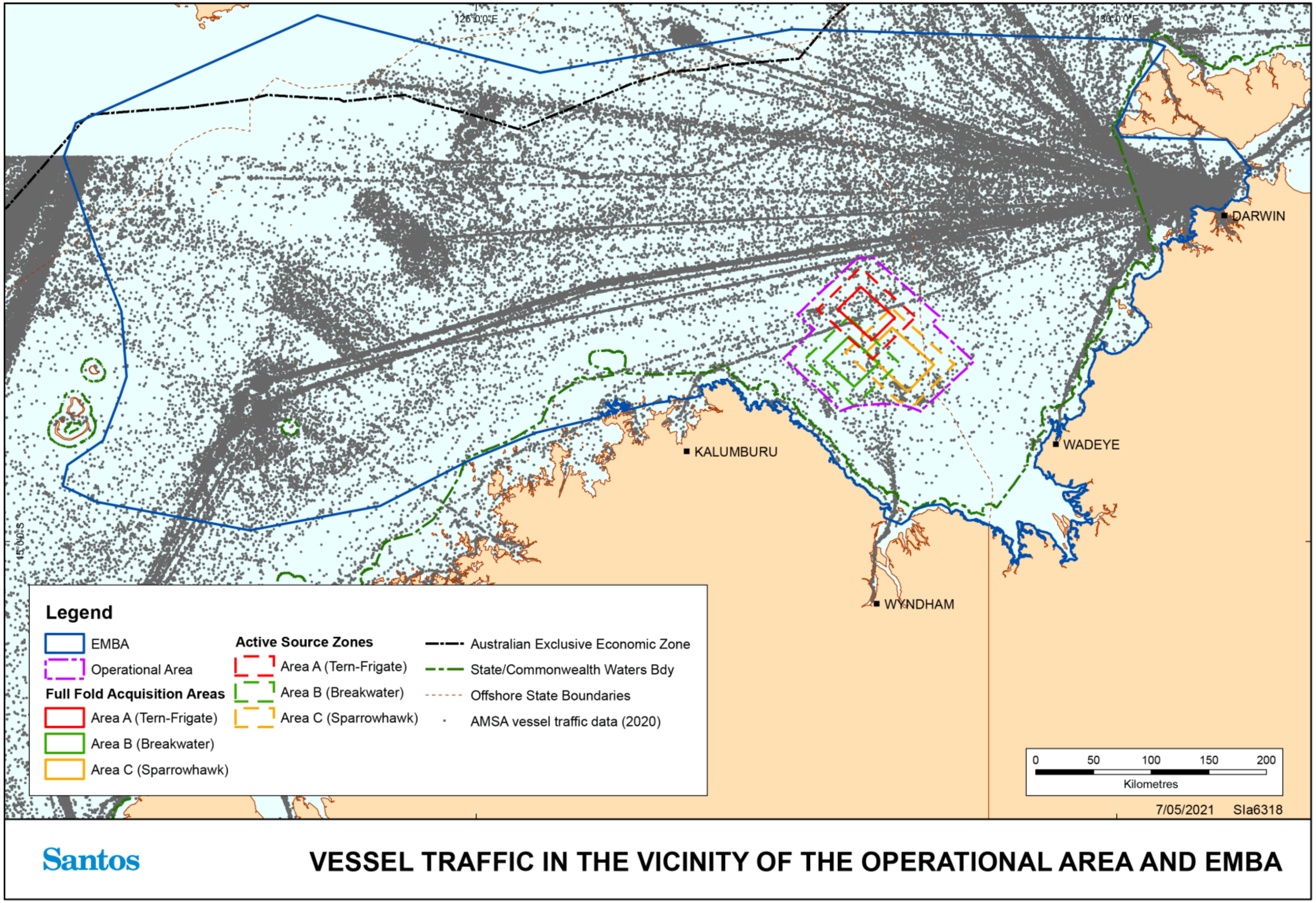


Figure 3-25: Vessel traffic data within and surrounding the Operational Area

3.8.3 Oil and Gas Activities

The Bonaparte Basin is an established hydrocarbon province with a number of commercial operations, including the Blacktip production platform and pipeline operated by Eni Australia B.V., which overlaps the southern portion of the Operational Area. Petroleum titleholders with titles within the Operational Area are listed in **Table 3-23** and shown in **Figure 3-26**.

Table 3-23: Oil and Gas Permits within 150 km of the Operational Area

Permit	Permit Type	Operator	Distance from the Operational Area
WA-454-P	Exploration Permit	Santos Offshore Pty Ltd	Overlaps
WA-27-R	Retention Lease	Bonaparte Gas and Oil Pty Ltd	Overlaps
WA-40-R	Retention Lease	Bonaparte Gas and Oil Pty Ltd	Overlaps
WA-522-P	Exploration Permit	Woodside Energy Ltd.	Overlaps
WA-33-L	Production Licence	Eni Australia B.V.	Overlaps
WA-6-R	Retention Lease	Neptune Energy Bonaparte Pty Limited	0.5 km
WA-488-P	Exploration Permit	Finniss Offshore Exploration Pty Ltd	1 km
NT/RL1	Retention Lease	Neptune Energy Bonaparte Pty Limited	9 km
WA-407-P	Exploration Permit	Octanex Bonaparte Pty Ltd	75 km

Santos

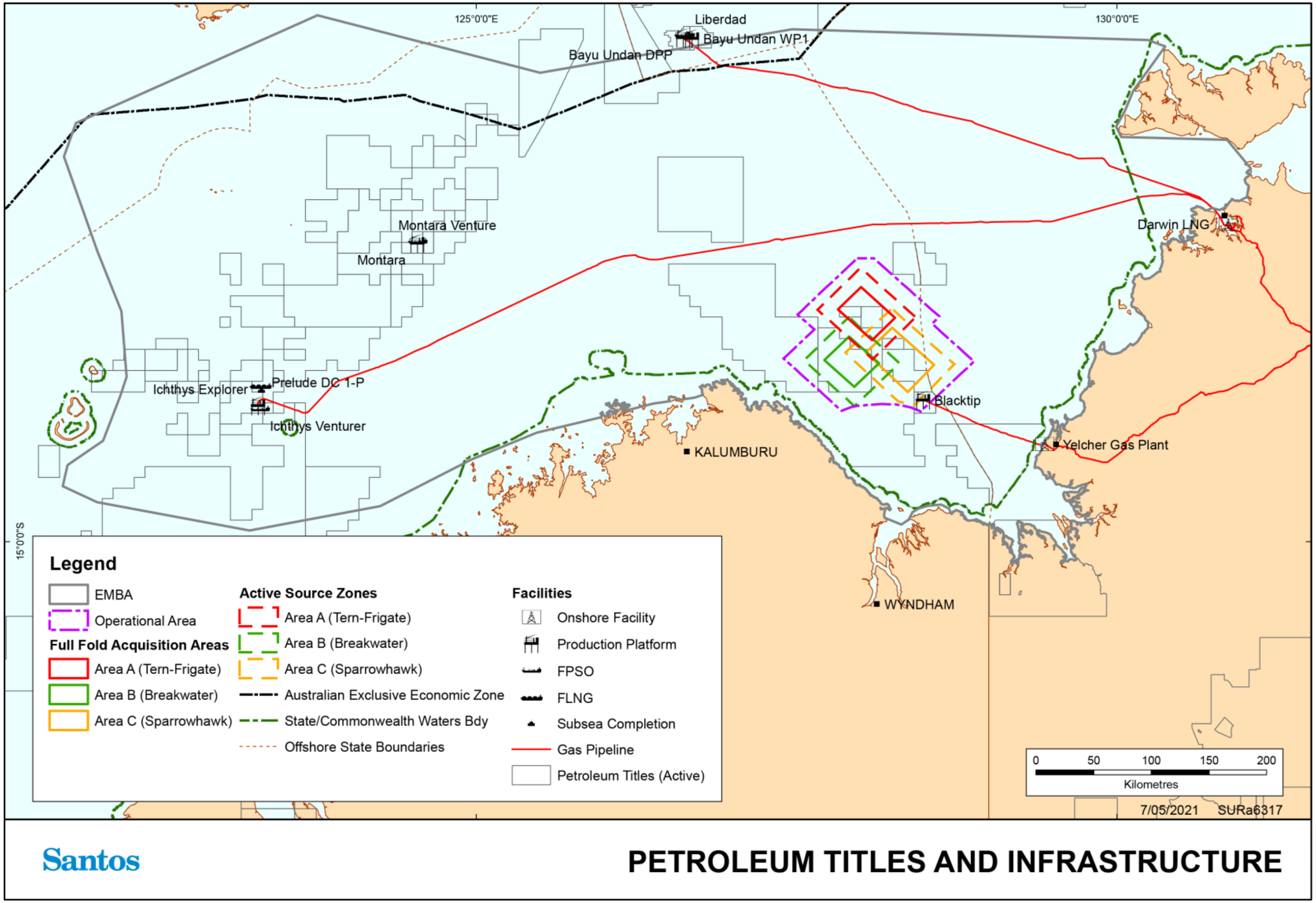


Figure 3-26: Petroleum titles and infrastructure

3.8.4 Tourism and Recreation

Most recreational and tourism activities in the region occur predominantly in State/Territory waters adjacent to population centres, such as Broome and Darwin. Tourism in the region typically peaks during the dry season (May to October), which includes activities such as recreational fishing, diving, snorkelling, wildlife watching and boating (DEWHA 2008a). Charter vessels may occasionally transit through the Operational Area and EMBA between Darwin and the northern Kimberley coastline.

Recreational fishing is allowed in the JBG, however interactions with tourism activities are considered unlikely due to the remoteness and predominantly deep waters of the Operational Area.

3.8.5 Defence Activities

Australian Border Force and Australian Defence Force vessels undertake civil and maritime surveillance within the region with the primary purpose of monitoring the passage of illegal entry vessels and illegal fishing activity within these areas. Refugees seeking asylum in Australia are also known to utilise the area, travelling between Indonesia and Australia.

The Operational Area overlaps with practice and training areas that comprise the North Australian Exercise Area (NAXA), a maritime military zone administered by the Australian Defence Force, as well as restricted airspace (**Figure 3-27**). The NAXA is used by the Royal Australian Air Force and the Royal Australian Navy for military operations including live weapons and missile firings.

The NAXA is the primary location of the KAKADU training exercise that operates biannually. The exercise involves numerous naval ships from various countries participating in the waters off Darwin and Northern Australia. Exercise KAKADU is Australia's premier international maritime exercise bringing together navies and air forces from the Asian, Pacific and Indian Ocean regions to test integration and war fighting abilities. During Exercise KAKADU, access may be restricted to all vessels and aircraft. Defence advised Santos during consultation that early advice of progress may enable compatible activities with minimal disruption to both parties.

Defence have advised that Exercise KAKADU will be in preparation throughout August 2022 with the exercise completed by 30 September 2022. Avoidance of the area during exercises is requested by Defence. The proposed survey period of the Petrel Sub-Basin SW 3D MSS (1 December to 31 March) avoids any potential conflicts with timing or location of military exercises that may overlap the Operational Area.

Defence also advised that unexploded ordinance (UXO) may be present on and in the sea floor of the Operational Area. According to the Defence UXO Database, the Operational Area is located within a former air-to-air weapons range, and may be affected by UXOs (Defence 2019).

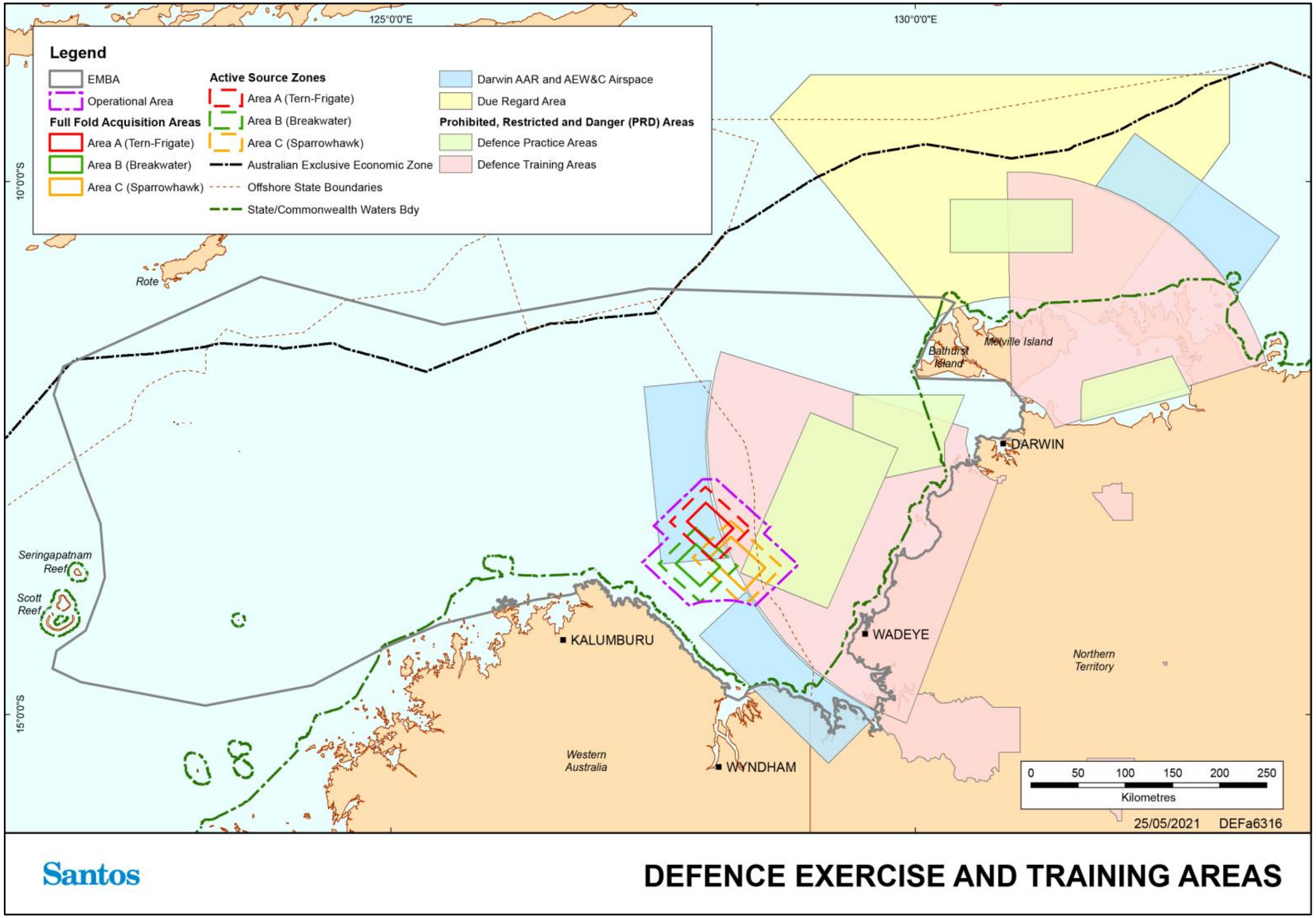


Figure 3-27: Defence Exercise and Training Areas

3.8.6 Maritime and Cultural Heritage

3.8.6.1 Maritime Archaeology

Historic shipwrecks and sunken aircraft are recognised and protected under the *Underwater Cultural Heritage Act 2019* that protects historic wrecks, sunken aircraft and associated relics. Under the Act, all wrecks and sunken aircraft more than 75 years old are protected, together with their associated relics regardless of whether their actual locations are known. The Commonwealth minister responsible for the environment can also make a declaration to protect any historically significant wrecks or articles and relics that are less than 75 years old.

A search of the Australasian Underwater Cultural Heritage Database confirms that there are no protected shipwrecks or sunken aircraft located within the Operational Area. The closest shipwreck to the Operational Area (approximately 53 km north) is the Sedco Helen, wrecked in 1970, located in depths of approximately 100 m.

3.8.6.2 Aboriginal Heritage

Indigenous Australian people have a strong continuing connection with the area that extends back some 50,000 years. The existence of any unknown Aboriginal sites or artefacts of significance within the offshore waters of northern Australia is considered highly unlikely. A search of the online aboriginal heritage Inquiry system was undertaken within the EMBA. Aboriginal Heritage sites are present along the coastline along the southern boundary of the EMBA, however, given that no shoreline accumulation of hydrocarbons is predicted, these are not expected to be impacted.

Aboriginal heritage records are provided in **Appendix C**.

3.8.6.3 Native Title

A search of the National Native Title Tribunal (NNTT) Register did not identify any Native Title areas or any pending titles within the Operational Area. However two Native Title areas were identified within the EMBA, south-west of the Operational Area, namely Uunguu Part A (Wanjina-Wunggurr (Native Title) Aboriginal Corporation RNTBC on behalf of the members of the Wanjina Wunggurr community), and Balanggarra (Combined) (Balanggarra Aboriginal Corporation RNTBC on behalf of the members of the Balanggarra community).

The Operational Area overlaps with the Representative Aboriginal Torres Strait Islander Body Area of the Northern Land Council and the Kimberley Land Council Aboriginal Corporation (NNTT 2019).

3.9 Periods of Peak Sensitivity or Activity

Timing of peak sensitivity or activity for threatened species and other relevant, significant sensitivities that may occur within or in proximity to the Operational Area is provided in **Table 3-24**.

Table 3-24: Timing of Key Sensitivities Relevant to the Operational Area and EMBA

Proposed Survey Timing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Conducted anytime from Dec 2021 to Mar 2023													
Environmental Sensitivity													Source
Marine Mammals													
Indo-Pacific/Spotted bottlenose dolphin: breeding, foraging and calving (Darwin Harbour)													DAWE 2020
Australian snubfin dolphin: foraging and breeding (Ord River)													DAWE 2020
Pygmy blue whale (northern migration)													DSEWPaC 2012a
Pygmy blue whale (southern migration)													DSEWPaC 2012a
Marine Turtles													
Flatback turtle: Nesting (Cape Domett)													DoEE 2017
Flatback turtle: Nesting (Waigait Beach)													DoEE 2017
Green turtle: Nesting (Kimberley)													DoEE 2017
Green turtle: Nesting (Cobourg Peninsula)													DoEE 2017
Olive ridley turtle: Nesting (Brace Point)													DoEE 2017
Foraging: Loggerhead, olive ridley, green and flatback turtles													DAWE 2020
Seabirds and Migratory Shorebirds													
Lesser crested tern: breeding (Kimberley)													Johnstone and Storr 1998
Roseate tern: breeding (Kimberley)													Johnstone and Storr 1998

Proposed Survey Timing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Conducted anytime from Dec 2021 to Mar 2023													
Environmental Sensitivity													Source
Lesser frigatebird: breeding (Kimberley)													Johnstone and Storr 1998
Commercial Prawn and Indicator Fish Species Spawning													
Banana prawn spawning													AFMA 2020
Juvenile banana prawn migration	Main cohort			Possible 2nd cohort							Main cohort		Longeran et al. 2002
Brown tiger prawn spawning													AFMA 2020
Grooved tiger prawn spawning													AFMA 2020
Blue endeavour prawn spawning													AFMA 2020
Red endeavour prawn spawning													AFMA 2020
Red emperor													DPIRD 2019
Goldband snapper													DPIRD 2019
Spanish mackerel (Kimberley stock)													DPIRD 2019
Commercial Fisheries													
Northern Prawn Fishery: Fishing Season	Closed season			Mainly banana prawns *New closure area for JBG applies*			Closed season	Mainly tiger prawns				Closed season	AFMA 2021 Larcombe et al. 2018
WA Northern Demersal Scalefish Managed Fishery													Newman et al. 2020
WA Mackerel Managed Fishery													Mackie et al. 2010
NT Demersal Fishery													
NT Spanish Mackerel Fishery													
NT Offshore Net and Line Fishery													

Proposed Survey Timing	Jan	Feb	Mar	Apr	Ma y	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Conducted anytime from Dec 2021 to Mar 2023													
Environmental Sensitivity													Source
Defence													
NAXA military exercises (e.g. KAKADU)													

Key:	
Sensitivity/activity occurs	
Peak period	
Peak fishing activity	
Extended peak spawning period	
Peak spawning/migration period	

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 Bonaparte Basin for several decades, undertaking exploration and appraisal activities across a range of permits and locations, including the southern Petrel Sub-Basin. Results from previous exploration drilling and seismic acquisition undertaken in the area have highlighted potential for further oil and gas resources.

In order to evaluate this potential and provide adequate coverage and data quality, Santos requires additional subsurface data via a seismic survey within petroleum permit areas WA-454-P, WA-545-P, WA-27-R and WA-40-R.

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 May 2021, including:

+ Petrel Sub-Basin 3D MSS Stakeholder Consultation package distributed to identified stakeholders in May 2021
+ Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package distributed to identified fishing licence holders in May 2021
+ Santos Offshore Quarterly Activity Update distributed to stakeholders in July 2021

- Email to relevant stakeholders advising the EP is available on the NOPSEMA Website for Public Comment.

Other interested persons were also informed of activities covered in this EP via the following channels:

- NOPSEMA Public Comment period, NOPSEMA website
- Notice regarding public comment period on Santos website
- Notice regarding public comment period in The Australian, West Australian, Kimberley Echo and NT News.

Based on Santos' experience with other seismic surveys undertaken offshore northern Australia, including the Fishburn 3D MSS (2017) and Bethany 3D MSS (2017), 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 6.3**)
- The level of potential industry seismic activity in the region over the next few years and potential impact on commercial fishing activity (addressed in **Section 6.4**).

Santos has considered all stakeholder responses and assessed the merits of all objections and claims about the potential impact of the proposed seismic survey. The process adopted to assess these claims is outlined in **Section 4.4**. 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. The list of stakeholders was then reviewed and refined based on the defined Operational Area (refer to **Section 2.3**), 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 WA) FishCube data (**Section 3.8.1.2**);
- Updated fishing licence holder contact details, from these identified fisheries, as provided by DPIRD WA and the Department of Industry, Tourism and Trade (DITT) in the Northern Territory;

- Utilisation of the WAFIC Oil and Gas consultation services to advise on 'relevant' commercial fisheries and fishers and review and distribution of commercial fisher consultation material;
- Discussions with identified stakeholders to identify other potentially impacted persons;
- Records from previous consultation activities in offshore northern Australia, including previous Bethany, and Fishburn 3D marine seismic surveys; and
- Active participation in industry bodies and collaborations (e.g., APPEA, AMOSC, NERA).

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 relevant 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 Northern Australian Exercise Area (NAXA) overlaps the Operational Area.
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.

Stakeholder	Relevant to Activity	Relevance/Reason for Engagement
Department of Agriculture, Water and the Environment (DAWE) – Biosecurity (marine pests)	Considered relevant persons under Regulation 11A(1) (a)	The DAWE (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, Water and the Environment (DAWE) – Fisheries	Considered relevant persons under Regulation 11A(1) (a)	DAWE (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, Water and the Environment (DAWE) –Biosecurity (vessels, aircraft and personnel)	Considered relevant persons under Regulation 11A(1) (a)	DAWE (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 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 (DNP)	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/Territory Government Departments/Agencies		
WA 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.

Stakeholder	Relevant to Activity	Relevance/Reason for Engagement
WA 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 a State Marine Park.
WA Department of Mines, Industry Regulation and Safety (DMIRS)	Considered relevant persons under Regulation 11A(1) (c)	DMIRS is responsible for the management of offshore petroleum in the adjacent State waters.
NT Department of Industry, Tourism and Trade (DITT)	Considered relevant persons under Regulation 11A(1) (b)	DITT is responsible for NT-managed fisheries. A small section of the Operational Area overlaps the area available to three of these fisheries
Pilbara Ports Authority	Considered relevant persons under Regulation 11A(1) (b)	WA Government Trading Enterprise governed under the Port Authorities Act 1999 WA and responsible for management of Dampier Port.
Neighbouring Operators/Exploration Companies		
Eni Australia B.V.	Considered relevant persons under Regulation 11A(1) (e)	Listed as the titleholder of adjacent petroleum permit WA-33-L.
Woodside	Considered relevant persons under Regulation 11A(1) (e)	Listed as the titleholder of adjacent petroleum permit WA-522-P and WA-279-P.
Finnis Offshore Exploration Pty Ltd	Considered relevant persons under Regulation 11A(1) (e)	Listed as the titleholder of nearby petroleum permit WA-488-P.
MEO International P/L	Considered relevant persons under Regulation 11A(1) (e)	Listed as the titleholder of nearby petroleum permits NT/P87 and WA-544-P
Neptune Energy Bonaparte Pty Ltd	Considered relevant persons under Regulation 11A(1) (e)	Listed as the titleholder of nearby petroleum permits NT/RL1
Octanex Bonaparte Pty Ltd	Considered relevant persons under Regulation 11A(1) (e)	Listed as the titleholder of nearby petroleum permits WA-407-P.
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.

Stakeholder	Relevant to Activity	Relevance/Reason for Engagement
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.
Recfishwest	Considered relevant persons under Regulation 11A(1) (e)	Recfishwest is the peak body representing recreational fishers in WA. Interactions with recreational fishing and tourism activities are considered unlikely due to the remoteness and predominantly deep waters of the Operational Area. Recfishwest is identified as being able to assist in reaching its membership to inform of survey timing should this be requested.
NT Seafood Council	Not considered relevant persons under Regulation 11A for the purposes of this activity	Industry association representing NT commercial fishing licence-holders operating in Territory-managed fisheries. A small section of the Operational Area overlaps two of these fisheries.
Australian Southern Bluefin Tuna Industry Association (ASBTIA)	Considered relevant persons under Regulation 11A(1) (e)	ASBTIA is listed on the AFMA website as a contact for petroleum operators to use when consultation with Commonwealth fishing operators is required. No fishing activity occurs in or near the Operational Area.
Commercial Fisheries – State/Territory Managed		
Mackerel Managed Fishery - Area 2 (WA)	Considered relevant persons under Regulation 11A(1) (d)	Based on a review of DPIRD FishCube data (**Section 3.8.1.2)** and consultation with WAFIC, the Operational Area overlaps with less than 1% of the 10 nautical mile (nm) catch and effort system reporting blocks that have reported fishing effort during the 11-year period (2009-2019). The two blocks overlapped by the Operational Area have been subject to relatively low fishing effort, compared with other areas that are regularly and intensively fished to the north and west of Kalumburu (over 90 km west of the Operational Area). Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been infrequent.
Northern Demersal Scalefish Managed Fishery (WA)	Considered relevant persons under Regulation 11A(1) (d)	The Operational Area is located in Zone A of Area 2 of the fishery, noting that the fishery primarily targets deeper waters in Zone B of Area 2 of the fishery (over 100 km north-west of the Operational Area). Based on a review of DPIRD FishCube data (**Section 3.8.1.2**) and consultation with WAFIC, the Operational Area overlaps with approximately 1.6% of the 10 nautical mile (nm) catch and effort system reporting blocks that have reported fishing effort during the 11-year period (2009-2019). The blocks overlapped have been fished by less than 3 vessels during the entire 11-year (2009-2019) period and during some years, no fishing has occurred.

Stakeholder	Relevant to Activity	Relevance/Reason for Engagement
		Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been infrequent.
Demersal Fishery (NT)	Considered relevant persons under Regulation 11A(1) (d)	Demersal fishing is allowed from 15 nm from the low water mark to the outer boundary of the Australian fishing zone, excluding the area of the Timor Reef Fishery (DPIR 2019). Only a small part of the Operational Area (comprising part of Area C and the surrounding Active Source Area and Operational Area) overlaps with the waters of NT-managed fisheries. Only three days of fishing by three licence holders was reported in the 60 nautical mile (nm) block overlapped by the Operational Area during the entire 5-year (2016-2020) period. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been relatively infrequent.
Offshore Net & Line Fishery (NT)	Considered relevant persons under Regulation 11A(1) (d)	The Offshore Net and Line Fishery is a quota managed fishery. Fishing is permitted from the low water mark to the outer boundary of the AFZ to the extent the waters are waters relevant to the Northern Territory (DPIR 2018). Most fishing is done in the coastal zone within 12 nautical miles (nm) of the coast. Only 2.5 days of fishing by three licence holders was reported in the 60 nautical mile (nm) block overlapped by the Operational Area during the entire 5-year (2016-2020) period. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been relatively infrequent.
Spanish Mackerel Fishery (NT)		Fishing is allowed from 15 nm from the highwater mark to the outer boundary of the AFZ but generally takes place around reefs, headlands and shoals. Analysis of 5 years of NT-DPIR fishing catch and effort data (2016-2020) shows that the Operational Area overlaps with approximately 1,700 km2 (0.44%) of the total area of fishing effort (i.e. 382,800 km2 for the period between 2016 and 2020). The 60 nautical mile (nm) block overlapped by the Operational Area was fished by four licence holders and for a total of 10.5 days during the entire 5-year (2016-2020) period. By comparison, the next fishing block located east of the Operational Area and in NT coastal waters was fished for 627 days. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been relatively infrequent.

Stakeholder	Relevant to Activity	Relevance/Reason for Engagement
Commercial Fisheries – Commonwealth-managed		
Northern Prawn Fishery (Commonwealth managed)	Considered relevant persons under Regulation 11A(1) (e)	The JBG comprises about 60,000 km^2 of the western portion of the NPF. The Operational Area overlaps with less than 1% of the total fishery. Fishing takes place in waters 35–70 m deep, with most fishing effort between 50 and 60 m. Water depths within the Acquisition Area range between 59 -103 m (generally outside of the main fishing depths). The fishery is known to fish at a low (<0.1 days/km2) to medium (0.1-0.25 days/km2) intensity within the JBG. The JBG fishery comprises less than 5% of the area of the NPF, however it contributes about 65% of the NPF's red-legged banana prawn catch and around 20% of the NPF's total banana prawn catch. The main fishing area in the JBG is understood to overlap with the Full Fold Acquisition Area B and Area C. Therefore, there is potential for interaction with the Petrel Sub-Basin SW 3D MSS.
Community-based Organisations		
Kimberley Land Council	Considered relevant persons under Regulation 11A(1) (e)	KLC is the peak Indigenous body in the Kimberley region and is considered relevant due to its involvement in the management of marine reserves.

4.3 Stakeholder Consultation

The approach to stakeholder consultation for this EP follows the process adopted by Santos for all its EPs. Some modifications to this approach have been made based on feedback from WAFIC, NTSC, 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 and email prior to providing the Petrel Sub-Basin 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 contained 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. The consultation package also 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 sourced data and in consultation with fisheries organisations, were provided the Petrel Sub-Basin 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package by email or 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 southern Bonaparte 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 five weeks to review consultation packs, although Santos accepted stakeholder feedback after this period.

4.4 Assessment of Stakeholder Objections and Claims

A summary of the stakeholder consultation undertaken for this EP, including Santos' assessment of all stakeholder comments received, is outlined in **Table 4-2**.

Full transcripts between Santos and stakeholders are provided in the *Petrel Sub-Basin 3D Marine Seismic Survey Environment Plan Sensitive Stakeholder Information Report* (7710-650-REP-0003) as a confidential submission to NOPSEMA.

Santos adopted the following process to address objections and claims received during the consultation process:

+ Santos acknowledged receipt of all comments made by stakeholders.
+ Santos assessed the merits of all objections and claims made by stakeholders. This included assessing all reasonably available options for resolving or mitigating the degree to which a stakeholder's functions, interests or activities may be affected. Control measures were proposed and adopted where reasonably practicable.
+ Santos responded to all stakeholder objections and claims, and advised the stakeholder how each of their objections and claims would be addressed in the EP.
+ Santos invited the stakeholder to provide additional feedback and comment.

- As soon as possible, or on publication of the EP on the NOPSEMA website, Santos advised relevant stakeholders listed in **Table 4-2** that the EP was available for public review and comment.
- A similar process was applied to information provided and requests made by stakeholders not deemed to be an objection or claim.

Santos recognises the importance of ensuring a high degree of transparency in how a titleholder manages ongoing stakeholder consultation during the life of a seismic survey. As such, should additional stakeholder comments be received to those described in **Table 4-2** then Santos will assess the comments using the above process and update the EP to document the assessment of additional objections or claims.

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

Santos

Table 4-2: Assessment of relevant identified stakeholders for the proposed Activity

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td colspan="3">Commonwealth departments/agencies</td></tr>
<tr><td rowspan="3">Australian Hydrographic Office (AHO)</td><td colspan="2">AHO was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
AHO was provided a follow-up email on 26 May 2021 inviting comment. No response has been received to date.
Santos will advise AHO when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
AHO notification requirements, as requested by AMSA and DoD (refer to below), are addressed in Section 8.13.
AHO has previously requested notification once any activities commence, as addressed in Section 8.13.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td>Australian Maritime Safety Authority (AMSA)</td><td colspan="2">AMSA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
AMSA responded on 10 May 2021 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. [REQUEST 001]
+ 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. [REQUEST 002]
+ To obtain a vessel traffic plot showing Automatic Identification System (AIS) traffic data for the area of interest, Santos should visit AMSA's spatial data gateway and portal to download digital data sets and maps. [INFORMATION 001]
Santos responded to AMSA on 11 May 2021 and addressed each of the matters raised in their correspondence of 10 May 2021 (refer assessment of stakeholder objections, claims, information and requests below).
AMSA was provided a reminder email on 26 May 2021 inviting any further comment.
Santos will advise AMSA when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.</td></tr>
</table>

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="5"></td><td colspan="2">Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>[REQUEST 001] Santos will notify AMSA’s JRCC at least 24–48 hours before operations commence for each survey and advise when operations start and end. Notification requirements are addressed in Table 8-4.</td><td>Santos responded to AMSA confirming this request would be taken into consideration in the drafting of the EP.</td></tr>
<tr><td>[REQUEST 002] Santos will notify the AHO no less than four working weeks before operations commence. Notification requirements are addressed in Table 8-3, CM-1 and in Table 8-4.</td><td>Santos responded to AMSA confirming this request would be taken into consideration in the drafting of the EP.</td></tr>
<tr><td>[INFORMATION 001] Santos notes the information provided on traffic data.</td><td>Santos responded to AMSA confirming this information would be taken into consideration in the drafting of the EP.</td></tr>
<tr><td>Department of Defence (DoD)</td><td colspan="2">DoD was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
DoD was provided a follow-up email on 26 May 2021 inviting comment.
DoD responded on 2 June 2021 advising that:
+ The survey area is within the North Australia Exercise Area (NAXA), Santos should inform itself as to the risks associated with conducting activities in the area and the Commonwealth took no responsibility in relation to unexploded ordnance that may be found [INFORMATION 001]
+ That a military exercise will be conducted in September 2022 and avoidance would be appreciated, however early advice of progress may enable compatible activities to be considered [REQUEST 001]
+ That updates and notifications should continue to be provided to DoD’s offshore petroleum email address [REQUEST 002]
+ That specific liaison should occur if military restricted airspace is activated [REQUEST 003]
+ That continued liaison should occur with the Australian Hydrographic Service [REQUEST 004]
Santos responded to DoD on 22 June 2021 and addressed each of the matters raised in their correspondence of 2 June 2021 (refer assessment of stakeholder objections, claims, information and requests below).
Santos will advise DoD when the Petrel Sub-Basin 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos’ Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	[INFORMATION 001] Santos is aware of the risks and responsibilities in conducting activities in the area and acknowledged the Department's position.	Santos responded to DOD confirming this information would be taken into consideration in the drafting of the EP.
	[REQUESTS 001 and 003] Santos advised it did not consider at this stage that any activity would be occurring during the identified exercise period but would ensure early notice is given as requested.	Santos responded to DOD confirming this information would be taken into consideration in the drafting of the EP.
	[REQUEST 002] Santos confirmed the required notifications and updates would continue to be provided to the Department	Santos responded to DOD confirming this information would be taken into consideration in the drafting of the EP.
	[REQUEST 001] Santos will notify the AHO no less than four working weeks before operations commence. Notification requirements are addressed in **Table 8-3**, CM-1 and in **Table 8-4**.	Santos responded to DOD confirming this information would be taken into consideration in the drafting of the EP.
Australian Fisheries Management Authority (AFMA)	AFMA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. AFMA was provided a follow-up email on 26 May 2021 inviting comment. AFMA responded on 4 June 2021 and advised that due to limited resources, it is unable to comment on individual proposals, however, it is 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**. [REQUEST 001]** Santos responded to AFMA on 11 June 2021 and addressed each of the matters raised in their correspondence of 4 June 2021 (refer assessment of stakeholder objections, claims, information and requests below). AFMA acknowledged Santos' response on 11 June 2021. Santos will advise AFMA when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td></td><td>[REQUEST 001]. Santos has consulted directly with relevant fishers and fishing industry associations as outlined in Table 4-1.</td><td>Santos responded to AFMA and advised of the consultation undertaken.</td></tr>
<tr><td rowspan="3">Department of Agriculture, Water and the Environment (DAWE) – Biosecurity (vessels, aircraft and personnel)</td><td colspan="2">DAWE was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
DAWE was provided a follow-up email on 26 May 2021 inviting comment.
DAWE responded on 7 June 2021 providing advice on the Australian Government's vessel movement requirements. [REQUEST 001] In summary, the department requested that Santos provide the following:
+ The names of the survey vessel and (up to) two support vessels for this survey.
+ If they survey area is within or outside the 12nM limit of Australian territorial seas
+ If the vessels are planned to be reported in MARS and biosecurity cleared to coastal before the survey begins.
DAWE also provided links to website sections for reference in understanding the biosecurity requirements for offshore (more than 12nM) installations and survey/research vessels. [INFORMATION 001]
Santos responded to DAWE on 30 June 2021 and addressed each of the matters raised in their correspondence of 7 June 2021 (refer assessment of stakeholder objections, claims, information and requests below).
Santos will advise DAWE when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>[REQUEST 001] Santos confirms that the survey area is wholly outside the 12nM limit of Australian territorial seas. Contracts for undertaking this survey have not been finalised and therefore names of the survey vessel and support vessels are not known at this stage. Once this information is confirmed Santos will ensure the Department is advised.
Santos confirms that if any of the vessels are sourced from outside Australia, the vessel master and shipping agents will comply with all requirements for seeking Australian biosecurity clearance, including pre-arrival and reporting prior to the survey commencement.
Santos will ensure the Department is kept informed of the progress of this EP and, once the EP has been accepted, the required notifications for this activity.</td><td>Santos responded to DAWE and provided the information requested.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	[INFORMATION 001] Santos has reviewed the department's webpage and confirms that all biosecurity requirements are understood and referenced in relevant commitments documented in the EP that will be submitted to NOPSEMA.	Santos responded to DAWE confirming this information would be taken into consideration in the drafting of the EP.
Department of Agriculture, Water and the Environment (DAWE) – Fisheries	The Department was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. The Department responded on 10 May 2021, noting the information and advising it would be in contact if it had any questions or comments. The department requested to be informed of future developments relating to the project **[REQUEST 001]**. It also requested that Santos communicate future developments with the Australian Fisheries Management Authority and the relevant fishing industry representation organisations in that region **[REQUEST 002].** Santos responded on 11 May 2021 and addressed each of the matters raised in their correspondence of 10 May 2021 (refer assessment of stakeholder objections, claims, information and requests below). Santos sent a follow-up email on 26 May 2021 inviting comment. Santos will advise DAWE when the Petrel Sub-Basin 3D MSS is available on the NOPSEMA Website for Public Comment. No further response received to date. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos has assessed the impact to fish and commercial fisheries in **Sections 6.1, 6.3 and 6.4.** Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	[REQUEST 001]. Santos will continue to keep the Department informed of future developments for this activity.	The Department's request will be incorporated in the drafting of the EP.
	[REQUEST 002]. Santos has consulted with AFMA and relevant fishing industry associations as outlined in **Table 4-1.**	Santos responded to the Department and advised of the consultation undertaken.
Department of Agriculture, Water and the Environment (DAWE) – Biosecurity (marine pests)	DAWE was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. Santos sent a follow-up email on 26 May 2021 inviting comment. No further response received to date. Management of invasive marine pest species is addressed in Section XX. Santos will advise DAWE when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.	

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td>Director of National Parks (DNP)</td><td colspan="2">DNP was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
DNP was provided a follow-up email on 26 May 2021 inviting comment.
DNP provided feedback on 1 July 2021 with the key points summarised as follows:
+ The proposed operational area is adjacent to the Oceanic Shoals Marine Park Multiple Use Zone (IUCN VI) (10 km north) and Joseph Bonaparte Gulf Marine Park (15 km south-east). Given the proximity of the proposed activity, we seek that the EP considers the potential impact upon the values of these marine parks. To take into account Australian marine parks, titleholders are expected to consider the impacts and risks of activities in the context of the management plan objectives and values, including the representativeness of the relevant values and the activity footprint on the representative area of the Australian marine park. Specific values for the Oceanic Shoals Marine Park and Joseph Bonaparte Gulf Marine were provided. [INFORMATION 001]
+ You should ensure that the EP [REQUEST 001]:
– 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.
– Clearly demonstrates that the activity will not be inconsistent with the management plan.
+ Further mitigation should be applied to avoiding impacts upon Flatback, Green and Olive Ridley species of turtles that forage throughout the operation area. [REQUEST 002] This may include, but not limited to:
– The use of low power and shut down zones
– Timing of the activity
– Adaptive management measures including limits to operations upon consecutive shutdowns as a result of sighting turtles, including prohibiting operations at night-time or low visibility conditions.
+ To ensure the cultural values are protected we are seeking that [REQUEST 003]:
– The Miriuwung, Gajerrong, Doolboong, Wardenybeng and Gija and Balangarra are consulted as they have responsibility for sea country in the JBG Marine Park. They are represented by the following Prescribed Body Corporates: Miriuwung and Gajerrong Aboriginal Corporation, and Balanggarra Aboriginal Corporation.</td></tr>
</table>

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td></td><td colspan="2">
– The Northern Land Council and the Kimberley Land Council are consulted are the Native Title Representative Bodies for the Northern Territory's northern region, and the Kimberley region in relation to the Oceanic Shoals Marine Park.
+ The proposed operational area overlaps the Sahul Shelf which is an identified key ecological feature and value for both Marine Parks. The Sahul Shelf is regionally important because of their role in enhancing biodiversity and local productivity relative to their surrounds. The EP should address the impacts and risks to the ecological values of the Sahul Shelf, particularly the impact of seismic activity upon the benthic communities and marine species that rely on this key ecological feature. This could include monitoring activities to measure effects on the Sahul Shelf and associated marine species before, during and after seismic surveys to assess the effectiveness of mitigation measures on protecting these values and could include monitoring the abundance, diversity and behaviour of key species and habitat. [REQUEST 004]
+ 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 process and content requirements were provided. [REQUEST 005]
+ The DNP also requests notification to marineparks@awe.gov.au if the EP is approved by NOPSEMA. [REQUEST 006]
Santos responded on 9 July 2021 and addressed each of the matters raised in their correspondence of 1 July 2021 (refer assessment of stakeholder objections, claims, information and requests below).
Santos will advise DNP when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.
</td></tr>
<tr><td></td><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td></td><td>[INFORMATION 001] The Petrel Sub-Basin SW 3D MSS will not take place in any zone of any Australian Marine Park (AMP) and, therefore, the activity is not subject to the zone prescriptions of the Marine Park Network. At its closest points, the Operational Area is located 10 km from the Oceanic Shoals AMP (Multiple Use Zone) and 12 km from the JBG AMP (Special Purpose Zone). The Active Source Zones (where the seismic source will routinely be discharged for the purpose of the acquisition), at their closest points, are located 18 km from the Oceanic Shoals AMP (Multiple Use Zone) and 23 km from the JBG AMP (Special Purpose Zone).</td><td>Santos responded to DNP confirming this information would be taken into consideration in the drafting of the EP.</td></tr>
<tr><td></td><td>[REQUEST 001] The EP has considered the potential impacts on the values of the AMPs, specifically with respect to underwater noise emissions and potential impacts in the unlikely event of a hydrocarbon (marine diesel) spill. In the context of the management plan, the Petrel Sub-Basin SW 3D MSS is expected to be undertaken in a manner that is consistent with the objectives of the management plan.
The potential impacts from underwater noise emissions to the values of the Oceanic Shoals and Joseph Bonaparte Gulf AMPS are summarised below.</td><td>Santos responded to DNP confirming this information would be taken into consideration in the drafting of the EP.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Received sound levels at both AMPs are predicted to be approximately 140 dB re 1 µPa SPL at times when the seismic source operates at a point within the Active Source Zones closest to the AMP. For the majority of the survey, when the seismic vessel and seismic source will be transiting at greater distances from the AMPs, the received sound levels will be less. These received sound levels are below any threshold for physical or significant behavioural impacts for any marine fauna. The potential impacts to the values of the Oceanic Shoals AMP are summarised as follows. **Marine ecosystems and Key Ecological Features (KEFs):** The AMP includes examples of ecosystems representative of the Northwest Shelf Transition. KEFs recognised as values of the AMP that are also located within the Operational Area are: + Carbonate bank and terrace system of the Sahul Shelf—an area characterised by terraces, banks, channels and valleys, supporting sponges, soft corals, sessile filter feeders, polychaetes and ascidians. + Pinnacles of the Bonaparte Basin—an area that contains the largest concentration of pinnacles along the Australian margin, where local upwellings of nutrient-rich water attract aggregations of fish, seabirds and turtles. The EP has assessed potential impacts of seismic sound emissions on the benthic habitats and communities within the KEFs, as well as plankton, fish communities and other marine fauna. The Petrel Sub-Basin SW 3D MSS does not overlap with either of the KEFs within the boundaries of the AMP and, as such, no impacts to the KEF within the AMP are expected. Outside of the AMP, the Active Source Zones for the survey have limited overlap with either KEF (1.5% of the carbonate bank and terrace system of the Sahul Shelf and 1.2% of the pinnacles of the Bonaparte Basin). The survey primarily occurs over featureless shelf and basin features and soft-sediment habitats. Carbonate banks in the KEF that rise to within 45 m water depth support the greatest biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans. The carbonate banks located within the Operational Area rise to approximately 62 m water depth and pinnacles located within the Operational Area rise to approximately 82 m water depth. At these greater depths, there is limited potential for extensive coverage of photosynthetic organisms such as hard corals to occur, although sponges, soft octocorals and filter-feeders may still be present at these depths. The habitat structure and condition of the carbonate bank and terrace system of the Sahul Shelf KEF and pinnacles of the Bonaparte Basin KEF will not be impacted. No impacts will occur to soft corals, sponges or filter-feeders. While a range of effects to some benthic invertebrate organisms such as crabs, molluscs and echinoderms (including sub-lethal effects and chronic mortality in	

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	some organisms) may occur in close proximity to the operating seismic source, changes to these communities are unlikely to be discernible from natural variation. Impacts to the fish communities associated with carbonate banks and pinnacles are primarily expected to be behavioural and temporary. Impacts to zooplankton will be localised and limited to tens of metres from the seismic source; no long-term impacts to plankton communities or fauna dependent on plankton as a food or recruitment source are predicted. Therefore, the ecological function and values of these KEFs will not be impacted. **EPBC Act listed species – Biologically important areas (BIAs) for foraging and inter-nesting habitat for marine turtles:** No seismic acquisition will occur near the defined Tiwi Islands turtle inter-nesting BIAs within the Oceanic Shoal AMP, therefore, inter-nesting turtles will not be disturbed in the AMP. The potential for behavioural effects to marine turtles is predicted to extend up to 5 km from the seismic source. As the Active Source Zones are located approximately 18 km from the AMP, no impacts to turtles within the AMP are predicted. The survey overlaps the Sahul Shelf where BIAs are defined for foraging marine turtles. Given the water depths of the Active Source Zones range from 45 m to 105 m, and the predominantly soft sediment environment, the area overlapped by the survey may not represent significant foraging habitat compared with other shallower and more productive areas of the Sahul Shelf. Marine turtle bycatch by fisheries in this region also suggest that turtles are more abundant in water depths less than 30 m, while relatively few turtles occur in water deeper than 40 m. Despite this, Santos has proposed mitigation for marine turtles, including shutdown zones. Given the transient nature of both foraging marine turtles and the seismic vessel, impacts to foraging turtles may include short-term disturbances, however, no long term or population level impacts are predicted. **Cultural, heritage, social and economic values:** The main commercial fishery operating in the same waters as the Petrel Sub-Basin SW 3D MSS is the Northern Prawn Fishery. The survey is planned to occur at a time that avoids the Northern Prawn Fishery fishing operations, and no impacts to prawn stocks are predicted. Sea country and other cultural values associated with the marine park are not expected to be affected by underwater sound emissions. No disturbance to traditional fisheries or other traditional practices will occur within the AMP. The potential impacts to the values of the Joseph Bonaparte Gulf AMP are summarised as follows. **Marine ecosystems and Key Ecological Features (KEFs):**	

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	The AMP includes examples of ecosystems representative of the Northwest Shelf Transition. The carbonate bank and terrace system of the Sahul Shelf KEF is recognised as values of the AMP and is also overlapped by the survey. The Petrel Sub-Basin SW 3D MSS does not overlap with either of the KEFs the KEF within the boundaries of the AMP and, as such, no impacts to the KEF within the AMP are expected. As summarised above for the Oceanic Shoals AMP, impacts within the KEF (outside of the AMP) will be limited and the ecological function and values of the KEF will not be impacted. The potential for behavioural effects to marine turtles is predicted to extend up to 5 km from the seismic source. As the Active Source Zones are located approximately 23 km from the AMP, no impacts to turtles within the AMP are predicted. No seismic acquisition will occur within the defined inter-nesting BIA or the habitat critical for flatback turtles at Cape Domett, consistent with recommendations in the Recovery Plan for Marine Turtles in Australia. The habitat critical area is 24 km from the Operational Area and, therefore, inter-nesting turtles will not be disturbed. It is also noted that turtles may nest year-round, with peak nesting activity occurring between July and September. Therefore, the revised timing of the survey (1 December to 31 March) avoids the period when peak nesting occurs in the region. As summarised above for the Oceanic Shoals AMP, impacts to foraging turtles may include short-term disturbances to transient individuals, however, no long term or population level impacts are predicted. **EPBC Act listed species – Biologically important areas (BIAs) including Australian snubfin dolphin:** The potential for significant behavioural effects to cetaceans is predicted to extend up to approximately 8.5 km from the seismic source. As the Active Source Zones are are located approximately 23 km from the AMP, no impacts to snubfin dolphins within the AMP are predicted. The received levels in the Australian snubfin dolphin BIA outside of the AMP, at its closest point near Cape Londonderry, are predicted to be approximately 130 dB re 1 µPa SPL from the closest modelling site. Distant pulses of sound may be audible to dolphins in the BIA when the seismic source is operating in the western part of the Operational Area but behavioural responses are not expected to be significant. **Cultural, heritage, social and economic values:** As noted above for the Oceanic Shoals AMP.	

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	[REQUEST 002] Consistent with EPBC Policy Statement 2.1, Santos will implement all management measures outlined in Part A of the policy statement, including the following management zones for cetaceans (including dolphins, as well as whales): + 3 km+ observation zone + 2 km low-power zone + 500 m shut down zone Pre-start observations and soft-start procedures will be implemented. Two MFOs will be on board the seismic vessel. At least one MFO will have a minimum of 12 months experience on a seismic survey vessel as an MFO in Australian waters. In addition to the standard measures for whales, Santos will also implement shutdown procedures for marine turtles, including a 250 m shutdown zone around the seismic source. This shutdown zone is considered to be conservative given that the potential for physical effects to turtles are predicted to be limited to 20 m from the seismic source. Visual observations for turtles at distances greater than 250 m from the seismic source (which itself is towed a distance behind the vessel) become impracticable. Noting that the flatback turtle BIA associated with the Cape Domett stock is the closest and most relevant to the Petrel Sub-Basin SW 3D MSS, the revised timing of the Petrel Sub-Basin SW 3D MSS (December to March) avoids the peak flatback turtle nesting and inter-nesting period (July to September). No further timing controls are applied to the survey with respect to turtles given foraging, nesting and inter-nesting occur throughout the year. The Operational Area also excludes the inter-nesting BIA and habitat critical for flatback turtles. Additonal adaptive management (e.g. extended shut down zones and additonal night-time or low visibility procedures) were considered but not deemed practicable on the basis that: + The potential for permanent threshold shift (PTS) or temporary threshold shift (TTS) is predicted to be limited only to turtles exposed within 20 m (i.e. the seismic airgun array itself) Behavioural disturbances are expected to be short-term given the transient nature of the survey vessel and marine turtles.	Santos responded to DNP confirming this information and request would be taken into consideration in the drafting of the EP
	[REQUEST 003] Santos confirms that attempts to have been made to consult with the representative bodies and prescribed body corporates. The Kimberley Land Council and/or Northern Land Council are relevant stakeholders for all Santos' offshore activities offshore Northern Australia. For this specific activity, the Miriuwung and Gajerrong Aboriginal Corporation	Santos responded to DNP advising of the consultation efforts undertaken and confirming this information and request would be taken into consideration in the drafting of the EP.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	and Balanggarra Aboriginal Corporation were not initially contacted with information and opportunity to consult but have been post the DNP's request. Responses have not been received to date from any of the organisations but Santos will continue attempts and ensure they are aware of the further opportunity afforded during the formal public comment period.	
	[REQUEST 004] The suggestion of monitoring to measure effects on the Sahul Shelf and associated marine species before, during and after seismic surveys is noted. Santos is open to research opportunities relating to potential impacts from its activities and where there is a data gap. However, baseline monitoring and monitoring during and after the survey will not be undertaken, given that: + Impacts to the Sahul Shelf habitats and ecological communities are expected to be limited, and the ecological function and values of the KEF will not be impacted + The Petrel Sub-Basin SW 3D MSS will not be undertaken within an AMP and no significant impacts are predicted within the AMPs or to AMP values more widely.	Santos responded to DNP confirming this information and request had been taken into consideration in the drafting of the EP and advising of the reasons for not including the requested monitoring.
	[REQUEST 005] Santos can confirm that notification details (in the event of a marine pollution incident that may impact on a marine park) are included in the EP, as well as the accompanying Oil Pollution Emergency Plan (OPEP). Santos acknowledges that DNP may request daily or weekly Situation Reports, depending on the scale and severity of the pollution incident.	Santos responded to DNP confirming this information and request would be taken into consideration in the drafting of the EP
	[REQUEST 006] Santos will notify the DNP if the EP is approved by NOPSEMA. As the activity will not occur in an AMP, we understand that the DNP will not require notification of the commencement or cessation of this activity.	Santos responded to DNP confirming this information and request would be taken into consideration in the drafting of the EP
State/Territory Government Departments		
WA Department of Transport (DoT)	DoT was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. DoT responded on 18 May 2021 advising: + If there is a risk of a spill impacting State waters from the activity, please ensure that the department is consulted as outlined in the Department of Transport Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (July 2020). **[REQUEST 001]** Santos responded to the Department on 19 May 2021 and addressed each of the matters raised in their correspondence of 18 May 2021 (refer assessment of stakeholder objections, claims, information and requests below). DoT was provided a follow-up email on 26 May 2021 inviting comment. DoT acknowledged Santos' advice on 1 June 2021. Santos will provide DoT with a copy of the Petrel Sub-Basin 3D Marine Seismic Survey OPEP.	

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">Santos will advise DoT when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>[REQUEST 001] Santos will provide DoT a copy of the Petrel Sub-Basin 3D Marine Seismic Survey OPEP, and a copy of the Petrel Sub-Basin 3D Marine Seismic Survey OPEP DoT Consultation Package.</td><td>Santos responded to DoT and acknowledged their request.</td></tr>
<tr><td rowspan="3">WA Department of Primary Industries & Regional Development (DPIRD)</td><td colspan="2">DPIRD was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
DPIRD was provided a reminder email on 26 May 2021 inviting comment. No response has been received to date.
Santos will advise DPIRD when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>In the absence of a specific response, Santos has taken DPIRD's previous general advice on MSS into consideration in the drafting of the EP.</td><td>No response required.</td></tr>
<tr><td>WA Department of Biodiversity and Conservation Attractions (DBCA)</td><td colspan="2">DBCA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
DBCA responded on 24 May 2021 with the following information and comments:
+ The proposed seismic survey is located in proximity to State waters and the North Kimberley Marine Park which is managed by DBCA under the Conservation and Land Management Act 1984 (CALM Act). These areas provide habitat for marine fauna species, including conservation significant species listed under the Biodiversity Conservation Act 2016 (BC Act). [INFORMATION 001]
+ The surveys have the potential to impact marine fauna, including potential behavioural alterations and/or physical injury depending on proximity and transmission of the noise source and species-specific sound reception characteristics. In particular, large marine fauna such as cetaceans and marine turtles may be sensitive to underwater noise and are likely to be present in the vicinity of the proposed activities. [CLAIM 001]</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))
	+ It is recommended that Santos undertake a risk assessment to determine the likelihood of potential impacts on marine fauna species which are likely to occur within the survey area, accounting for the scale and biological significance of the noise to be produced. Management of the operations should then be commensurate with the level of risk associated with the activities. **[REQUEST 001]** + Based on DBCA's understanding, best practice management of any significant underwater noise with the potential to impact marine fauna should include the following: + Underwater noise modelling to determine the horizontal and vertical range of the noise and consequently the range of potential impact. Based on current scientific information from published literature, noise impact thresholds for particular species or categories of marine fauna can be established and used in conjunction with the noise modelling results to determine appropriate management zones**. [REQUEST 002]** + Management zones may be based on the likelihood of a behavioural response, physical harm including Temporary Threshold Shift and / or Permanent Threshold Shift for particular species or categories of marine fauna over the range of the noise. Management zones may involve observation zones, low power zones and shut-down zones where relevant marine fauna are observed to enter within the range of potential impact determined for a particular species or category of marine fauna. Pre start-up visual observation and acoustic monitoring to detect fauna beneath the surface, soft-start procedures and stop-work procedures should be standard practice. **[REQUEST 003]** + Operations should be managed such that qualified Marine Fauna Observers (MFOs) are stationed on the vessel at all times and provide early warning of relevant marine fauna entering a management zone to initiate an appropriate management response. **[REQUEST 004]** + Further information on best practice underwater noise management can be found in EPBC Act Policy Statement 2.1 – Interactions between offshore seismic exploration and whales, noting however that this information is specific to interactions between seismic activities and whales and therefore additional information for other marine fauna species is likely to be required. **[INFORMATION 002]** + If operations are to be undertaken at night (i.e. with start-up after daylight hours), acoustic monitoring is recommended as visual observations are likely to be ineffective. Overnight operations also require consideration of artificial light and vessel strike as part of a holistic management approach. DBCA recommends that vessel lighting is designed to align with the standards of the National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (DoEE 2020) as far as practicable. **[REQUEST 005]** + DBCA also requested Santos continue to provide all future notifications to EMBAdmin@dbca.wa.gov.au. **[REQUEST 006]** DBCA was provided a reminder email on 26 May 2021 inviting comment. Santos responded to DBCA on 9 June 2021 and addressed each of the matters raised in their correspondence of 24 May 2021 (refer assessment of stakeholder objections, claims, information and requests below). Santos will advise DBCA when the Petrel Sub-Basin 3D MSS is available on the NOPSEMA Website for Public Comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	[INFORMATION 001] Santos notes DBCA response.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
	[INFORMATION 002] Santos notes DBCA response.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
	[CLAIM 001] Santos acknowledges that seismic surveys have the potential to impact marine fauna as stated by the Department.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
	[REQUEST 001] The EP includes a comprehensive risk assessment of the underwater sound levels that will be produced and the potential physical and behavioural effects to marine fauna, including cetaceans and marine turtles. The risk assessment includes an assessment of management measures that are appropriate to reduce the level of risk to marine fauna to as low as reasonably practicable and to an acceptable level.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
	[REQUEST 002] Underwater noise modelling has been completed for this project by acoustic specialists, JASCO Applied Sciences. The modelling examines the potential effects of underwater sound to different marine fauna groups based on single impulses, as well as accumulated sound exposure levels over time. The modelling references internationally recognised thresholds for physical and behavioural effects based on the best available science	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
	[REQUEST 003] Consistent with EPBC Policy Statement 2.1, Santos will implement all management measures outlined in Part A of the policy statement, including the following management zones for cetaceans (including dolphins, as well as whales): + 3 km+ observation zone + 2 km low-power zone + 500 m shut down zone In addition, Santos is proposing to implement shutdown procedures for marine turtles, including a 250 m shutdown zone around the seismic source. This shutdown zone is considered to be	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	conservative given that the potential for physical effects to turtles, such as TTS, are predicted to be limited to 20 m from the seismic source.	
	[REQUEST 004] Santos can confirm that two MFOs will be on board the seismic vessel. At least one MFO will have a minimum of 12 months experience on a seismic survey vessel as an MFO in Australian waters.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
	[REQUEST 005] Consistent with Part A of EPBC Policy Statement 2.1, Santos will implement night-time and low visibility procedures to manage start-up of the seismic source after daylight hours. The option of Passive Acoustic Monitoring (PAM) was assessed and is not considered to be a practicable option for this particular survey. There are no known aggregation areas for foraging, breeding, calving or resting habitat for cetaceans within or in close proximity to the Operational Area. The key cetacean species identified in the region include Australian snubfin dolphin and Australian humpback dolphin whose distribution is restricted to shallow coastal and estuarine waters. The Active Source Zones for the survey are located over 30 km offshore from coastal waters and a BIA designated for Australian snubfin dolphins. The effectiveness of PAM on board seismic vessels can be limited more by noise interference from the vessel and seismic impulses. Although PAM can be used to supplement visual observations made by the MFO, the method is dependent upon animals vocalising, which is not always the case if animals are disturbed. It can also be difficult to detect the distance and direction of cetaceans to enable implementation of precaution zones. Given that the Operational Area is not significant for cetaceans, and the limited detections expected from the use of PAM, the cost of this option is considered to outweigh the limited potential for any further reduction to an already low level of risk to cetaceans. National Light Pollution Guidelines for Wildlife were considered during the assessment. The potential impacts of light emissions to marine fauna, including shorebirds and turtles is considered to be minimal due to the continual movement of the vessels and distance from shorelines. The seismic vessel will be moving steadily at a low speed of approximately 4.5 knots, which is below speeds typically associated with significant marine fauna injury or mortality. Some level of avoidance of the vessel by marine fauna is also possible given the underwater sound emissions during the survey. Santos has a Santos Protected Marine Fauna Interaction and Sighting Procedure, which ensures compliance with Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	[REQUEST 006]] Santos will ensure all required notifications are provided to the Department.	Santos responded to DBCA and acknowledged their comments which have been considered in the drafting of this EP.
WA Department of Mines, Industry Regulation and Safety (DMIRS)	DMIRS was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. DMIRS was provided a reminder email on 26 May 2021 inviting comment. DMIRS responded on 8 June 2021 as follows: + 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. **[INFORMATION 001]** + Requested Santos continue to send commencement and cessation notifications to DMIRS. **[REQUEST 001**] Santos responded to DMIRS on 9 June 2021 and addressed each of the matters raised in their correspondence of 8 June 2021 (refer assessment of stakeholder objections, claims, information and requests below). Santos will advise DMIRS when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	[INFORMATION 001] Noted by Santos.	Santos responded to DMIRS and acknowledged this information.
	[REQUEST 001] Santos has addressed the department's notification requirements in **Table 8-4.**	Santos responded to DMIRS and acknowledged their request.
NT Department of Industry, Tourism and Trade (DITT) – Fisheries Division	DITT (Fisheries) was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. DITT was provided a reminder email on 26 May 2021 inviting comment. Santos will advise DITT when the Petrel Sub-Basin 3D MSS is available on the NOPSEMA Website for Public Comment. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No Assessment required.	No response required.
NT Department of Industry, Tourism and Trade (DITT) – Energy Division	DITT (Energy) was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. DITT was provided a reminder email on 26 May 2021 inviting comment. Santos will advise DITT when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No Assessment required.	No response required.
Pilbara Ports Authority	Pilbara Ports Authority was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. The Authority was provided a reminder email on 26 May 2021 inviting comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos will advise the Authority when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No Assessment required.	No response required.
Darwin Port Corporation	The Corporation was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. The Corporation was provided a reminder email on 26 May 2021 inviting comment. Santos will advise the Corporation when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No Assessment required.	No response required.
Other stakeholders		
Kimberley Land Council (KLC) **Northern Land Council (NLC)**	Both the KLC and NLC were provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. The KLC was provided advice re the consultation package via its online inquiry portal and a follow-up phone call made by Santos on 10 May 2021. The Councils were provided a reminder email on 26 May 2021 inviting comment. No responses have been received to date. Following a request from the Director of National Parks, two other organisations affiliated to the KLC - Miriuwung and Gajerrong Aboriginal Corporation and Balanggarra Aboriginal Corporation - were also provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 5 July 2021 inviting comment. Santos will advise all four organisations when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No assessment required.	No response required.
Marine Tourism WA	MTWA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment. MTWA was provided a reminder email on 26 May 2021 inviting comment. No response has been received. Santos will advise MTWA when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests
	No assessment required.	No assessment required.

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td colspan="3">Other operators</td></tr>
<tr><td rowspan="3">Woodside</td><td colspan="2">Woodside was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
Woodside was provided a reminder email on 26 May 2021 inviting comment.
Woodside requested shape files of the proposed seismic area on 28 May 2021 [REQUEST 001] which were provided by Santos on 2 June 2021.
Woodside made the following inquiries on 22 June 2021:
+ Will any data be recorded within WA-522-P?
+ Whether an Ingress Agreement will be forthcoming given the vessel will be manoeuvring within WA-522-P for reasons related to petroleum exploitation?
Santos will advise Woodside when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td></tr>
<tr><td>[REQUEST 001] Information was provided with no assessment required.</td><td>No further response required.</td></tr>
<tr><td rowspan="3">Other O&G companies:
Eni Australia
Inpex
Finnis Offshore Exploration Pty Ltd
MEO International P/L
Neptune Energy Bonaparte Pty Ltd
Octanex Bonaparte Pty Ltd</td><td colspan="2">Santos provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 7 May 2021 inviting comment.
Santos provided a reminder email on 26 May 2021 inviting comment.
ENI Australia replied on 26 May 2021 requesting that consultation requests be sent to the engineering manager (brett.gillespie@eni.com).
Santos will advise the companies when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))
Fishing bodies	
Western Australian Fishing Industry Council (WAFIC)	WAFIC was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package including additional information for commercial fishers via email on 7 May 2021 inviting comment. WAFIC was provided a reminder email on 26 May 2021 inviting comment. WAFIC responded on 16 June 2021 and provided the following feedback: As published in the Risk Assessment on the potential impacts of seismic surveys on marine finfish and invertebrates undertaken by the Department of Primary Industries and Regional Development, the proposed seismic survey with a water depth ranging between 59 m-103 m and an air gun array volume of 3500 in^3 has the following risks **[INFORMATION 001]:** + Mobile invertebrates – Moderate to High + Immobile invertebrates – Severe to High + Finfish demersal – High + Pelagic – Negligible Santos responsed to WAFIC on 17 June 2021. Commercial fishers have advised WAFIC that they are encountering a significant change in catchability of mackerel species following seismic survey activity, so fish behaviour and distribution are changing which is having a direct impact on the economic viability of commercial fishers and potential fish stocks for those species. There is an opportunity for further research into this indirect impact to fully understand the effect. **[CLAIM 001]** Based on the risks above, assessment of the impacts at the population level for key species should be undertaken and included in the EP. Risk mitigation and risk control measures should be implemented to ensure all impacts are managed and detailed evidence-based analysis has considered the timing of the survey to minimise impacts to commercial fishing operations and the ecological impacts to fish species both during and post survey. **[REQUEST 001]** Santos responded to WAFIC on **9** July 2021 and addressed each of the matters raised in their correspondence of 17 June 2021 (refer assessment of stakeholder objections, claims, information and requests below). Santos will advise the companies when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future. As a key commercial fishing sector stakeholder, consultation with WAFIC will be ongoing for this and other Santos' activities. **WAFIC Fee for Service**

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">Santos requested WAFIC Fee for Service to assist with consultation with commercial fishers for the Petrel Sub-Basin SW 3D MSS.
Draft consultation material was provided for WAFIC review on 3 May 2021. WAFIC provided comments on the draft material on 6 May 2021 requesting clarification on recreational fishing rules, application of safety zones and the consultation process.
Santos responded on 6 May 2021 as follows:
+ Recreational fishing will not be allowed to occur on any of the vessels involved in the survey.
+ The 3 nm reference is to a safety zone that we request mariners respect around the seismic vessel and its streamers, so not additional area around the support vessels.
+ Specific discussion on the timing for activity in Area A in the event it had to be done outside the October to March window would be covered in the ongoing consultation section of the submitted EP.
WAFIC sent the agreed consultation material to relevant fishers on behalf of Santos on 7 May 2021.
WAFIC will forward the Public Comment notification to relevant fishers.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>[INFORMATION 001] Santos has referenced DPIRD Fisheries Research Report No. 288: Risk Assessment of the Potential Impacts of Seismic Air Gun Surveys on Marine Finfish and Invertebrates in Western Australia (Webster et al. 2018) in the Petrel Sub-Basin SW 3D MSS EP, including the risk rankings assigned to invertebrates, demersal and pelagic finfish. Santos notes that the DPIRD risk assessment was undertaken at the level of individual adult finfish and invertebrate organisms and assumed that an individual organism remains stationary (i.e. does not flee) while positioned directly in the path of the seismic source. Therefore, the WA DPIRD risk assessment represents a conservative scenario that is not necessarily representative of real-life exposures to invertebrates or finfish. Santos has considered additional activity-specific and situation-specific context to assess potential risks to populations. With regards to mobile demersal and pelagic finfish, in particular, we note that these individuals are likely to exhibit some level of avoidance response and there is limited potential for any mortality or injury to fish species targeted by WA fisheries. This is consistent with a significant body of research that has looked at the effects of seismic exposure to both captive and free-swimming demersal and pelagic fish species. Therefore, temporary behavioural responses and potential changes in distribution have been a focus of the impact assessment, including potential impacts to commercial fish stocks.
The assessment of impacts to the spawning and recruitment of commercial fish stocks is based on spawning information, distributions and core depth ranges provided by DPIRD. A spatial-</td><td>Santos responded to WAFIC noting this information.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	temporal analysis has been conducted to determine the overlap between the survey and the principal spawning ranges and periods of key commercial indicator species for the relevant fisheries, specifically goldband snapper and red emperor (indicator species for the Northern Demersal Scalefish Managed Fishery; NDSMF) and Spanish mackerel (indicator species for the Mackerel Managed Fishery; MMF). Based on a representative "racetrack" 3D acquisition plan and the full 100-day duration of the survey overlapping each species' spawning period, the spatial-temporal overlaps within the Kimberley fisheries management unit represent potential disturbance to the following percentages of the stocks: + Goldband snapper: 0.19% + Red emperor: 0.08% + Spanish mackerel: 0.03% In the context of the large natural variability in spawning biomass and recruitment, the potential for disturbance to approximately 0.19% or less of the spawning biomass of each species in the Kimberley management unit is expected to have a negligible effect and no discernible population level impacts are expected. Further detail will be available in the EP, but this provides an indication of the limited impacts we predict at the population (stock) level. Santos acknowledges the potential impacts of this activity on the fisheries, fish habitat and commercial fishers as detailed in **Sections 6.1, 6.3 and 6.4**. Santos has made commitments to minimise interference with commercial fishers (**Section 6.1.3**), minimise potential impacts to fishery resources (**Section 6.2.4**) and mitigate temporary commercial loses should they arise (**Section 8.6.2**).	
	[CLAIM 001] Spanish mackerel do not possess swim bladders and are therefore a species of fish that has a relatively limited ability to detect changes in sound pressure, although Santos notes in the EP that as a pelagic species an avoidance response and change in distribution is likely to occur. However, such effects are expected to be short term. Santos notes your suggestion that this is a potential area of future research. Santos contributes a significant amount to research in areas where we conduct our activities in Australia. Santos partnered with the Commonwealth Government's Australian Institute of Marine Science (AIMS) and committed funding to the recent North West Shoals to Shore Research Program. Santos is open to new opportunities for research where there is a data gap relevant to our activities and notes mackerel as being a potential future research topic. Santos acknowledges the potential impacts of this activity on the fisheries, fish habitat and commercial fishers as detailed in **Sections 6.1, 6.3 and 6.4**.	Santos responded to WAFIC and acknowledged their response.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Santos has made commitments to minimise interference with commercial fishers (**Section 6.1.3**), minimise potential impacts to fishery resources (**Section 6.2.4**) and mitigate temporary commercial loses should they arise (**Section 8.6.2**).	
	[REQUEST 001] In terms of potential interactions with commercial fishing operations, Santos notes the following: + The main fishery operating in the Joseph Bonaparte Gulf is the Commonwealth-managed Northern Prawn Fishery. Santos has consulted extensively with the fishery and has recently agreed to limit the timing of the survey such that the full survey (i.e. Areas A, B and C) will now occur either between 1 December 2021 and 31 March 2022 or between 1 December 2022 and 31 March 2023. This is to avoid interaction with the NPF's fishing activities in the western Joseph Bonaparte Gulf. + Review of DPIRD fishery catch and effort data for the period 2009-2019 identified two WA fisheries with previous fishing effort overlapped by the Petrel Sub-Basin SW 3D MSS Operational Area, the NDSMF and the MMF. – The 10 nautical mile (nm) blocks overlapped by the Operational Area fished by the NDSMF have been fished by less than three vessels during the entire 11-year (2009-2019) period and during many of these years, no fishing in the Operational Area has taken place at all. More productive and viable areas for this fishery (i.e. fished consistently throughout each year are located over 150 km north-west of the Operational Area. – Of the two 10 nm blocks in the Operational Area fished by the MMF between 2009 and 2019, one block was only fished during four of the 11 years and the other bock was only fished during one year. Waters further west form the Operational Area are fished more frequently. Therefore, historical MMF fishing effort in the Operational Area has been infrequent. In addition, fishing effort within the MMF primarily takes place between May and November. The intended December to March timing of the survey avoids this period. + Given that the NDSMF and MMF fish in the area very infrequently, there is very limited potential for interaction with WA commercial fishing operations. Consequently, no further changes to survey timing are proposed to reduce impacts to these commercial fishing operations.	Santos responded to WAFIC and acknowledged their response.
Northern Territory Seafood Council (NTSC)	NTSC was provided the Petrel Sub-Basin 3D MSS Stakeholder Consultation package including additional information for commercial fishers via email on 7 May 2021 inviting comment.	

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">On 7 May 2021 NTSC requested an alteration to the Operational Area map that had been provided to show the WA/NT maritime boundary. [REQUEST 001]. This was provided by Santos on the same day.
NTSC advised that the request for feedback would be included in an NTSC business update to licence-holders with email addresses.
NTSC licence-holders in the relevant fisheries were also provided the consultation package via post on 10 May 2021, as requested by NTSC.
NTSC was provided a reminder email on 26 May 2021 inviting comment.
On 10 June NTSC verbally advised Santos that it would not be providing any formal comment on the consultation package.
Santos will advise the NTSC when the Petrel Sub-Basin 3D MSS is available on the NOPSEMA Website for Public Comment.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.
As a key commercial fishing sector stakeholder, consultation with NTSC will be ongoing for this and other Santos' activities.
All fisheries are described in Section 3.8.1, and potential impact to fisheries, fish habitat and commercial fishers are discussed in Sections 6.1, 6.3 and 6.4.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td>Northern Prawn Fishery Pty Ltd</td><td colspan="2">NPF was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package including additional information for commercial fishers via email on 7 May 2021 inviting comment. NPF has previously advised that it provides the information to licence-holders.
NPF replied on 10 May 2021 acknowledging receipt of information, informing that they would be providing comments and requesting to be provided shapefiles for Areas A, B and C.
NPF was provided a reminder email on 26 May 2021 inviting comment.
A meeting was held between Santos and representatives of the NPF on 3 June 2021 and NPF advised it would provide a written response on behalf of all licence-holders.
NPF responded on 11 June 2021 advising it was extremely concerned with the proposal and raising the following issues:
+ NPFI has investigated fishing activity and can confirm that the survey will occur through very productive fishing grounds for the NPF fleet [INFORMATION 001]
+ Interactions with Threatened, Endangered and Protected (TEP) species occur in the area of the proposed seismic survey and these areas are inhabited by endangered sawfish species. When they do so, depends on their life stage. Sawfish have been recorded by NPF operators and prawn broodstock collectors in the proposed MSS areas for many years. The immediate and long-term impacts of habitat disturbance on the sawfish in this area is unknown and could be significant. [INFORMATION 002]</td></tr>
</table>

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">

+ NPFI invests considerable time and resources to better understand sawfish populations, mitigate interactions with the species and protect important sawfish habitat and strongly recommends that due consideration be given to TEPs in the EP **[REQUEST 001].**
+ For sustainability purposes and to improve prawn stocks in the JBG, NPFI and AFMA have agreed to close the JBG fishery to fishing for the first half of the year. As such, the fishery will be closed from 1st December each year to 1st August the following year for the next five years. Industry and AFMA will be monitoring the health and productivity of JBG and how it responds to the new management plan through stock assessments and catch and revenue data. **[INFORMATION 003]**
+ NPFI continues to be concerned about the potential immediate and future impacts of seismic on prawn stocks given the lack of available scientific information on the impact of such activity on tropical prawns. NPFI is concerned that if seismic activity does have negative impacts and/or skews the results of the JBG closure, this will reduce the benefits of the stock protection/rebuilding strategy that the JBG first season closure is aimed at achieving. This would be unacceptable to industry given the catch and revenue that industry is foregoing by not fishing in the first season to improve the sustainability of the JBG stock. Negative impacts of seismic activities on prawn stock would also potentially jeopardise the NPF's Marine Stewardship Certification (MSC). **[INFORMATION 004]**
+ As such, NPFI recommends that Santos take all measures to minimise and mitigate impacts on both NPF fishing operations and prawn stocks in the area as much as possible. **[REQUEST 002]**
+ To minimise impacts on NPF fishing operations, NPFI requests that all seismic activity is undertaken outside of NPF fishing seasons – i.e. seismic activity should only occur in the periods from 1st December to 1st August the following year. **[REQUEST 003]**
+ NPFI will be seeking compensation from Santos on behalf of the NPF Statutory Fishing Rights holders should there be any disruption to, or displacement of, NPF commercial fishing activities from the proposed seismic survey. **[INFORMATION 005]**
+ NPFI encourages investment by Santos in research to better understand the impacts of its activities on both tropical prawn stocks and TEP species. **[REQUEST 004]**

Santos responded to NPFI on 2 July 2021 and addressed each of the matters raised in their correspondence of 11 June 2021 (refer assessment of stakeholder objections, claims, information and requests below).

Santos will advise the NPFI when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.

As a key commercial fishing sector stakeholder, consultation with NPF will be ongoing for this and other Santos' activities.

All fisheries are described in **Section 3.8.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Sections 6.1**, **6.3** and **6.4**.

Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.

</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>[INFORMATION 001] Santos acknowledges that the Petrel Sub-Basin SW 3D MSS Operational Area overlaps an area that has historically been subject to significant fishing activity by the NPF in</td><td>Santos responded to NPFI and acknowledged their response.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	the JBG. The original 1 October to 31 March survey window was proposed to avoid what was previously the main (banana prawn) fishing season in the JBG (1 April to 15 June). Overlap with NPF fishing activities would have been limited to the last half of the tiger prawn fishing season (1 August – 30 November), a period that Santos understands is normally subject to lower levels of fishing effort in the JBG.	
	[INFORMATION 002] [REQUEST 001] Santos acknowledges that sub-adults and adults of some sawfish species may occur in the offshore waters of Operational Area. Juvenile sawfish (i.e. pups) generally inhabit river and estuarine environments in shallow, nearshore waters where the nursery sites are reported. Therefore, juveniles are unlikely to occur within the Operational Area but may be present in the shallower waters of the EMBA. The presence of sawfish in the Operational Area is likely to be limited to occasional transient adult individuals. Impacts to sawfish as a result of the survey are likely to be limited to temporary behavioural disturbances and no impacts to key life stages or habitats are expected.	Santos responded to NPFI and acknowledged their response.
	[INFORMATION 003] Details of the closure area and seasonal closures will be provided in the EP and have been considered as part of the assessment of impacts to the fishery.	Santos responded to NPFI and acknowledged their response.
	[INFORMATION 004] Santos acknowledges that there is no specific research available on the effects of seismic on tropical prawn species, however there are detailed studies that have been undertaken into the effects of seismic on other decapod crustaceans and associated fisheries as well as other studies into the effects of noise on crustaceans that are not caused by seismic impulses but provide insight into how crustaceans receive and respond to sound and vibration. Given prawns' similar physiology and anatomy as other decapod crustaceans, the available research, therefore, provides a reasonable indication of the types of effects that may occur to prawns. As crustaceans lack an air-filled chamber, it is highly unlikely that they can detect changes in sound pressure. They instead detect vibrations and particle motion changes in the water and seabed, and the studies indicate that responses are limited to within tens or hundreds of metres around where the seismic source is operating. Effects are, therefore, expected to be localised and temporary. Santos' assessment of the potential impacts of the Petrel Sub-Basin SW 3D MSS on the JBG prawn stocks has considered the following: + Effects to adult female prawns berried with eggs – No mortality to females or significant impacts to eggs	Santos responded to NPFI and acknowledged their response.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	+ Effects to eggs and larvae dispersed in the water column – Some mortality of eggs and larvae is possible when exposed near the seismic source, but in the context of natural larvae mortality and the naturally variable annual recruitment rates by the stocks, the potential risk of the survey on dispersed prawn eggs and larvae in the JBG is negligible. + Effects to migrating juveniles recruiting to the adult stock – Given the limited behavioural responses reported in certain studies, the survey will not prevent juveniles from reaching offshore waters where the adult stock resides and where the core fishing areas are located. In addition, no mortality of juvenile and sub-adult prawns is expected. Santos has also reviewed historical seismic surveys within the JBG against NPFI's reported catch and effort for the JBG component of the fishery. Between 2007 and 2014, catch per unit effort (CPUE) in the JBG banana prawn fishery was relatively high compared with other years, increasing from a typical CPUE of 0.73 tonnes per day in 2007 to between 1.0 and 1.5 tonnes per day for the next seven years. This period of increased catch also coincided with a period of seismic surveys in the JBG. CPUE was noted as being very low in 2015 and 2016, however, no seismic surveys were undertaken in the JBG between 2013 and 2016, and the low CPUE is likely the result of an unprecedented global marine heat wave which impacted marine species throughout Australia, particularly the tropical waters in the north. Seismic surveys occurred again in the JBG in 2017 and 2018 when banana prawn CPUE was once again above average. The CPUE data suggests that these seismic surveys have not previously resulted in impacts on the JBG stocks at a population level and larger scale environmental factors have a much greater influence on recruitment, prawn biomass and CPUE. Based on our assessments and noting the high naturally variability in annual recruitment rates, Santos does not expect the Petrel Sub-Basin SW 3D MSS to result in stock-level impacts to prawns or skew the monitoring results of the JBG closure. It is noted that prawns in the JBG may spawn year-round, although peak spawning periods for banana prawns are approximately September to November and also March to May. Peak brown tiger prawn spawning is understood to occur approximately July to October and peak grooved tiger prawn spawning is around February and then again August-September.	
	[REQUEST 002] [REQUEST 003] Following discussions with the NPFI and internally, Santos formally advised NPFI on 2 July 2021 that it would be able to meet its request to change the start of the survey so that it takes place between 1 December and 31 March of either 2021 or 2022. This applies to all areas of the survey (Area A, B, and C). All survey activities will therefore take	Santos responded to NPFI and acknowledged their response.

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	place well within the 1 December to 1 August timeframe NPFI has requested and not directly impact NPF commercial fishing activities. While the revised timing for the survey has been adopted primarily to prevent overlap with NPF fishing activities, it also reduces seismic acquisition during peak prawn spawning periods, providing reassurance that potential impacts to prawns will be minimized further.	
	[INFORMATION 005] Santos is committed to ensuring commercial fishing licence holders are no worse off as a result of the seismic survey and Santos will consider the merit of any claims, in accordance with the Santos Commercial Fishers Payment Claim Protocol, which was provided to NPFI and other commercial fishing stakeholders in the consultation package and will be summarised in the EP.	Santos responded to NPFI and acknowledged their response.
	[REQUEST 004] Santos contributes a significant amount to research in areas where it conducts activities. Santos partnered with the Australian Institute of Marine Science (AIMS) and committed funding to the North West Shoals to Shore Research Program which has investigated the effects of large-scale seismic surveys on demersal finfish and pearl oysters. Santos is open to new opportunities for research where there is a data gap relevant to its activities and notes prawns and TEP species in the JBG as being potential research topics.	Santos responded to NPFI and acknowledged their response.
Commonwealth Fisheries Association (CFA)	The CFA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package including additional information for commercial fishers via email on 7 May 2021 inviting comment. The CFA was provided a reminder email on 26 May 2021 inviting comment. Santos will advise the CFA when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS. As a key commercial fishing sector stakeholder, consultation with the CFA will be ongoing for this and other Santos' activities. All fisheries are described in **Section 3.8.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Sections 6.1**, **6.3** and **6.4**. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No assessment required.	No response required.
Pearl Producers Association (PPA)	The PPA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package on 7 May 2021.	

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">PPA provided alternative contact details via email on 7 May 2021. These were used by Santos for communications from that date on. The above information was re-sent to these contacts on 7 May 2021.
Santos sent a follow-up email on 26 May 2021 inviting comment.
Santos will advise the PPA when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
As a key commercial fishing sector stakeholder, consultation with the PPA will be ongoing for this and other Santos' activities.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
No further response received to date.
All fisheries are described in **Section 3.8.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Sections 6.1**, **6.3** and **6.4**.
Neither the NT Seafood Council or the WA Fishing Industry Council advised that pearl oyster fisheries were relevant for this activity but Santos chose to include the PPA as a potentially interested stakeholder.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td rowspan="3">**Australian Southern Bluefin Tuna Industry Association (ASBTIA)**</td><td colspan="2">ASBTIA was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 29 September 2020.
Santos sent a follow-up email on 26 May 2021 inviting comment.
Santos will advise the PPA when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
All fisheries are described in **Section 3.8.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Sections 6.1**, **6.3** and **6.4**.
As a key commercial fishing sector stakeholder, consultation with the PPA will be ongoing for this and other Santos' activities.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
</table>

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3">Recfishwest</td><td colspan="2">Recfishwest was provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package via email on 29 September 2020.
Santos sent a follow-up email on 26 May 2021 inviting comment.
Santos will advise Recfishwest when the Petrel Sub-Basin 3D MSS is available on the NOPSEMA Website for Public Comment.
This stakeholder also receives Santos' Quarterly Consultation Update for WA. The Q3 Update, distributed on 8 July 2021, included information on the Petrel Sub-Basin SW 3D MSS.
All fisheries are described in Section 3.8.1, and potential impact to fisheries, fish habitat and commercial fishers are discussed in Sections 6.1, 6.3 and 6.4.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td colspan="3">Commercial fishing licence-holders</td></tr>
<tr><td rowspan="3">Northern Prawn Fishery (Commonwealth)</td><td colspan="2">These licence holders were provided with the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package (for Northern Prawn Fishery) via email by NPF Pty Ltd or directly by Santos.
Refer to NPF comments received, as the representative body for licence-holders. Comments were received from several individual fishers in this fishery and records of these discussions are provided in the Sensitive Information Stakeholders Report provided to NOPSEMA. In each instance the individual licence-holder stated that the NPF would provide the consolidated, formal comment to Santos on their behalf.
Santos will advise the licence-holders through NPFI when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
All fisheries are described in Section 3.8.1, and potential impact to fisheries, fish habitat and commercial fishers are discussed in Sections 6.1, 6.3 and 6.4.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td>Mackerel Managed Fishery - Area 2 (WA)</td><td colspan="2">These licence holders were provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package (for Mackerel Managed Fishery (Area 2) via WAFIC on 10 May 2021.
Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery.
Santos will advise the licence-holders through WAFIC when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
All fisheries are described in Section 3.8.1, and potential impact to fisheries, fish habitat and commercial fishers are discussed in Sections 6.1, 6.3 and 6.4.</td></tr>
</table>

Stakeholder	Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))	
	Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No assessment required.	No response required.
Northern Demersal Scalefish Managed Fishery (WA)	These licence holders were provided the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package (for Northern Demersal Scalefish Managed Fishery) via WAFIC on 10 May 2021. Refer to WAFIC comments received. No comments received to date from individual fishers in this fishery. Santos will advise the licence-holders through WAFIC when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. All fisheries are described in **Section 3.8.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Sections 6.1**, **6.3** and **6.4**. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No assessment required.	No response required.
Spanish Mackerel Fishery (NT)	Santos provided these licence holders with the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package (for Spanish Mackerel Fishery) via email on 7 May 2021 and/or post on 10 May 2021. Refer to NTSC comments received, as the representative body for licence-holders. No comments received to date from individual fishers in this fishery. Santos will advise the licence-holders when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment. All fisheries are described in **Section 3.8.1**, and potential impact to fisheries, fish habitat and commercial fishers are discussed in **Sections 6.1**, **6.3** and **6.4**. Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.	
	Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests	Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests
	No assessment required.	No response required.
Demersal Fishery (NT)	Santos provided these licence holders with the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package (for Demersal Fishery) via email on 7 May 2021 and/or post on 10 May 2021. Refer to NTSC comments received, as the representative body for licence-holders. No comments received to date from individual fishers in this fishery.	

<table>
<tr><th>Stakeholder</th><th colspan="2">Stakeholder Consultation Summary (OPGGS(E) Regulation 16 (b)(i))</th></tr>
<tr><td rowspan="3"></td><td colspan="2">Santos will advise the licence-holders when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
All fisheries are described in Section 3.8.1, and potential impact to fisheries, fish habitat and commercial fishers are discussed in Sections 6.1, 6.3 and 6.4.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
<tr><td rowspan="3">Offshore Net & Line Fishery (NT)</td><td colspan="2">Santos provided these licence holders with the Petrel Sub-Basin SW 3D MSS Stakeholder Consultation package and Petrel Sub-Basin 3D MSS Additional Information for Commercial Fishers package (for Offshore Net & Line Fishery) via email on 7 May 2021 and/or post on 10 May 2021.
Refer to NTSC comments received, as the representative body for licence-holders. No comments received to date from individual fishers in this fishery.
Santos will advise the licence-holders when the Petrel Sub-Basin SW 3D MSS is available on the NOPSEMA Website for Public Comment.
All fisheries are described in Section 3.8.1, and potential impact to fisheries, fish habitat and commercial fishers are discussed in Sections 6.1, 6.3 and 6.4.
Santos considers the level of consultation to be adequate and will address any comments from this stakeholder should they arise in the future.</td></tr>
<tr><td>Assessment of the merits of objections and claims (OPGGS(E) Regulation 16 (b)(ii)), information and requests</td><td>Statement of response, or proposed response, to the objections and claims (OPGGS(E) Regulation 16 (b)(iii)), and information and requests</td></tr>
<tr><td>No assessment required.</td><td>No response required.</td></tr>
</table>

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 the seismic survey, Santos will notify all relevant stakeholders listed, or as revised, in **Table 8-3** in **Section 8.6.1**. The notification will include information on survey timing, vessel movements and vessel details.
+ Upon completion of the seismic survey, Santos will provide a cessation notification to the relevant stakeholders listed, or as revised, in **Table 8-3** in **Section 8.6.1**. The final cessation notification will advise stakeholders that the survey has ended.
+ Santos' Quarterly Consultation Update (see **Section 4.6**) will include the Petrel Sub-Basin 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.

Santos will assess any additional stakeholder objections or claims in accordance with **Section 4.4**.

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 Petrel Sub-Basin 3D MSS will be included in Santos' Quarterly Consultation Update distributed in July 2021. This document is provided in **Appendix D**.

The Quarterly Consultation Update is circulated to a broad group of Santos' stakeholders, including many of the stakeholders identified in **Table 4-2**.

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

OPGGS(E)R 2009 Requirements
Regulation 13. Environmental assessment
Evaluation of environmental impacts and risks 13(5) The environment plan must include: (a) details of the environmental impacts and risks for the activity; and (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. 13(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 impact and risk assessment refers to a process whereby planned and unplanned events that will or may occur during an activity are quantitatively and/or qualitatively assessed for their impacts on the environment (physical, biological, and socio-economic) at a defined location and specified period of time. In addition, unplanned events are assessed on the basis of their likelihood of occurrence which contributes to their level of risk.

Santos has undertaken environmental impact and risk assessments for the planned events (including any routine, non-routine and contingency activities) and unplanned events in accordance with the OPGGS(E)R.

Provided in this section of the EP is the following information relating to the environmental impact and risk assessment approach:

+ Terminology used; and
+ Summary of the approach.

A full description of the process applied in identifying, analysing and evaluating the impacts and risks relating to the planned activity is documented in Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004_5).

Santos

5.1 Impact and Risk Assessment Methodology

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' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004_5).

Table 5-1: Impact and risk assessment terms and Definitions

Term	Definition
Acceptability	Determined for both impacts and risks. Acceptability of events is in part determined by the consequence of the impact following management controls. Acceptability of unplanned events is in part determined from its risk ranking following management controls. For both impacts and risks, acceptability is also determined from a demonstration of the ALARP principle, consistency with Santos Policies, consistency with all applicable legislation and consideration of relevant stakeholder consultation when determining management controls.
Activity	Specific tasks and actions undertaken throughout the life cycle of oil and gas exploration, production and decommissioning.
ALARP	As Low As Reasonably Practicable The term refers to reducing risk to a level that is As Low As Reasonably Practicable. In practice, this means showing through reasoned and supported arguments, that there are no other practicable options that could reasonably be adopted to reduce risks further.
Authorised Person	Person with authority to make the decision or take the action. Examples are Vessel Master, Field Superintendent, Supervisor, Person-in-charge, Company Authorised Representative, and Project Manager.
Control Measure	Means a system, an item of equipment, a person or a procedure, that is used as a basis for managing environmental impacts and risks[1].
DMIRS	Department of Mines, Industry Regulation and Safety
Environment	Includes the natural and socio-economic values and sensitivities, which will or may be affected by the activity. Is defined by NOPSEMA and DMIRS as: (a) ecosystems and their constituent parts, including people and communities; and (b) natural and physical resources; and (c) the qualities and characteristics of locations, places and areas; and (d) the heritage value of places. (e) the social, economic and cultural features of the matters mentioned in paragraphs (a), (b), (c) and (d).
Environmental consequence	A consequence is the outcome of an event affecting objectives. Note 1 An event can be one or more occurrences and can have several cases. Note 2 An event can consist of something not happening. (Reference ISO 73:2009 Risk Vocabulary)
Environmental impact	Defined by NOPSEMA[1] as any change to the environment, whether adverse or beneficial, wholly or partly resulting from a planned or unplanned event[1]. Defined by DMIRS[2] as any change to the environment, whether adverse or beneficial, that wholly or partly results from a petroleum activity of an operator.

[1] Defined by the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009

Term	Definition
ENVID	Environmental hazard identification workshop
Environmental risk	Applies to unplanned events. Risk is a function of the likelihood of the unplanned event occurring and the consequence of the environmental impact that arises from that event.
Hazard	A situation with the potential to cause harm
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.
Impact assessment	The process of determining the consequence of an impact (in terms of the consequence to the environment) arising from a planned or unplanned event over a specified period of time.
Likelihood	The chance of an unplanned event occurring.
Non-routine planned event	An attribute of the planned activity that may occur or will occur infrequently during the planned activity. A non-routine planned event is intended to occur at the time.
Planned activity	A description of the activity to be undertaken including the services, equipment, products, assets, personnel, timing, duration and location and aspect of the activity.
Planned event	An event arising from the activity, which is done with intent (i.e. not an unplanned event) and has some level of environmental impact. A planned event could be routine (expected to occur consistently throughout the activity) or non-routine (may occur infrequently if at all). Air emissions, bilge water discharge and drill cuttings discharge would be examples of planned events.
Receptor	A feature of the environment that may have environmental, social and/ or economic values.
Risk	The effect of uncertainty on objectives.
Risk assessment	The process of determining the likelihood of an unplanned event and the consequence of the impact (in terms of economic, human safety and health, or ecological effects) arising from the event over a specified period of time.
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
SLT	Senior Leadership Team
Unplanned event	An event that results in some level of environmental impact and may occur despite preventative safeguards and control measures being in place. An unplanned event is not intended to occur during the activity.

5.2 Summary of the Environmental Impact and Risk Assessment Approach

5.2.1 Overview

Santos operates under an overarching Risk Management Policy. The company Risk Procedure (SMS MS1 ST01) underpins the Risk Management Policy and is consistent with the requirements of AS/NZS ISO 31000:2018, Risk Management – Guidelines (ISO, 2018).

The key steps to risk management are illustrated in **Figure 5-1**. The forum used to undertake the assessment is the environmental hazard workshop, referred to as an ENVID, which is described in Section 4 of Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004_5).

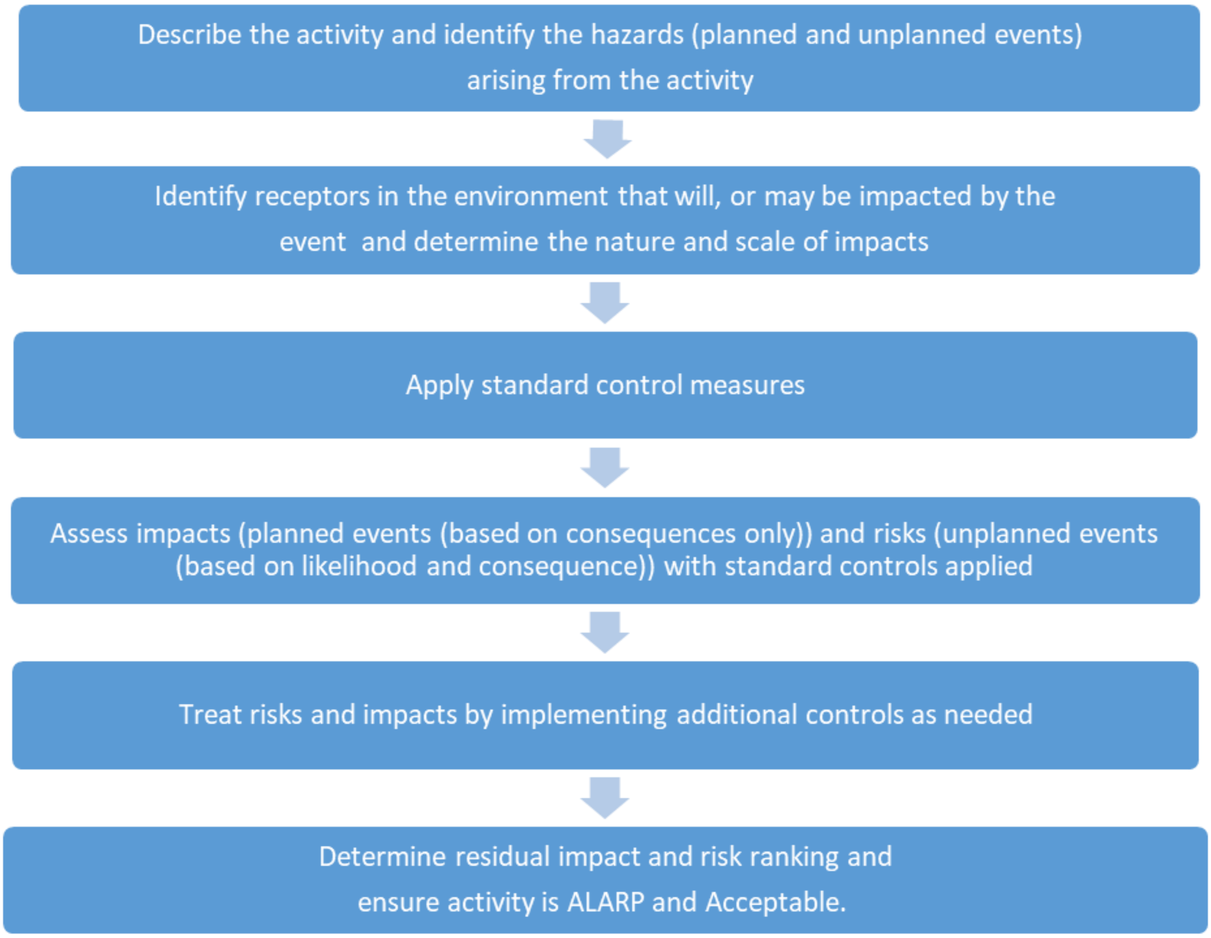


Figure 5-1: Hazard Identification and Assessment Guideline

Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004) 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;
+ Santos policy and SMS requirements;

+ Principles of Ecologically Sustainable Development (ESD); and
+ Santos acceptable levels of impact and risk.

These factors were considered in an environmental impact and risk assessment workshop held in September 2020 in which environmental hazards were identified and assessed (ENVID workshop). The workshop involved participants from Santos' Health, Safety and Environment (HSE), Projects and Operations departments and specialist environmental consultants.

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

A description of the activity is required in order to determine the planned events that will take place and the credible unplanned events that may occur. The location, timing and scope of the activity must be described in order to determine the impacts from planned events, and the impacts and risks from unplanned events since these have a bearing upon the environment that may be affected (EMBA) by the activity.

The outcome of this assessment is detailed in the relevant sub-sections of **Section 6** and **Section 7**.

5.2.3 Identify Receptors and Determine Nature and Scale of Impacts

A description of the environment (natural and socio-economic) within which hazards from the activity will, or may occur, is required. This constitutes a crucial stage of the risk assessment, as an understanding of the environment that will or may be affected is required to determine the type and consequence of impacts from the activity being assessed. The environment must be understood with respect to the spatial and temporal limits of the activity and key resources at risk that will or could be impacted by planned and unplanned events. Santos has developed a *Values and Sensitivities of the Marine and Coastal Environment* (EA-00-RI-10062) reference document which describes the existing environment that may be affected by Santos activities and is reviewed and updated on an annual basis.

Where the existing environment is being reviewed for regulatory approvals, a comparison shall be made against the *Values and Sensitivities of the Marine and Coastal Environment* (EA-00-RI-10062). A new protected matters search is required to ensure a thorough understanding of the existing environment to ensure all risks are assessed.

The extent of actual impacts from each planned activity or risks from each unplanned activity, are assessed using, where required, modelling (e.g. 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 **Section 3.2**.

5.3 Describe the Environmental Performance Outcomes and Control Measures

For each planned and unplanned event, a set of Environmental Performance Outcome(s), Control Measures, Environmental Performance Standards and Measurement Criteria are identified. The definitions of the performance outcomes, control measures, standards and measurement criteria must be consistent with OPGGS(E)R, and the NOPSEMA EP Content Requirements Guidance Note (NOPSEMA, 2019).

For any hazard, additional controls, must also be considered and either accepted for use or rejected based on whether the standard controls reduce impacts and risks to levels that are ALARP and acceptable (**Section 5.5** and **Section 5.6**).

Controls are allocated in order of preference according to **Figure 5-2**.

Control	Effectiveness	Example
Eliminate		*Removal of the risk.* Refueling of vessels at port eliminates the risks of an offshore refueling.
Substitute		*Change the risk for a lower one.* The use of low-toxicity chemicals that perform the same task as a more toxic additive.
Engineering		*Engineer out the risk.* The use of oil-in-water separator to minimise the volume of oil discharged.
Isolation		*Isolate people or the environment from the risk.* The use of bunding for containment of bulk liquid materials.
Administrative		*Provide instructions or training to people to lower the risk.* The use of Job Hazard Analysis to assess and minimise the environmental risks of an activity.
Protective		*Use of protective equipment.* Containment and recovery of spilt hydrocarbons.

Figure 5-2: Hierarchy of Controls

5.4 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 using the Corporate Santos Risk Matrix (**Appendix E**) and the more detailed environmental consequence descriptors provided as guidance in **Table 5-2**.

These detailed environmental consequence descriptions are based on the consequence 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.

The level of information required to complete the impact or risk assessment depends on the nature and scale of the impact or risk. 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. Impacts to social and economic values are also considered based on existing knowledge and feedback from stakeholder consultation. As the result of historic consultation with stakeholders, the social and economic values in the region that are of interest are evident.

As planned events are expected to occur during the activity, the likelihood of their occurrence is not considered during the risk assessment, and only a consequence level is assigned.

Table 5-2: Summary Environmental Consequence Descriptors

Consequence Level	Consequence Level Description
I	**Negligible** - No impact or negligible impact.
II	**Minor** - Detectable but insignificant change to local population, industry or ecosystem factors.
III	**Moderate** - Significant impact to local population, industry or ecosystem factors.
IV	**Major** - Major long-term effect on local population, industry or ecosystem factors.
V	**Severe** - Complete loss of local population, industry or ecosystem factors AND/ OR extensive regional impacts with slow recovery.
VI	**Critical** - Irreversible impact to regional population, industry or ecosystem factors.

For unplanned events, the consequence level of the impact is combined with the likelihood of the impact occurring (**Table 5-3**), to determine a residual risk ranking using the Santos corporate risk matrix (**Appendix E**). For oil spill events, potential impacts to environmental receptors are assessed where they occur within the EMBA using results from modelling.

Santos

Table 5-3: Likelihood Description

No.	Matrix	Description
f	Almost Certain	Occurs in almost all circumstances OR could occur *within days to weeks*
e	Likely	Occurs in most circumstances OR could occur *within weeks to months*
d	Occasional	Has occurred before in Santos OR could occur *within months to years*
c	Possible	Has occurred before in the industry OR could occur *within the next few years*
b	Unlikely	Has occurred elsewhere OR could occur *within decades*
a	Remote	Requires exceptional circumstances and is unlikely even in the long term OR only occurs as a *one in 100 year event*

5.5 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 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'.

5.6 Evaluating Impact and Risk Acceptability

Santos considers an impact or risk associated with the activities to be acceptable if the following criteria are met:

+ The consequence of a planned event is ranked as I or II; or a risk of impact from an unplanned event is ranked Very Low to Medium;
+ An assessment has been completed to determine whether further information or studies are required to support or validate the consequence assessment;
+ Assessment and management of risks have addressed the principles of ecologically sustainable development;
+ That the acceptable levels of impact and risks have been informed by relevant species recovery plans, threat abatement plans and conservation advice can be demonstrated;
+ Performance standards are consistent with legal and regulatory requirements;
+ Performance standards are consistent with Santos' EHS Policy;
+ Performance standards are consistent with industry standards and best practice guidance (e.g., National Biofouling Management Guidance Guidelines for the Petroleum Production and Exploration Industry (Marine Pest Sectoral Committee, 2018));
+ Performance outcomes and standards are consistent with stakeholder expectations; and
+ Performance standards have been demonstrated to reduce the impact or risk to ALARP.

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 seven 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
Interaction with commercial fishers	I – Negligible
Interactions with other marine users	II – Minor
Noise emissions	II – Minor
Cumulative and additive seismic impacts	I – Negligible
Light emissions	I – Negligible
Planned operational discharges	I – Negligible
Atmospheric emissions	I – Negligible

6.1 Interaction with Commercial Fisheries

6.1.1 Description of Event

Interaction with Commercial Fisheries	
Aspect	Interactions with commercial fisheries through undertaking the Activity. The presence of vessels in the Operational Area could potentially inhibit or be an inconvenience to commercial fishing vessels. For commercial fishing licence holders, the level of interaction could lead to temporary displacement. The presence of vessels and the towed streamers could also pose a collision risk (refer to **Section 7.67.6**).
Extent	Operational Area
Duration	For the duration of the Activity as described in **Section 2**.

6.1.2 Nature and Scale of Environmental Impacts

Commercial fishers may be temporarily impacted by the physical presence of the seismic vessel. The potential effects of noise from the seismic survey on commercial fishers is addressed in **Section 6.3.2.11** and **Section 6.4**.

Commercial fishers are considered to be the main marine user with potential to be materially affected by the proposed seismic survey. Based on a detailed review of fisheries overlapping the Operational Area (**Section 3.8.1**), analysis of fishing effort data, and through consultation with fishing stakeholders (**Section 4**), there are a number of Commonwealth, WA and NT managed commercial fisheries that have historically fished within the Operational Area and therefore have the potential for interference:

+ Commonwealth Northern Prawn Fishery (NPF)
+ WA Northern Demersal Scalefish Managed Fishery (NDSMF)
+ WA Mackerel Managed Fishery (MMF) – Area 1 (Kimberley)
+ NT Demersal Fishery (DF)
+ NT Spanish Mackerel Fishery (SMF)
+ NT Offshore Net and Line Fishery (ONLF)

While the boundaries of several other fisheries overlap the Operational Area, no fishing effort in the Operational Area has been identified through review of fishery publications and historical fishing data as evidenced in **Section 3.8.1** or consultation (**Section 4**).

The limited maneuverability of the seismic survey vessel while towing the source array and streamers means that commercial fishing vessels may be asked to take measures to avoid the immediate vicinity of the seismic survey vessel and associated equipment. In addition, commercial fishing vessels may be asked to remove fishing gear such as traps and lines to avoid interaction with the seismic survey vessel and in-water equipment. Potential impacts to commercial fisheries caused by a seismic vessel in the Operational Area, therefore, range from operational inconveniences (e.g. manoeuvring around the seismic vessel and requested area of avoidance) 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).

The Operational Area overlaps with waters that have historically been fished by the above fisheries. As summarized in **Section 3.8.1**, the level of overlap from the Operational Area with historic fishing effort in each fishery is as follows:

+ Commonwealth NPF: 4% (44% of the JBG fished area for 2013-2019)
+ WA NDSMF: 1.1%

Santos

+ WA MMF – Area 1: 0.95%
+ NT DF: 0.53%
+ NT SMF: 0.49%
+ NT ONLF: 0.51%

However, the potential for interaction with commercial fishing vessels may be significantly over-represented by the Operational Area, as the Activity will not occupy the entire Operational Area for the duration of the Activity. The potential for interaction is instead limited to the area near where the seismic survey vessel is operating. Typically, other vessels are requested to provide a wide berth of seismic surveys, in the order of 3 nm (5.6 km) around the seismic survey vessel and towed streamers. As the seismic survey vessel acquires seismic data along the sail lines in the racetrack formation described in **Section 2.5**, the vessel may return to pass within approximately 560-600 m of a location on a previously acquired sail line approximately every 14 – 27 hours (depending on the line lengths). During the period while the seismic survey vessel is absent, fishing vessels will not be excluded and can potentially continue to access waters to fish. However, it is acknowledged that anticipating the seismic survey vessel's movements in order to trawl nets or deploy traps or lines in the immediate vicinity of the survey activities could be challenging and, therefore, there is the potential for displacement or reduced fishing effort and catch levels to occur in the vicinity of the broader racetrack.

To provide a more representative area of where interaction with commercial fishers may occur, the impact assessment considers a single week's worth of seismic acquisition lines in the racetrack with a 3 nm (5.6 km) buffer applied to represent the avoidance distance typically requested of other vessels. Based on this rationale, the estimated spatial extent of potential disturbance is approximately 1,591 km². As mentioned above, fishing vessels will not be excluded from this entire area and may continue to fish in this area to some degree. However, this approach provides a conservative indication of the potential extent of impacts to commercial fisheries as a result of physical interaction. Following seven days of acquisition, the seismic survey vessel will have progressed to a different part of the survey area and so the area of potential interaction is not expected to be any larger. Based on the above approach, an analysis has been conducted to determine the area of overlap with the historic fishing effort of each fishery and, therefore, the maximum extent of potential disturbance to fishers (refer to **Table 6-2**).

For the NPF, it is noted that the survey will overlap a very small part of the total fishery, which extends from Cape Londonderry on the north Kimberley coast of WA, throughout waters offshore from the NT, the Gulf of Carpentaria and north-west Queensland. However, it is acknowledged that although the JBG comprises less than 5% of the total area of the NPF, it contributes about 65% of the NPF's red-legged banana prawn catch and around 20% of the NPF's total banana prawn catch (combined *P. merguensis* and *P. indicus*) (Loneragan et al. 2002). Therefore, the assessment of spatial overlap with the NPF is based on fishing activities only within the JBG (between Cape Londonderry and Darwin) to represent the fishery's specific interests in this area.

Further, the assessment of the spatial overlap with the NPF focuses only on the areas where more than five vessels have fished each year and, therefore, where a level of fishing intensity has been mapped and reported annually by ABARES. There are other areas in the JBG where prawn trawlers fish, but these areas are accessed by less than five vessels in total. Fishing intensity has been mapped by combining the available spatial data for the years 2013–2019 (seven years), which demonstrates that similar areas are consistently fished each year. The area of mapped fishing intensity is also consistent with confidential fishing data provided by the NPFI to Polarcus in 2019 and to Santos in 2021. By limiting the assessment of spatial overlap to the area of mapped fishing intensity within the JBF, the percentage of spatial overlap is increased and it is therefore conservative. The maximum potential area of overlap with mapped NPF fishing intensity is presented in **Figure 6-1**.

Assessment of overlap with the WA NDSMF and MMF is based on fishing effort data available from DPIRD for the period 2009-2019 (11 years). Assessment of overlap with the NT DF, SMF and ONLF is based on fishing effort data available from NT DITT for the period 2016-2020 (five years). The timing of the Petrel Sub-Basin SW 3D MSS in relation to the fishing activities is also discussed.

Table 6-2: Spatial Overlap with Relevant Commercial Fisheries from Seven Days of Acquisition

Fished Areas	Area of Fishing Effort (km^2)*	Spatial Overlap (km^2)	Spatial Overlap (%)
Northern Prawn Fishery – Entire fishery	151,232	1,288	0.85%
Northern Prawn Fishery – JBG area	13,748	1,288	9.37%
WA Northern Demersal Scalefish Managed Fishery	142,173	354	0.25%
WA Mackerel Managed Fishery	55,375	306	0.55%
NT Demersal Fishery	315,310	274	0.09%
NT Spanish Mackerel Fishery	337,351	274	0.08%
NT Offshore Net and Line Fishery	326,966	274	0.08%

*The area of fishing effort for WA managed fisheries is based on historic fishing effort data from 2009 to 2019 (obtained from WA DPIRD Fisheries). The area of fishing effort for NT managed fisheries is based on historic catch and effort data from 2016 to 2020 obtained from NT DITT. The area of fishing effort for the Commonwealth managed NPF is based on the information presented in the ABARES Fishery Status Reports (data is based on fishing intensity mapped for the 2013 - 2019 fishing seasons, where more than 5 vessels had fished during each year).

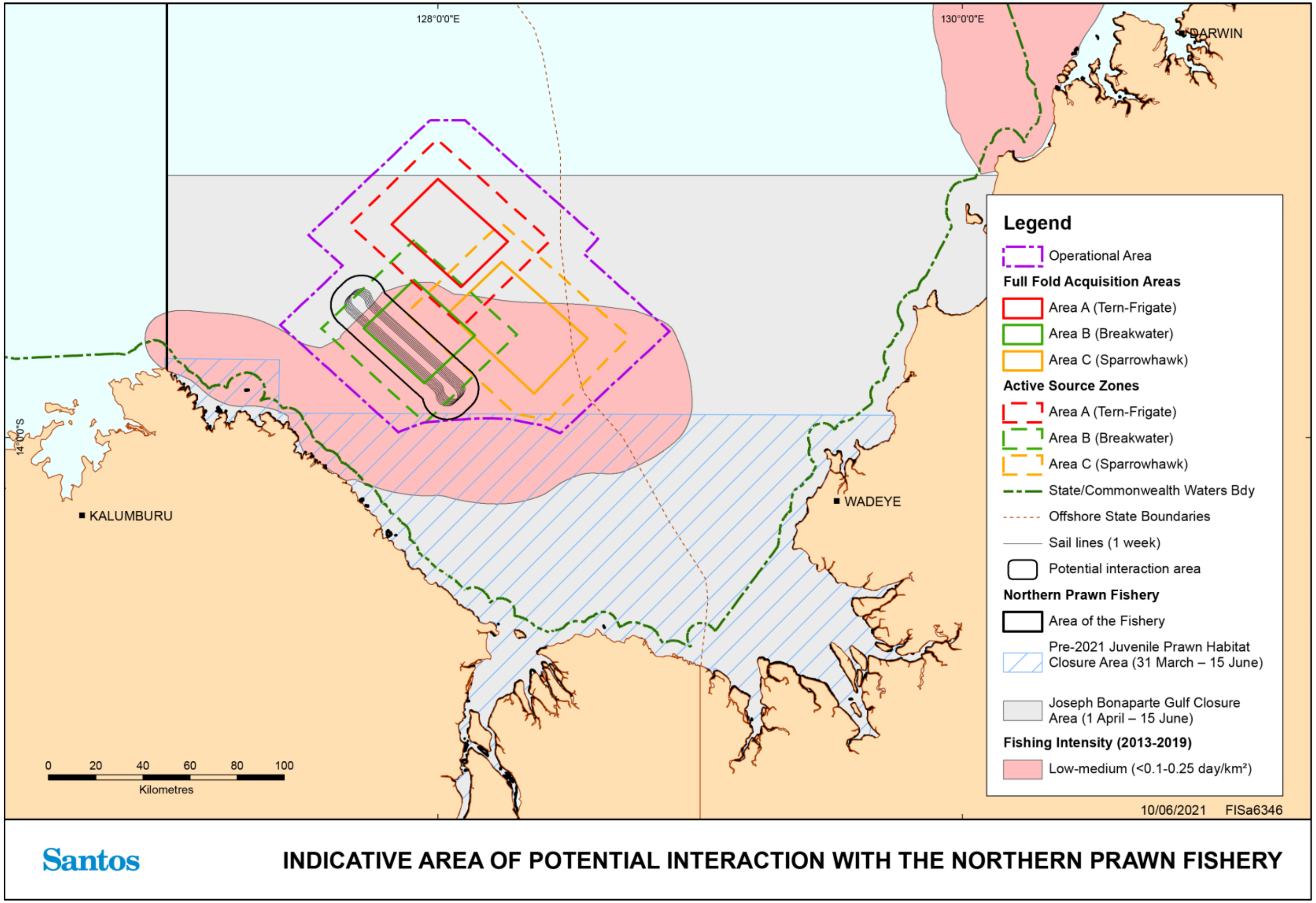


Figure 6-1: Indicative Area of Potential Interaction with the NPF in the JBG

6.1.2.1 Northern Prawn Fishery

The highest intensity fishing areas for the NPF are in the Gulf of Carpentaria between the NT and Queensland, with relatively low intensity fishing within the JBG. However, it is acknowledged that the JBG contributes significantly to the NPF's red-legged banana prawn and banana prawn catch (Loneragan et al. 2002).

Fishing effort data published by ABARES and additional data provided in confidence by the NPFI indicates that fishing in the western JBG occurs in the southern part of the Operational Area, as well as in waters to the south and west of the Operational Area (**Figure 6-1**). The level of fishing intensity here has usually been defined by ABARES as 'low intensity (<0.1 days/km²)' or in some years medium 'medium intensity (0.1-0.25 days/km²)', compared with the Gulf of Carpentaria and other areas of the fishery which are more frequently subjected to medium intensity (0.1-0.25 days/km²) or high intensity 0.25-0.55 days/km2²) fishing each year. Fishing in the JBG generally takes place in waters 35 – 80 m deep, with most fishing effort between 50 and 60 m.

The Petrel Sub-Basin SW 3D MSS Operational Area overlaps with approximately 44% of the fished area in the JBG described by ABARES as 'low intensity' fishing. However, the likely area where fishing activities may be disrupted by the survey (based on seven days of racetrack acquisition in Area B or Area C) represents approximately 9.37% of the 'low-medium intensity' JBG fished area. Only Areas B and C may result in this level of overlap. The spatial overlap with the low intensity JBG fished area from a week of acquisition in Area A represents just 0.62% of the low intensity JBG fished area, and interaction within the low intensity JBG fished area is limited to times when the seismic vessel may be turning and running in or running out of sail lines in the south-west corner of the Area A Active Source Zone. It is acknowledged that the low intensity JBG fished area is only indicative and vessel presence may vary each year. There is also still the potential for interaction with a lower number of fishing vessels (less than 5 vessels) outside of this area, but the potential for interaction is considered to be limited.

The NPF operates during two separate seasons. The first season is from 1 April to 15 June, and during this time banana prawns are mainly caught. Conversely, during the second season (1 August – 1 December) tiger prawns are predominately caught. Either season has the potential to end early, with the end of the seasons determined using catch-rate thresholds; when catch rates across the fishery fall below a set level, the closure of the season is triggered in order to ensure that overfishing does not occur and adequate spawning biomass is retained for subsequent recruitment of the stock (Dichmont et al. 2012; Larcombe et al. 2018; AFMA 2021).

Prior to 2021, fishing in the JBG during the banana prawn fishing season (1 April – 15 June) was required to take place in deep waters to the north of a seasonal closure area that protected nearshore banana prawn nursery and migration habitats in the southern part of the JBG (**Figure 6-1**). However, from 2021, a new closure area (**Figure 6-1**) will apply to the whole of the JBG south of latitude 13°S during the first 1 April to 15 June fishing season. The new closure area effectively means that banana prawn fishing season will no longer occur in the JBG in the areas it has done previously, which are the waters overlapping the Operational Area. Only a small part of the Operational Area is located outside of the closure area (**Figure 6-1**) and this is in water depths greater than approximately 100 m and no significant pawn fishing effort is expected here. Only fishing during the 1 August to 1 December tiger prawn season is now permitted in the JBG closure area, south of latitude 13°S.

As noted in **Section 3.8.1**, historical fishing catch and effort in the JBG has typically been substantially lower during the tiger prawn season compared with the banana prawn season. Based on the historic catch data, tiger prawn catch levels are historically greater in fishing grounds outside of the JBG, particularly from the Gulf of Carpentaria and the north coast of the NT, which are closer to the fishery's primary landing ports of Darwin (NT) and Cairns and Karumba (Queensland) (Parsa et al. 2020).

The above assessment indicates that the Petrel Sub-Basin SW 3D MSS would have a limited spatial overlap with the NPF's fished area in the JBG (less than 10%) and fishing activities in the JBG would only occur during the less active tiger prawn fishing season. However, following consultation with the NPFI, Santos agreed to reduce impacts to the NPF further and has committed to acquire the full Petrel Sub-Basin SW 3D MSS during the period 1 December to 31 March. The December to March survey window avoids the 1 April to 15 June NPF banana prawn fishing season (although due to the new closure area, fishing activities will no longer take place within the JBG and Operational Area during this season). The survey will also avoid the 1 August – 1 December tiger prawn fishing season.

Given the Petrel Sub-Basin SW 3D MSS will not coincide with prawn fishing in the JBG, there is no potential for disruption to NPF fishing activities.

6.1.2.2 WA Northern Demersal Scalefish Managed Fishery

The Operational Area is located in Zone A of Area 2 of the NDSMF, noting that the NDSMF primarily targets deeper waters in Zone B of Area 2 of the fishery (over 100 km north-west of the Operational Area). Based on a review of FishCube data, fishing effort has only previously been reported in the north-east portion of the Operational Area and not within any of the Full-fold Acquisition Areas (refer to **Figure 3-18**). The 10 nm blocks overlapped by the Operational Area have been fished by less than three vessels during the entire 11-year (2009-2019) period and during many years, no fishing has occurred in the Operational Area at all.

The Operational Area overlaps with approximately 1,603 km² (1.1%) of the total 142,173 km² area where fishing effort has been recorded during the 11-year period (2009-2019). Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been infrequent.

The area of overlap based on seven days of racetrack acquisition is even less and represents approximately 0.25% of the area where fishing effort has occurred previously.

Alternative and more viable fishing grounds are available to commercial fishers. The most productive areas for this fishery that are fished consistently throughout each year (Zone B of the fishery) are located over 150 km north-west of the Operational Area. NDSMF annual catches have consistently exceeded 1,000 tonnes and been within Allowable Catch Tolerance Levels of 903 to 1,332 tonnes per year since 2008 and the vast majority is landed from Zone B (Newman et al. 2019).

Given that the NDSMF fish in the area very infrequently, it is unlikely that interaction with NDSMF vessel will occur. Therefore, the Petrel Sub-Basin SW 3D MSS is not expected to result in operational inconvenience or temporary displacement from significant fishing grounds.

6.1.2.3 WA Mackerel Managed Fishery (Area 1)

Based on a review of FishCube data, the Operational Area overlaps with less than 526 km^2 (0.95%) of the total area where fishing effort has been recorded (55,375 km^2) during the 11-year period (2009-2019). The two 10 nm blocks overlapped by the Operational Area (refer to **Figure 3-19**) have been subject to relatively low fishing effort, compared with other areas that are more regularly and intensively fished to the north and west of Kalumburu (over 90 km west of the Operational Area).

The two blocks overlapped by the Operational Area are located in the southern half of the Operational Area, within or adjacent to the Area C Full-fold Acquisition Areas, and in water depths of approximately 70 m or less. One of the blocks has only been fished in 2019, with less than three vessels reported for the block. The other block overlapped by the Operational Area is located in the vicinity of a shallow bank feature on the southern boundary of the Operational Area. This block has reported 45 days of fishing effort during the entire 11-year period (2009-2019) and was only fished during four of the 11 years. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been infrequent.

The area of overlap based on seven days of racetrack acquisition is even less and represents approximately 0.55% of the area where fishing effort has occurred previously.

Fishing effort occurs year round but typically takes place between May and November. The survey is scheduled to occur between 1 December and 31 March, therefore, there is no potential for interaction during the peak of the season.

Alternative and more viable fishing grounds are available to commercial fishers and the potential for interaction is limited. Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time.

Given the low number of vessels accessing this part of the fishery, compared with other areas, the potential for disruption to this fishery is limited.

6.1.2.4 NT Demersal Fishery

The Operational Area has a very limited overlap with NT-managed fisheries, with just 1,668 km^2 of the eastern part of the Operational Area (comprising part of Area C and its surrounding Active Source Area) extending into these waters (refer to **Figure 3-21**).

Analysis of five years of NT fishing effort data (2016-2020) shows that the Operational Area overlaps with approximately 1,668 km^2 (0.53%) of the total area of fishing effort (315,310 km^2). Only three days of fishing by three licence holders was reported in the 60 nm block overlapped by the Operational Area during the entire 5-year (2016-2020) period. By comparison, the fishing block located approximately 6 km north-east of the Operational Area was fished for 659 days by 16 licence holders. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been relatively infrequent.

The area of overlap based on seven days of racetrack acquisition is even less and represents just 274 km^2 (approximately 0.09%) of the area where fishing effort has occurred previously.

Alternative and more viable fishing grounds within the fishery are available to commercial fishers. Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time.

Given the low number of vessels accessing this part of the fishery, compared with the broad area over which the fishery operates, the potential for disruption to this fishery is limited.

6.1.2.5 NT Spanish Mackerel Fishery

The Operational Area has a very limited overlap with NT-managed fisheries, with just 1,668 km^2 of the eastern part of the Operational Area, representing only 0.49% of the total area of fishing effort (337,351 km^2) (**Figure 3-22**).

The 60 nm block overlapped by the Operational Area was fished by four licence holders and for a total of just 10.5 days during the entire 5-year (2016-2020) period. By comparison, the next fishing block located east of the Operational Area and in NT coastal waters was fished for 627 days. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been relatively infrequent.

The area of overlap based on seven days of racetrack acquisition is even less and represents just 274 km^2 (approximately 0.08%) of the area where fishing effort has occurred previously.

Alternative and more viable fishing grounds in coastal waters are available to commercial fishers. Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time.

Given the low number of vessels accessing this part of the fishery, compared with the broad area over which the fishery operates, the potential for disruption to this fishery is limited.

6.1.2.6 NT Offshore Net and Line Fishery

Analysis of five years of NT fishing effort data (2016-2020) shows that the Operational Area overlaps with approximately 1,668 km^2 (0.51%) of the total area of fishing effort (326,966 km^2) (**Figure 3-23)**.

Only 2.5 days of fishing by three licence holders was reported in the 60 nm block overlapped by the Operational Area during the entire 5-year (2016-2020) period. By comparison, the next fishing block located east of the Operational Area and in NT coastal waters was fished for 736 days. Therefore, the Operational Area overlaps a very small proportion of the fishery, where historical fishing effort has been relatively infrequent.

The area of overlap based on seven days of racetrack acquisition is even less and represents just 274 km^2 (approximately 0.08%) of the area where fishing effort has occurred previously.

Alternative and more viable fishing grounds within the fishery are available to commercial fishers. Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time.

Given the low number of vessels accessing this part of the fishery, compared with the broad area over which the fishery operates, the potential for disruption to this fishery is limited.

6.1.3 Environmental Performance Outcomes and Control Measures

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

+ Survey information provided to regulatory authorities and marine users directly affected by planned activities prior to commencement of the survey (EPO-1);
+ No unplanned interactions with commercial fishers (EPO-2); and
+ Commercial fishing licence holders are no worse off as a result of the seismic survey (EPO-3).

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 maneuverability.	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. Stakeholder's 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 (safety) zone established to reduce potential for collision or interference with other marine user activities.	Requested minimum 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.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-5	Support vessel present and operational 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, including AIS (virtual or installed) to mark the location of streamer tail buoys.	Reduces the risk of vessel collision with the seismic survey vessels and deployed equipment. Enables commercial vessels to understand the extent of in-water equipment in addition to vessel position.	Negligible as it is a standard maritime requirement that the seismic vessel will be fitted with AIS, and the seismic tail buoys can be readily equipped with virtual or installed AIS.	**Adopted** – The safety benefits of having AIS outweigh any costs. This is a maritime requirement. An additional level of visibility is provided by providing virtual or installed AIS for the tail buoys.
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 vessel movements are not operationally compatible.	**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. Santos commits to working with relevant commercial fisheries to enable fair and reasonable concurrent operations.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
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 and financial loss. 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.
Additional control measures				
N/A	Using more than one support vessel to further reduce the potential for collision or interference with other marine users	An additional support vessel allows for communication and management of interactions, if there is an interaction with more than one approaching third party vessel, to ensure the exclusion (safety) zone is observed. The only benefit would be if the primary committed support vessel is non-operational (e.g. breakdown) or in the event of multiple simultaneous vessel collision threats.	Additional costs associated with having an additional vessel during the survey can extend into hundreds of thousands of dollars, and there is an increased environmental and safety risk of 'small' vessels being at sea.	**Not adopted –** An additional vessel will not significantly reduce the risk of interface with commercial vessels. Both the survey vessel and committed support vessel will be monitoring for and communicating with approaching commercial vessels. It is highly unlikely that there would be multiple simultaneous vessel collision threats given existing controls in place and regulated maritime practices (e.g. SOLAS, COLREGs). The survey vessel will avoid large commercial vessels, including cargo ships.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	Reduce survey area to decrease overlap with commercial fisheries.	Minimises displacement of fishing vessels from known fishing areas.	The Operational Area overlays commercial fishing activities.	**Not Adopted** – Santos would not be able to obtain the data for the identified hydrocarbon prospects being targeted. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement. As assessed, acquisition has the potential to disrupt up to just 9.37% of NPF fishing activities in the JBG and for a small proportion of the fishing season. Overlap with other commercial fisheries is less (<1%).
N/A	Amend timing of the survey to further reduce overlap with commercial fishing activities.	During stakeholder consultation, Santos agreed to acquire the full survey during the period 1 December to 31 March to avoid interaction with the NPF. The 1 December to 31 March survey window does not overlap with the 1 April to 15 June banana prawn fishing season or the 1 August to 1 December tiger prawn fishing season in the NPF. Therefore, there is no potential for disruption to NPF fishing activities. Further reducing the survey window provides no additional benefit to the NPF in terms of their fishing activities. The 1 December to 31 March survey window also avoids the May to November peak	If the seismic survey window is limited too much, Santos may not have sufficient time to be able to acquire all of the data necessary to adequately interpret hydrocarbon reservoirs and Santos may not meet work programme commitments made under title. The 1 December to 31 March survey window has been identified such that it limits overlap with commercial fishing activities and other key environmental sensitivities. The survey window provides 121 days in which to	**Not Adopted** – The survey currently has limited spatial and temporal overlap with commercial fisheries. Amending the timing or reducing the survey window further will provide limited, if any, additional benefit to fisheries. Given the exact timing of the survey will be subject to vessel availability and a number of other commercial, operational and environmental factors, some level of flexibility is required for the survey window. Reducing the survey window could prevent

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		fishing period in the MMF. It is possible that some mackerel fishing may be undertaken by the MMF during the December to March period, but waters within the Operational Area represent approximately 0.55% of the area where fishing effort has occurred previously. Fishing has only occurred here during four of the 11 years. Therefore, further reducing the survey window provides limited additional benefit to the MMF. The spatial overlap with all other commercial fisheries that have previously fished in the Operational Area represents less than 1% of their respective areas of historical fishing effort and fishing activities in these fisheries occur year-round. Therefore, altering survey timing will achieve no benefit to these fisheries.	complete the survey, which is expected to take up to 100 days. There is, therefore, limited flexibility to acquire the survey given potential delays that could occur during this window that are outside of Santos' control. The proposed timing is also key to Santos for operational and commercial reasons, with the timing intended to allow for the contracted seismic vessel to transition to/from the Petrel Sub-Basin SW 3D MSS to other seismic surveys that could potentially occur off northern Australia during the same years allowed for under this EP (e.g. phases of the Keraudren Extension 3D MSS from 1 February to 31 July in 2021 or 2022 or other seismic surveys in the region). The commercial viability of the Petrel Sub-Basin SW 3D MSS depends on the ability to utilise a seismic vessel that is already in Australian waters and potentially acquire the Petrel Sub-Basin SW 3D MSS and other Santos seismic surveys of north-west Australia consecutively. The cost of contracting and mobilising a separate seismic vessel for the Petrel Sub-Basin SW 3D MSS	Santos from being able to complete the survey or it could mean the survey is not financially feasible, if contracting of a seismic vessel cannot align with other potential Santos surveys in Australian waters. Given limited additional benefit can be gained for commercial fisheries by altering or reducing the survey window, the potentially significant cost to Santos means that this option is not practicable.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			or to cover the cost of periods of vessel downtime if scheduling of the various surveys cannot align, can be several millions of dollars. This would mean that the Petrel Sub-Basin SW 3D MSS is not financially feasible and it is likely it could not go ahead.	

6.1.4 Impact and Consequence Ranking

Receptor	Consequence Level
Commercial fisheries	
Threatened / Migratory Fauna	N/A – related to socio-economic receptors only.
Physical Environment/ Habitat	
Threatened ecological communities	
Protected Areas	
Socio-economic receptors	Through consultation Santos understands that the NPF is concerned about seismic surveys (refer to **Section 4**). The seismic survey has the potential to interact with six commercial fisheries; NPF NDSMF (WA), MMF (WA); DF (NT), SMF (NT), and the ONLF (NT). 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 (5.6 km) exclusion zone around the seismic vessel and streamers for safety reasons. An exclusion zone is standard practice for a seismic vessel and no specific 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 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 recognises 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 impact assessment. 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 commercial fishers is considered to be I – Negligible – *No impact or negligible impact*. This assumes the implementation of all proposed control measures. The justification for this consequence assessment is:

Receptor	Consequence Level
	• Commercial fishers will still be permitted to enter the Operational Area providing the requested exclusion (safety) zone around the seismic vessel is observed. • Any interactions or displacements will be temporary and limited to a maximum of 100 days. • The survey will not interfere with the NPF banana prawn or tiger prawn fishing seasons. • The spatial overlap of survey activities is predicted to represent less than 1% of the fished areas for all other fisheries and fishing within the Operational Area by these fisheries is infrequent. • Although the survey may result localised and short-term displacement and inconveniences to fishers, the Operational Area is not frequently fished by any of the WA or NT commercial fisheries, and the data demonstrates that more viable and productive fishing grounds for each fishery are available outside of the Operational Area, and in most instances these fishing areas are closer to the main landing ports. • Santos commits to ongoing engagement with commercial fishers before, during and after the seismic survey.
Overall worst-case consequence	I – Negligible

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 December to 31 March).

Stakeholders have been informed of the proposed seismic activity as detailed in **Section 4**. 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 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.

Santos commits to working with relevant stakeholders to enable fair and reasonable concurrent operations. 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 Negligible and cannot be reduced without compromising seismic survey objectives.

Therefore, the proposed control measures for interaction with commercial fisheries are considered appropriate to manage the consequence to ALARP.

6.1.6 Acceptability Evaluation

Is the consequence ranked as I (Negligible) or II (Minor)?	Yes – I (Negligible).
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 outcomes and standards consistent with stakeholder expectations?	Yes – Control measures and associated performance standards have been included to address stakeholder concerns. The timing of the Petrel Sub-Basin 3D MSS (1 December to 31 March) was defined, giving consideration to consultation with commercial fisheries stakeholders. Despite there being potential for the survey and fishing activities to occur concurrently, Santos agreed to reduce the proposed timing of the survey in response to a request from the NPFI to undertake the seismic survey outside of NPF fishing seasons (i.e. from 1 December to 1 August the following year). Santos has selected a survey window of 1 December to 31 March the following year, thereby meeting and exceeding stakeholder expectations. Relevant stakeholders were also 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 survey, 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 and 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 commercial fishers 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.		
Defined Acceptable Levels			
Does the predicted impact meet the defined acceptable level of impact (refer to **Section 5.6**)?	**Defined Acceptable Level of Impact**	**Comparison with Predicted Levels of Impact**	**EPO**
	No unplanned interactions with commercial fishers. Commercial fishing license holders are no worse off as a result of the seismic survey.	Santos considers the level of impact to commercial fisheries and fishers to be of an acceptable level. Santos has committed to concurrent operations with commercial fishers, thereby not excluding fishers from their fishing groundings. Santos will provide advanced notification of proposed surveys, and communicate operational survey plans and daily operational reports so that commercial fishers are informed. It is through these control measure that Santos will ensure there are no unplanned interactions with commercial fishers. The predicted level of impact does not exceed the defined acceptable level of impact given that: • Commercial fishers will still be permitted to enter the Operational Area providing the requested exclusion (safety) zone around the seismic vessel is observed. • Any interactions or displacements will be temporary and limited to a maximum of 100 days. • The spatial overlap of survey activities is predicted to represent less than 10% of	EPO-1 EPO-2 EPO-3

		the NPF 'low intensity' JBG fished area, and less than 1% of the fished areas for all other fisheries. • The survey will not interfere with the banana prawn or tiger prawn fishing seasons. • The survey window avoids the May to November peak fishing period in the MMF, and limited fishing effort normally takes place in the Operational Area anyway. • Although the survey may result localised and short-term displacement and inconveniences to fishers, the Operational Area is not frequently fished by any of the WA or NT commercial fisheries, and the data demonstrates that more viable and productive fishing grounds for each fishery are available a significant distance from the Operational Area. • Santos commits to ongoing engagement with commercial fishers before, during and after the seismic survey. • Santos commits to assessing the merits of all evidence-based displacement payment claims (refer to **Section 8.6.2**).	

6.2 Interaction with other marine users

6.2.1 Description of Event

Interaction with other marine users	
Aspect	Interactions with other marine users while 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. The level of interaction could lead to temporary avoidance by other users. The presence of vessels and the towed streamers could pose a collision risk (refer to **Section 7.6**).
Extent	Operational Area
Duration	For the duration of the Activity as described in **Section 2**.

6.2.2 Nature and Scale of Environmental Impacts

Santos has identified the following stakeholders as potential marine users of the Operational Area (other than commercial fishers): tourism/recreation, commercial shipping, Defence and other petroleum exploration and production operations, including associated vessel activities. These users maybe temporarily impacted by the physical presence of the seismic vessel. The potential physical interaction between the seismic survey vessel and commercial fishers is addressed above in **Section 6.1**. The potential effects of noise from the seismic survey on other marine users is assessed in **Section 6.3**.

Tourism/recreation

Tourism and recreational activities are known to take place along the northern Kimberly coastline, however interactions with the Petrel Sub-Basin SW 3D MSS are considered unlikely due to the remoteness and predominantly deep waters of the Operational Area (refer to **Section 2**). The Operational Area does not include any specific sites of interest to tourism and recreation. Most recreational and tourism activities in the region occur predominantly in State/Territory waters adjacent to population centres, such as Broome and Darwin. Tourism in the region typically peaks during the dry season (May to October), which is avoided by the proposed timing of the survey (December to March). In the event that tourism/recreational activities are present within the Operational Area (e.g. charter vessel transiting through the Operational Area), displacement would be minimal given the transient nature of the seismic activities. With controls adopted as identified below, no significant impacts are expected.

Commercial Shipping

Heavy vessel traffic directly north of the Operational Area is expected, due to vessels heading in and out of Darwin (refer to **Section 3.8.2**). Vessel traffic within the Operational Area itself is relatively low. The number of vessels passing through the Operational Area each month in 2020 ranged from eight to 24 vessels, equivalent to a single vessel being present in the Operational Area every 1 – 4 days. Further, the number of vessels passing through the Operational Area during the proposed survey period (December to March) ranged from just eight to 12 vessels. It is noted that some vessels may transit through the Operational Area, while some of the vessels recorded may be fishing vessels rather than commercial shipping and may remain within the Operational Area for a number of days.

Twenty-four-hour radar and visual watch and open radio communications between vessels will occur during the seismic survey. Early communication between vessels allows for the speed and course of vessels to be ascertained in a timely manner and any necessary adjustment of course to be confirmed. Given the seismic survey vessel will be towing the streamer array, maneuverability will be limited, and commercial vessels may be required to change course. Vessels will be requested to give way 3 nm (5.6 km) around the seismic vessel and trailing streamers.

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.

Defence

The Operational Area overlaps with practice and training areas that comprise the North Australian Exercise Area (NAXA), which is used for military operations including live weapons and missile firings. The NAXA is the primary location of the KAKADU training exercise that operates biannually. During Exercise KAKADU, access may be restricted to all vessels and aircraft. However, Defence have advised Santos during consultation that early advice of progress may enable compatible activities with minimal disruption to both parties.

Defence have advised that Exercise KAKADU will be in preparation throughout August 2022 with the exercise completed by 30 September 2022. Avoidance of the area during exercises is requested by Defence. The proposed survey period of the Petrel Sub-Basin SW 3D MSS (1 December to 31 March) avoids any potential conflicts with timing or location of military exercises that may overlap the Operational Area.

Petroleum Exploration and Production Operations

The Bonaparte Basin is an established hydrocarbon province with a number of commercial operations. Vessels associated with nearby petroleum operations (e.g. Blacktip facility and gas pipeline in the south of the Operational Area) may be asked to deviate from intended routes to avoid the seismic vessel, in-water equipment and support vessels, if transiting through the Operational Area. Santos will also implement simultaneous operations (SIMOPS) procedures and gain an Access Authority for accessing waters around the Eni Blacktip facility. Based on the controls identified below, no significant implications are expected.

Santos will work collaboratively with other petroleum operators to ensure interactions offshore are minimised. With controls adopted as identified below, no significant implications are expected.

6.2.3 Environmental Performance Outcomes and Control Measures

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

+ Survey information provided to regulatory authorities and marine users directly affected by planned activities prior to commencement of the survey (EPO-1); and
+ No unplanned interactions with other marine users (EPO-4).

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 maneuverability.	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 are aware of upcoming seismic survey operations so they can plan their business accordingly.	Limited additional costs to Santos. Stakeholder's 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 (safety) zone established to reduce potential for collision or interference with other marine user activities.	Requested minimum 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.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-5	Support vessel present and operational 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, including AIS (virtual or installed) to mark the location of streamer tail buoys.	Reduces the risk of vessel collision with the seismic survey vessels and deployed equipment. Enables commercial vessels to understand the extent of in-water equipment in addition to vessel position.	Negligible as it is a standard maritime requirement that the seismic vessel will be fitted with AIS, and the seismic tail buoys can be readily equipped with virtual or installed AIS.	**Adopted** – The safety benefits of having AIS outweigh any costs. This is a maritime requirement. An additional level of visibility is provided by providing virtual or installed AIS for the tail buoys.
CM-10	Notices to Department of Defence (DoD)	Ensures defence operations are aware of the presence of the seismic survey vessel, and the relatively slow speed and restricted maneuverability.	Costs associated with the personnel time in issuing notifications and closing out queries and responses.	**Adopted** – The DoD will be contacted five weeks prior to the commencement of the survey, and following the cessation of activities.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
Additional control measures				
N/A	Using more than one support vessel to further reduce the potential for collision or interference with other marine users	An additional support vessel allows for communication and management of interactions, if there is an interaction with more than one approaching third party vessel, to ensure the exclusion (safety) zone is observed. The only benefit would be if the primary committed support vessel is non-operational (e.g. breakdown) or in the event of multiple simultaneous vessel collision threats.	Additional costs associated with having an additional vessel during the survey can extend into hundreds of thousands of dollars, and there is an increased environmental and safety risk of 'small' vessels being at sea.	**Not adopted –** An additional vessel will not significantly reduce the risk of interface with commercial vessels. Both the survey vessel and committed support vessel will be monitoring for and communicating with approaching commercial vessels. It is highly unlikely that there would be multiple simultaneous vessel collision threats given existing controls in place and regulated maritime practices (e.g. SOLAS, COLREGs). The survey vessel will avoid large commercial vessels, including cargo ships.

Santos

6.2.4 Impact and Consequence Ranking

Receptor	Consequence Level
Interaction with other marine users	
Threatened / Migratory Fauna	N/A – related to socio-economic receptors only.
Physical Environment/ Habitat	
Threatened ecological communities	
Protected Areas	
Socio-economic receptors	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 II – Minor – *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 temporary and limited to a maximum of 100 days. Other marine users will not be restricted from entering the Operational Area. However, given the low maneuverability 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***. 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	II – Minor

6.2.5 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 December to 31 March).

Stakeholders have been informed of the proposed seismic activity as detailed in **Section 4**. Santos is committed to continued engagement with relevant stakeholders in the Operational Area.

The area of avoidance 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. Without the detailed data this survey will acquire future 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.

Santos

6.2.6 Acceptability Evaluation

Is the consequence ranked as I (Negligible) or II (Minor)?	Yes – II (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 Activity. 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 – Based on available information and the proposed control measures, Santos considers interference impacts to marine users to be at an acceptable level.		
Defined Acceptable Levels			
Does the predicted impact meet the defined acceptable level of impact (refer to **Section 5.6**)?	Defined Acceptable Level of Impact	Comparison with Predicted Levels of Impact	EPO
	No unplanned interactions with other marine users.	Santos considers the level of impact to other marine users to be of an acceptable level, given that any disruptions to third party vessels are anticipated to be temporary and no inconsistent with normal maritime navigational and communication practices.	EPO-1 EPO-4

6.3 Noise Emissions

6.3.1 Description of Event

Noise emissions	
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 1 µPa. 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 1 µPa @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 1 µPa @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 are 162 dB re 1µPa and for Sikorsky-61 is 108 dB re 1 µPa 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	The extent of underwater noise from the seismic source has been based on acoustic modelling. The acoustic source levels of potential seismic source options being considered for the Petrel Sub-

	Basin SW 3D MSS have been modelled by JASCO Applied Sciences (JASCO) (Koessler and McPherson 2021; **Appendix F**) and the loudest used as a "worst-case" for the purpose of the impact assessment. Acoustic modelling results are described extensively below. The extent of underwater noise from vessels and helicopters is localised.
Duration	For the duration of the Activity, as described in **Section 2**.

6.3.2 Nature and Scale of Environmental Impacts

6.3.2.1 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 or impairment 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 (i.e. zooplankton), including fish, coral and invertebrate eggs and larvae;
+ Invertebrates, including commercially targeted prawn stocks;
+ Fish, including commercial indictor fish stocks;
+ Sharks and rays;
+ Cetaceans;
+ Marine reptiles; and
+ Seabirds and migratory shorebirds; and commercial fisheries.

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 to inform the impact assessment, and interpretation of the numerical noise modelling results. These are discussed for each receptor in **Appendix G** (Technical Appendix: Noise Impacts on Marine Fauna).

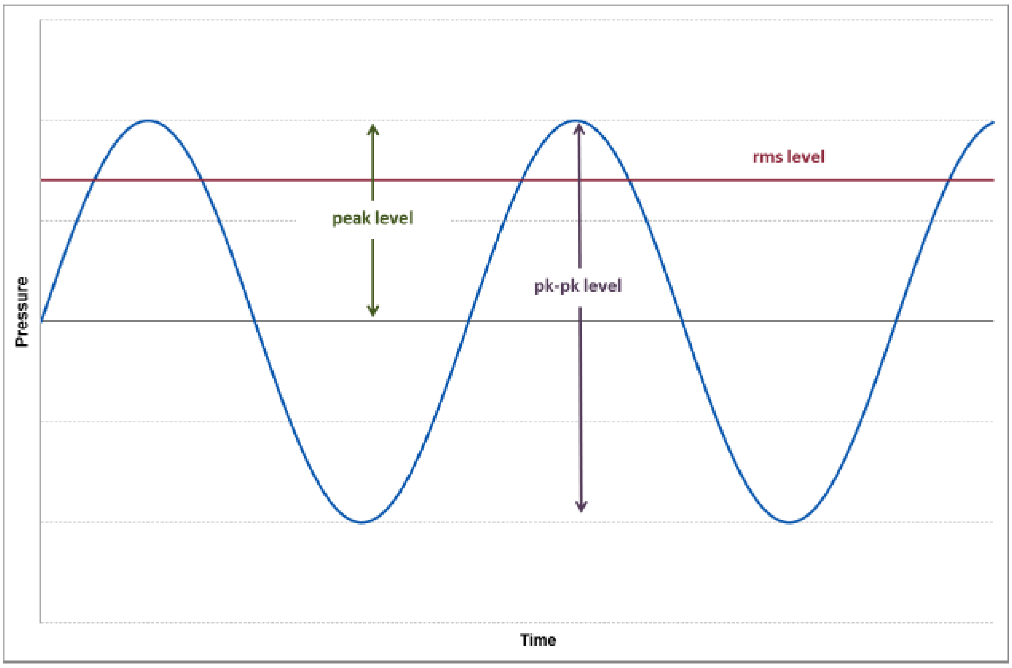
To understand the extent and magnitude of underwater acoustic noise that may result from the Petrel Sub-Basin SW 3D MSS, JASCO was commissioned to model expected sound fields caused by the survey (Koessler and McPherson 2021; refer to **Appendix F** for full copy of the modelling report). It is best 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 G**), 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 et al. 2016).

6.3.2.2 Sound Metric Terminology

Given the multiple measures commonly used to express sound metrics, it is important to ensure any comparisons between specific sound level values are made using the same measures. These sound level metrics are summarised in **Table 6-3**.

Table 6-3: Sound Level Metrics Definition

Metric	Definition
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 (as defined below). 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) Impulsive sounds	Zero-to-peak sound pressure (PK), the greatest magnitude of the sound pressure during a specified time interval. PK levels are modelled to assess mortality and potential mortal injury to fish, turtles, fish eggs and larvae. Unit: dB re 1 µPa 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. 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.

Metric	Definition
	Unit: dB re 1 µPa
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); 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. Unit: dB re 1 µPa
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, 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 SEL_{24h}. Unit: dB re 1 µPa^2·s
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.

6.3.2.3 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 this Section, with additional detail provided in **Appendix F** and **Appendix G**.

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, 24 hours 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. 2010). Hence, thresholds based on a 24-hour exposure period are considered to be a conservative measure of potential effect.

6.3.2.4 Acoustic Modelling

To assess the potential magnitude and extent of impacts from underwater noise produced during the Petrel Sub-Basin SW 3D MSS, JASCO (a specialist in the field of marine acoustics) modelled sound propagation at several locations that were representative of the different water depths, bathymetry and seabed properties within the Acquisition Area (Koessler and McPherson 2021; **Appendix F**).

The objective of this acoustic modelling study was to evaluate the potential effects of sound on marine fauna including cetaceans, marine reptiles, fishes, elasmobranchs, benthic invertebrates and zooplankton, and on socio-economic receptors such as commercial fisheries and marine protected areas.

A summary of the acoustic modelling is provided below.

6.3.2.4.1 Model Scenarios

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 Full-fold Acquisition Areas. Six standalone single impulse sites and three representative accumulated sound exposure scenarios were defined (**Figure 6-2**), based upon the acquisition parameters described in **Section 2.5**. Water depths of single impulse sites ranged from 62 m to 103 m.

Noting that the EP retains optionality on the whether sail lines in each Full-fold Acquisition Area will be acquired in a north-west to south-east orientation or in a north-east to south-west orientation, the three accumulated sound exposure scenarios included examples of lines acquired in both directions. The orientations of the modelled seismic source at the single impulse sites and the accumulated sound exposure scenarios were selected to assess the furthest potential sound propagation distance broadside (generally the loudest horizontal direction from the source) from the seismic source towards receptors in both shallow water and deep-water as relevant to the survey. The rationale for selecting each scenario is as follows:

+ Area A: Scenario 1 comprised three full lines plus an additional partial line orientated north-east to south-west. Water depths ranged from approximately 75 m to 103 m covering the deeper basin waters as well as running adjacent to shallower bank and pinnacle features. The sail orientation was selected to assess the broadside sound propagation into deeper basin waters and to assess the north-west to south-east orientation. Furthermore, this sail line orientation maximizes the number of consecutive lines as opposed to the north-west, south-east direction. Several consecutive lines generally result in large distances to thresholds for the accumulated sound exposure scenarios, as opposed to a single line, due to the additive increase in sound energy from relatively close sources.

+ Area B: Scenario 2 comprised three full lines plus an additional partial line orientated north-west to south-east. Water depths ranged from approximately 62 m to 80 m. The orientation of the sail lines for this scenario was selected to examine the broadside sound propagation towards coastal and shallow water receptors including important areas for turtle internesting areas as well as inshore dolphin habitats. The selected lines, as shown in **Figure 6-2**, were based on an earlier line plan and as such, two lines do not lie within the Full-fold Acquisition Area. The selection of these lines and the associated modelled results are still valid, however, as the water depths are similar inside and outside of this part of Full-fold Acquisition Area B, and the modelled lines are closer to nearshore receptors than the current line plan.
+ Area C: Scenario 3 comprised two full lines plus an additional partial line orientated north-west to south-east. Water depths ranged from approximately 60 m to 80 m covering the both the deeper and shallow waters towards the shore. The orientation of the sail lines for this scenario was selected to examine the broadside sound propagation (the loudest horizontal source level direction) towards NT waters as well shallow water areas.

All three scenarios consider the full range of water depths relevant to commercial fisheries.

It is acknowledged that the 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. 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 (24-hour) sound exposures arising from seismic acquisition.

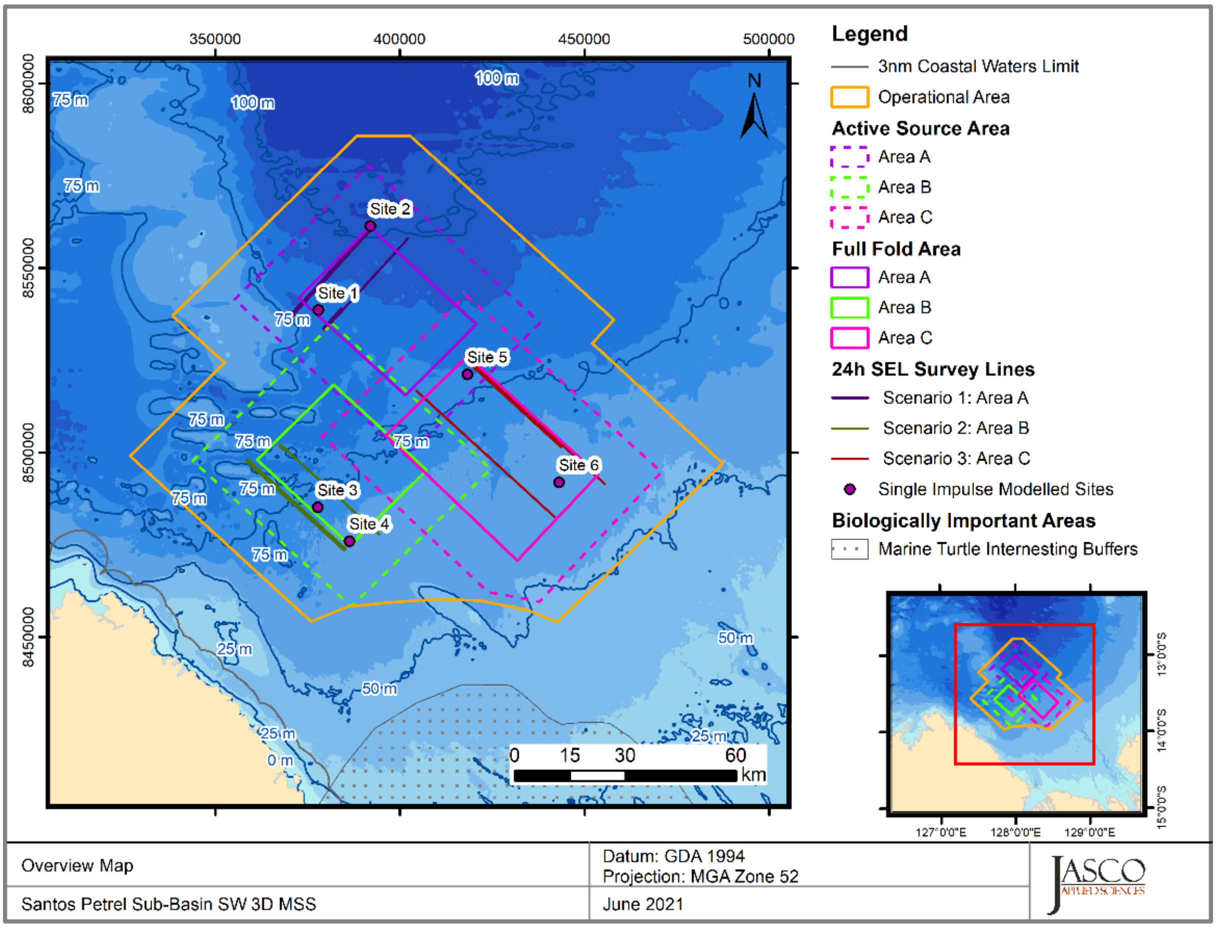


Figure 6-2: Location of Single Impulse Sites and SEL_{24h} Scenarios for Acoustic Modelling

6.3.2.4.2 Source Levels

Preliminary source modelling was conducted to determine the source with the highest equivalent far-field acoustic output of two comparable source arrays (which were defined as being between 2,495 cui and 3,480 cui to meet the technical specification and objectives of the survey). These arrays were coupled with single impulse propagation modelling to determine the array most likely to produce the largest ranges to thresholds. This was determined to be a 3,480 cui seismic source with a 6 m tow depth.

Therefore, the acoustic modelling considered the 3,480 cui seismic source in a triple source configuration, towed at 6 m depth behind a single vessel (Koessler and McPherson 2021; **Appendix F**). 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.

The 3,480 in^3 source was selected for further detailed sound propagation modelling and the impact assessment based on it producing the greatest sound levels. **Table 6-4** shows the PK and per-pulse SEL source levels in the horizontal and vertical planes.

Table 6-4: Far-field source level specifications for the 3480 in3 seismic source (Koessler and McPherson 2021).

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)	
		10–2,000 Hz	2,000–25,000 Hz
Broadside	248.6	225.3	185.6
Endfire	247.6	225.2	190.5
Vertical	258.1	230.9	197.8
Vertical (surface affected)*	258.1	233.5	200.8
* The vertical source level that accounts for the "surface ghost" (the out of phase reflected pulse from the water surface) is presented for comparison with the output of other seismic source models.			

When the final seismic source is selected for the Petrel Sub-Basin SW 3D MSS, Santos will undertake source modelling using the same JASCO Airgun Array Source Model (AASM) to confirm if the source specifications are comparable and the potential impacts and risks will be within those assessed and found to be acceptable in this EP. Further information regarding this control measure are provided in **Section 6.3.4** below, with a corresponding environmental performance standard provided in **Section 8.6**.

6.3.2.4.3 Sound Propagation Model

Three complementary underwater acoustic propagation models were used in conjunction with the selected modelled seismic 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 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.

Contours of the modelled underwater sound fields were computed, sampled either as the maximum value over all modelled depths (maximum-over-depth: MOD) or at the seafloor for the two single pulse locations, and for the two cumulative SEL_{24h} scenarios. The modelled distances for each of the sound exposure thresholds 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. 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.

6.3.2.4.4 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. This includes programs conducted in 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. 2018a, 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 (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 2021), and where uncertainty exists, values which lead to a conservative estimation of the transmission loss are selected.

6.3.2.5 Plankton

6.3.2.5.1 Receptors

The assessment considers the effects of seismic sound on zooplankton, including eggs and larvae suspended in the water column. Planktonic receptors considered to be of particular value include:

+ Commercial prawn eggs and larvae; and
+ Commercial fish eggs and larvae.

6.3.2.5.2 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 a number of 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 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 these results, 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 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 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 CSIRO simulation was based on a hypothetical 3D survey of 2,900 km² in size and over a 35-day period. 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). 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.

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 the 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.

6.3.2.5.3 Thresholds

Popper et al. (2014) has published exposure guidelines for fish eggs and larvae (**Appendix G**) which are based on pile driving. Although pile driving and seismic surveys both produce impulsive sound, thresholds derived from pile driving are potentially conservative given that pile driving impulses result in a more rapid rise time in peak pressure than seismic pulses. The thresholds in **Table 6-5** have been considered in the assessment of noise impacts to plankton.

Table 6-5: Sound level threshold criteria and values for mortality, injury, TTS and behavioural impacts to plankton

	Plankton (fish 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. (2016a); 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 $\mu Pa^2 \cdot s$ (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 (R_{max})	110-160 m	50 m	N/A	N/A	N/A	N/A

[1] Popper et al. (2014)

6.3.2.5.4 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;
+ According to information provided by NPFI in relation to previous seismic surveys in the region, less than 1% of prawn larvae survive the 2-4 week planktonic larval phase to reach suitable coastal nursery habitats where they may settle, further indicating that natural mortality rates are high and recruitment rates may vary considerably;
+ In the seismic exposure 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;
+ Sætre and Ona (1996) calculated that under the 'worst-case' scenario, the number of larvae killed during a typical seismic survey was 0.45% of the total population, and they concluded that mortality rates caused by exposure to airgun sounds are so low compared to natural mortality that the impact from seismic surveys must be regarded as insignificant;
+ Estimated distances for mortality of fish eggs and larvae (maximum 160 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)) (refer to **Table 6-5**), 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;
+ The magnitude of such localised impacts is negligible and is not expected to be discernible at the regional scale when considering the large natural spatial and temporal variability and scale of plankton and spawning biomass throughout the wider region; and
+ 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.

The potential impacts to plankton are considered further in the context of prawn and fish spawning and recruitment in **Section 6.3.2.6** and **Section 6.3.2.7** below.

6.3.2.5.5 Summary

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

6.3.2.6 Invertebrates

6.3.2.6.1 Receptors

Soft sediment habitats that cover the majority of the Operational Area support relatively little seabed structure or sessile epibenthos. They are sparsely covered by sessile filter-feeding organisms (e.g. gorgonians, sponges, ascidians and bryozoans) and mobile invertebrates (e.g. echinoderms, prawns and detritus-feeding crabs) (Brewer et al. 2007; DSEWPaC 2012a). The shelf and basin geomorphological features that make up the majority of the seabed within the Operational Area are dominated by 'infaunal plains' which mainly support infauna with scattered epifauna (Przeslawski et al. 2011). Woodside (2004) observed infauna assemblages comprised mainly of two phyla, Arthropod crustaceans (including burrowing shrimps and crabs) and tube-dwelling Annelida (polychaete worms).

Banks and shoals in the western part of the Operational Area, as well as two pinnacle type features in the north of the Operational Area provide a higher proportion of hard substrate in an otherwise soft sediment environment, and support a greater abundance and diversity of epifauna biota such as octocorals and sponges (Przeslawski et al. 2011). At their shallowest points, the banks rise to approximately 62 m water depth and the two pinnacle features rise to within approximately 82 m and 90 m of the sea surface. These features are part of broader regional scale KEFs.

Commercial invertebrate species, such as banana and tiger prawns, are key invertebrate species in the JBG, as evidenced by NPF fishing activities in the JBG.

Key invertebrate receptors considered in this assessment include:

+ Benthic invertebrate communities associated with the carbonate bank and terrace system of the Sahul Shelf KEF and the pinnacles of the Bonaparte Basin KEF; and
+ Spawning and recruitment of commercially significant prawn stocks in the JBG.

6.3.2.6.2 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 are utilised by animals to maintain their orientation, direct their movements through the water and may play a key role in controlling the behaviour responses of invertebrates to a wide range of stimuli. They may also function as acoustic particle motion detectors and thus play a role in the detection of underwater sound (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.

Santos acknowledge 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), which provide risk assessment outcomes for mobile and immobile invertebrates of 'moderate to high' and severe to high' respectively. Santos notes, however, that the DPIRD risk assessment was undertaken based on the worst-potential effect at the level of *individual* invertebrate organism and assumed that an individual is positioned directly in the path of the seismic source. Therefore, the WA DPIRD risk assessment represents a conservative scenario that is not necessarily representative of real-life exposures to all invertebrate organisms that may be exposed within a seismic survey area, or impacts at a population or community level. Santos has considered the available scientific research, as well as additional activity-specific and situation-specific context to assess potential risks to populations.

The potential sensitivities of invertebrate organisms are summarised in **Table 6-6**, 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 G**.

Table 6-6: Sensitivities for Invertebrates

	Summary of Potential Sensitivities
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; Webster et al. 2018). Several studies have been undertaken on decapod crustaceans (lobsters, prawns, crabs) 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 tens of hundreds 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. Lethal effects have not been observed in studies of exposure of lobsters, crabs or shrimps (Christian et al. 2003; Andriguettto-Filho et al. 2005; Parry and Gason 2006; Payne et al. 2007; Day et al. 2016a). No behavioural response or evidence of animals migrating out of a seismic survey area have been reported in snow crabs (Christian et al. 2003) or in shrimp (Celi et al. 2013). A pilot study on snow crabs (Christian et al. 2003) exposed captive adult male crabs and egg-bearing female crabs to approximately 197–237 dB re 1 µPa PK-PK and SELs of <130–187 dB re 1 µPa².s. The crabs were exposed to 200 pulses over a 33-minute period. No acute or chronic (12 weeks post-exposure) mortality impacts were observed in the adult crabs. Stress indicators

	Summary of Potential Sensitivities
	in the snow crabs also showed no evidence of significant acute or chronic impacts. The crabs also did not exhibit any overt startle response during the exposure period or avoidance of the area following exposure. DFO (2004) also exposed caged egg-bearing crabs to 132 hours of impulses from a seismic survey with maximum received sound levels of approximately 190 dB re 1 µPa PK. Neither acute nor chronic lethal or sub-lethal injury to the female crabs or crab embryos were observed up to five months following exposure. Payne et al. (2007) conducted a pilot study of the effects of exposure to seismic sound on various health indicators of American lobster. Adult lobsters were exposed at approximately 2 m range from a seismic source for either 20 or 200 times to average pressures of 202 dB re 1µPa PK-PK or 50 times to 227 dB re 1µPa PK-PK, and then monitored over several months for changes to survival, food consumption, turnover rate, and serum biochemistry. No immediate or delayed mortality was observed, nor damage to mechano-sensory systems and the ability of lobsters to right themselves when turned over. There was evidence of a decrease in serum enzymes and increases in food consumption in the weeks to months post exposure, which may indicate stress effects or potential osmo-regulatory disturbance. The results therefore indicate the potential for sub-lethal effects but there were no obvious impacts to long-term survival and, therefore, limited ecological implications. Payne et al. (2008) did not observe any startle responses in aquarium experiments with lobsters and shrimp exposed to approximately 200 dB re 1µPa PK-PK. 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). Exposure to seismic sound did not result in any mortalities to adult lobsters, even at close proximity directly beneath the seismic source, were not affected. Day et al. (2016a, 2016b) suggested that lobsters may be able to adapt or compensate for long-term statocyst impairment. Day et al. (2016a) 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). Day et al. (2019) found that airgun exposure caused damage to the righting reflect and statocysts in rock lobsters (*Jasus edwardsii*). Following exposure equivalent to a full-scale commercial array (3,100 cui) passing within 100–500 m, lobsters showed impaired righting and significant damage to the sensory hairs of the statocyst. Reflex impairment and statocyst damage persisted up to 365 days post-exposure and did not improve following moulting. For this study, maximum measured received noise levels were 209-213 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

	Summary of Potential Sensitivities
	or have been seen in field studies where there have been repeated exposures that are not necessarily reflective of an actual seismic survey. For example, Matishov (1992; cited in Parry and Gason 2006) reported a single scallop shell splitting in a sample of three scallops, but this was located 2 m beneath a seismic source element and therefore exposed to maximum sources levels (which is not representative of a typical commercial seismic survey). Recent Australian studies (Przeslawski et al. 2016a, 2018; Day et al. 2016b, 2017) have focussed on commercial scallops (*Pecten fumatus*), and found no evidence of immediate mortality or change in condition following exposure to seismic survey. Day et al. (2016b, 2017) concluded that repeated seismic sound exposures resulted in a chronic increase in mortality over timeframes of approximately four months post-exposure, though not beyond naturally occurring rates of mortality. Sub-lethal effects to exposed scallops were also observed by Day et al. (2016b, 2017) indicating a compromised capacity for homeostasis and potential immunodeficiency over acute (hours to days) and chronic (months) timescales post exposure. Exposures did not elicit energetically expensive behaviours (i.e. extensive swimming or long periods of valve closure), but scallops showed significant changes in some behavioural patterns during exposure (e.g. “flinch” response) and scallops showed an increase in recessing into sediment following exposure (Day et al. 2017). 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.
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.

6.3.2.6.3 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 6-7.**

Table 6-7: 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 of invertebrates 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 lower level of 202 dB re 1 µPa (PK-PK) has been applied in this assessment. This is a precautionary threshold to determine potential impacts considering other studies (Christian et al. 2003) observed no lethal or sub-lethal effects in response to levels as high as 237 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 levels of 226-232 dB re 1 µPa PK levels at which no acute or chronic impacts to corals 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	512-604 m	N/A – Particle motion was not modelled for this Activity due to low mollusc species diversity and absence of ecologically or commercially significant bivalve species in the JBG.	Not exceeded on the seafloor at any sites

[1] Payne et al. (2008)
[2] Day et al. (2016a)
[3] Heyward et al. (2018)

6.3.2.6.4 Impact Assessment

Based on the research summarised in **Table 6-7** and in **Appendix G**, limited impacts to benthic invertebrates are expected. Based on the no-effect criteria for crustaceans, 202 dB re 1 µPa (PK-PK) was reached at a range of 512-604 m from the seismic source. Therefore, effects to some organisms may occur across the Full-fold Acquisition Areas and Active Source Zones. Some benthic invertebrate species may experience sub-lethal effects or sessile invertebrates such as bivalve molluscs may experience chronic mortality in some individuals in the weeks or months following exposure within tens or hundreds of metres from the seismic source.

The effects on the infauna communities that dominate the Operational Area are likely to include sub-lethal effects to Arthropod crustaceans (burrowing shrimps and crabs). The effects of seismic exposures to organisms such as polychaete worms have not been studied but it is possible that these organisms could also experience a range or sub-lethal to chronic mortality effects, similar to the effects observed in bivalve molluscs by Day et al. (2016b, 2017). Should this occur, the continuous natural cycle of death, recovery and recruitment of invertebrates from adjacent sediments will occur in parallel over the same timescales, and therefore it is questionable whether any impacts from seismic exposure would be detectable from natural fluctuations in relative abundance, benthic community composition and structure. Day et al. (2017) and Payne et al. (2007, 2008) acknowledge that the changes observed in their research are likely within the range of variation that can occur from other common natural and anthropogenic stressors. The ecological implications of such impacts on benthic invertebrate communities are not expected to be significant or long- term.

Sponges and corals that may occur in association with hard substrate, including the bank and pinnacle features within the Operational Area are not expected to be impacted. The threshold value of 226 dB re 1 µPa PK for corals and sponges was not reached at any of the modelling sites (**Appendix F**). It is also important to note, the 226 dB re 1 µPa PK reported in Heyward et al. (2018b) is not a threshold above which impacts are expected to occur, but a level at which no short term or long term effects were observed.

Consequently, indirect impacts on higher trophic level species that target benthic invertebrates as a food source are also not expected. For example, benthic organisms are a key food source for demersal fish species; following the passing of the seismic source, benthic invertebrates are still available to be foraged and any chronic mortality that occurs over the weeks or months following exposure is expected to be negligible in the context or natural mortality and recruitment.

Carbonate bank and terrace system of the Sahul Shelf KEF and pinnacles of the Bonaparte Basin KEF

The Operational Area (including the Active Source Zones for Areas A and B) overlaps with bank features that are included within the carbonate bank and terrace system of the Sahul Shelf KEF. Banks in the KEF that rise to within 45 m water depth support more biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans (Brewer et al. 2007; Nichol et al. 2013). The Operational Area (and Area A) also includes two small pinnacle features within the pinnacles of the Bonaparte Basin KEF. Pinnacles provide areas of hard substrate in an otherwise soft sediment environment.

The banks located within the Operational Area rise to approximately 62 m. The pinnacles located within the Operational Area rise to approximately 82 and 90 m. At these depths, there is limited potential for extensive coverage of photosynthetic organisms such as hard corals to occur, but sponges and soft octocorals may be present at these depths. Based on the potential effects described above, no impacts to sponges or corals will occur. The habitat structure and condition of the carbonate bank and terrace system of the Sahul Shelf KEF and pinnacles of the Bonaparte Basin KEF will not be impacted. Impacts to invertebrates that occur in the JBG, such as crabs, molluscs and echinoderms, are predicted to be localised. Changes to these communities are unlikely to be discernible from natural variation. Therefore, the ecological function and values of these KEFs will not be impacted.

Spawning and recruitment of commercially significant prawn stocks

The most commercially and economically significant invertebrate species in the JBG are prawns, targeted by the NPF. Species caught include white banana prawns, red-legged banana prawns, brown tiger prawns, grooved tiger prawns, blue endeavour prawns and red endeavour prawns. Banana prawns and tiger prawns are indicator stocks for the fishery, while endeavour prawns are a non-target (but still retained) catch species. Historically, the JBG has been particularly significant for banana prawns, with the JBG contributing about 65% of the NPF's red-legged banana prawn catch and around 20% of the NPF's total banana prawn catch.

White banana prawns can generally be found at depths of 16 – 25 m but can occur to depths of 45 m. Red-legged banana prawns are found at depths of 35 – 90 m (AFMA 2021), hence the red-legged banana prawns targeted by the NPF are the species most likely to be present in significant numbers in the Operational Area. Tiger prawns inhabit shelf waters to depths of 200 m but make up a smaller component of the catch in the JBG.

The biological stock structure of the banana and tiger prawn species is uncertain. There is some evidence that there may be separate biological stocks within the NPF, however, the boundaries of these biological stocks are unknown. In the JBG, a single separate stock for banana prawns is assumed for stock assessment purposes, although stock status for the species is reported at the management unit level (the whole of the Northern Prawn Fishery) (Parsa et al. 2020).

The banana prawn and tiger prawn stocks are assessed as being Sustainable (Larcombe et al. 2018; Parsa et al. 2020). Although biological stock boundaries are uncertain and a stock–recruitment relationship is not established, the status of the stocks is based on a weight-of-evidence approach, with the harvest strategy in the NPF designed to ensure adequate remaining spawning biomass closing the fishing seasons if catch rates fall below set catch-rate trigger levels. The species has shown resilience to fishing pressure, with strong subsequent recruitment following historical high levels of catch and fishing mortality. The stock biomass is therefore unlikely to be depleted and that recruitment is unlikely to be impaired (Larcombe et al. 2018; Parsa et al. 2020).

From 2021, a closure area will apply to the whole of the JBG south of latitude 13°S to exclude fishing during the banana prawn fishing season. Only fishing during the 1 August to 1 December tiger prawn season is now permitted in the JBG closure area. During stakeholder consultation, the NPFI advised Santos that they had concerns regarding a seismic survey taking place within the closure area on the basis that it could impact the banana prawn stock recovery and, therefore, potentially influence catch monitoring that is to be undertaken over the next 5 years for the purposes of assessing the JBG prawn biomass and potential reopening of the JBG to fishing during the banana prawn season.

The assessment of impacts to spawning and recruitment of banana and tiger prawn stocks in the JBG considers:

+ Potential effects to the adult spawning biomass, specifically adult female prawns berried with eggs;

+ Potential effects to eggs and larvae dispersed in the water column; and
+ Potential effects to migrating juveniles recruiting to the adult stocks.

Effects to adult female prawns berried with eggs

Impacts on prawns are assessed based on research undertaken on seismic exposures to a variety of decapod crustaceans, including lobster, shrimp and crab. As summarised in **Table 6-7** and in **Appendix G**, lethal effects have not been observed in studies of exposure of lobsters, crabs or shrimps (Christian et al. 2003; Andriguettto-Filho et al. 2005; Parry and Gason 2006; Payne et al. 2007; Day et al. 2016a). No behavioural response or evidence of animals migrating out of a seismic survey area have been reported in snow crabs (Christian et al. 2003) or in shrimp (Celi et al. 2013). A range of studies have exposed female crustaceans bearing eggs to sound pressures of approximately 196–237 dB re 1 µPa PK-PK, with no reports of acute or chronic mortality in the adult lobsters and no mortality of embryos (Christian et al. 2003; DFO 2004). Day et al. (2016a, 2016b) also reported that exposures equivalent to approximately 205 dB re 1 µPa (PK) did not impact the condition or development of eggs carried by female lobsters, or the size or morphology of the larvae once hatched. Therefore, potential exposure of berried females to the seismic source is not expected to result in any mortalities in addition to natural or fishing mortalities and, therefore, no reduction in the adult spawning biomass. Significant impacts to eggs carried by the females are also unlikely to occur, with berried eggs protected by adults expected to be less sensitive than dispersed planktonic eggs, as assessed below.

Effects to eggs and larvae dispersed in the water column

Female prawns produce hundreds of thousands of eggs each year, released in batches over multiple spawning events (refer to **Section 3.8.1.4**). Prawns in the JBG spawn to some degree throughout the entire year. Banana prawns have two peak spawning periods, September – November and March – May. Brown tiger prawns have a spawning peak between July and October. Grooved tiger prawns have a spawning peak in in August-September, with a secondary peak in February. Fertilized eggs disperse in the water column and are carried by tides and currents. Larvae hatch within 24 hours and some larvae will eventually settle in nursery habitats in shallow coastal waters (mangroves, creeks, seagrass beds). Loneragan et al. (2002) found that offshore spawning resulted in the advection of larvae over large distances in the JBG before settlement in their nursery habitats. Less than 1% of larvae survive the 2-4 week offshore planktonic larval phase. The majority of larvae will either not reach appropriate settlement habitat, or may be lost to predation or other natural factors.

During the egg and larval dispersal phase, some eggs and larvae may be impacted by seismic impulses emitted during the Petrel Sub-Basin SW 3D MSS. As described in **Section 6.3.2.5**, mortality and injury to zooplankton, including eggs and larvae, is likely limited to metres to tens of metres from a seismic source, although based on the Popper et al. (2014) threshold for eggs and larvae, some impacts could occur up to 160 m from the seismic source during the Petrel Sub-Basin SW 3D MSS.

To assess the potential impacts to dispersed prawn eggs and larvae, the overlap of the survey and proportion of suitable spawning habitat for the JBG prawn stocks has been considered. The assessment primarily considers the spawning range of red-legged tiger prawns on the basis that is it the most significant commercial prawn species in the JBG, but also because its depth range (35 – 90 m) has the greatest overlap with the Active Source Areas where depths range from 45 – 105 m. Tiger prawns may also spawn in the JBG but they make up a smaller proportion of the prawn catch. Their depth range extends up to 200 m water depth so assessment based on the red-legged banana prawn depth range is likely to provide a conservative estimate for tiger prawns. White banana prawns occur in water depths less than 45 m and so are unlikely to be impacted by the survey.

The area of the JBG that corresponds with the red-legged banana prawn 35 – 90 m depth range is approximately 40,000 km^2. Some level of spawning may occur throughout this area, throughout the year. However, to provide a further level of conservatism, the assessment of potential spatial overlap with spawning habitat is limited to the area that has historically been targeted for prawns by the NPF (based on the 2013 – 2019 NPF fishing intensity data presented in **Figure 6-1** in **Section 6.1.3**). The correlation with historic fishing effort is considered to represent the core area where adult prawns may be found in greatest abundance in the JBG. This area covers 13,748 km^2 and is, therefore, significantly smaller than the area covered by the depth range for the species in the JBG.

In any 24 hour period of seismic data acquisition, during which eggs and/or larvae released from the adult spawning stock may drift through the survey area, the potential effects footprint associated with the 160 m effects range (based on the Popper et al. (2014) threshold) applied to sail lines would be equivalent to approximately 64 km^2 (0.47%) of the 13,748 km^2 core area of adult prawns in the JBG.

Given the proposed survey period of 1 December to 31 March, the maximum number of acquisition days that could coincide with the peak spawning periods for red-legged banana prawns (September – November and March – May) is 31 days (March only), providing a maximum temporal overlap of approximately 17%.

Therefore, the total spatio-temporal overlap with the core area and peak spawning periods for red-legged banana prawns is 0.08% (0.47% of the core area per day may be exposed for 17% of the peak spawning period). Using 0.08% as a proxy for the proportion of red-legged banana prawn eggs and larvae in the JBG that could be impacted, and in the context of natural larvae mortality (potentially higher than 99% given the less than 1% settlement rate) and naturally variable annual recruitment rates, the potential risk of the Petrel Sub-Basin SW 3D MSS on dispersed prawn eggs and larvae in the JBG is negligible.

Noting again that the area where spawning may occur is likely larger than the core area assessed and that some level of spawning occurs year-round, the proportion of eggs and larvae released during spawning that may be affected by the survey is likely to be even less.

Effects to migrating juveniles recruiting to the adult stock

The migration of juvenile banana prawns from coastal nursery grounds to the offshore adult stock in the JBG is variable but appears to be split into two periods, with the migration of the main cohort occurring sometime between November and March, with a possible second cohort migrating from April to June (Neil Loneragan, CSIRO Division of Marine Research, pers. comm., April 2000). Migration of the juveniles occurs throughout the southern and eastern coastal waters of the JBG and is thought to be triggered by rainfall and river discharge. The main migration period and migration route in the southern part of the JBG has been mostly protected from fishing mortality by the NPF using seasonal closures (closed 1 December to 31 March). Until 2021, a closure area in the southern part of the JBG has also applied each year during the 1 April to 15 June banana prawn fishing season, followed by another closure season from 15 June to 1 August, preventing fishing during the migration of the second cohort.

The Operational Area overlaps with waters where the adult banana prawn stock resides, as indicated by the area that has historically been targeted for prawns by the NPF (based on the 2013 – 2019 NPF fishing intensity data presented in **Figure 6-1** in **Section 6.1.3**). The fishing area, and apparent core area where adult prawns tend to occur, includes waters in the southern half of the Operational Area as well as in shallower waters to the south and west of the Operational Area. The majority of the

Santos

Operational Area is located in deeper waters to the north of the pre-2021 closure area intended to protect the main migration area (refer to **Figure 6-1**).

As summarised in **Table 6-7** and in **Appendix G**, lethal effects have not been observed in studies of lobsters, crabs or shrimps exposed to seismic impulses (Christian et al. 2003; Andriguettto-Filho et al. 2005; Parry and Gason 2006; Payne et al. 2007; Day et al. 2016a). In addition, no behavioural response or evidence of animals migrating out of a seismic survey area have been reported in snow crabs (Christian et al. 2003) or in shrimp (Celi et al. 2013).

Therefore, while the Operational Area overlaps the adult prawn stock that juveniles migrate offshore to recruit to, it is located at the farthest extent of the migration. The survey will not disturb juveniles from migrating through nearshore waters or prevent juveniles from reaching offshore waters greater than 35 m water depth where the adult stock resides. In addition, no mortality of juvenile and sub-adult prawns is expected based on the available studies on decapod crustaceans (Christian et al. 2003; Andriguettto-Filho et al. 2005; Parry and Gason 2006; Payne et al. 2007; Day et al. 2016a).

6.3.2.6.5 Summary

Based on the impact assessment no long term or population impacts to invertebrates (crustaceans, molluscs, corals, filter-feeders) are predicted. Thus, the consequence level for benthic invertebrates is assessed as negligible. No effects to benthic invertebrates are expected within the pinnacles of the Bonaparte Basin and the carbonate bank and terrace system of the Sahul Shelf KEFs.

The potential risk to commercial prawns within the JBG is also considered to be limited and at an acceptable level based on:

+ Lethal effects to crustaceans have not been observed in studies (Christian et al. 2003; Andriguettto-Filho et al. 2005; Parry and Gason 2006; Payne et al. 2007; Day et al. 2016a);
+ No significant impacts to adult female prawns berried with eggs are expected during the spawning season given that there have been no reports of acute or chronic mortality in the adult lobsters and no mortality of embryos exposed to seismic impulses (Christian et al. 2003; DFO 2004);
+ The potential for mortality to dispersed eggs and larvae is limited to an insignificant proportion of the total biomass that will occur across the JBG, compared to natural mortality rates and variability in recruitment; and
+ The survey will not prevent juvenile prawns from migrating to the adult stocks in offshore waters.

6.3.2.7 Fish, Sharks and Rays

6.3.2.7.1 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;
+ Sharks and rays, including whale sharks and sawfish;
+ Potential site-attached fish assemblages with the carbonate bank and terrace system of the Sahul Shelf KEF and the pinnacles of the Bonaparte Basin KEF; and
+ Spawning and recruitment of commercially significant fish species.

6.3.2.7.2 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 detect sound and vibration to some degree (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 pressure 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 and rays, including whale sharks and sawfish) (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 2019).

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 therefore can 'hear' the seismic source.

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.

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.

The potential impacts and sensitivities are summarized in **Table 6-8**, further detail on relevant scientific studies and research undertaken used to inform this impact assessment is included in **Appendix F** and **Appendix G**.

Santos has taken into consideration WA 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.

Table 6-8: 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 direct 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 standard 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.

6.3.2.7.3 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 F** and **Appendix G**, the threshold criteria in **Table 6-9** have been adopted for the assessment of potential noise impacts to fish. **Table 6-9** provides the modelled distances for the criteria.

Table 6-9: 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). Environmental Resources Management Australia (ERM) undertook a detailed literature review of potential fish mortality and physical injury as a result of exposure to seismic sources (ERM 2017). Of the 28 studies reviewed, only three observed direct mortality and in each case, mortalities occurred to caged fish at very close proximity to the seismic source (<2 m), which is not representative of real-life exposures from seismic surveys as fish are free-swimming and are not typically exposed at such close range. 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 sound exposure criteria proposed by Popper et al. (2014) for mortality and injury are considered to be highly conservative and provide a precautionary approach in the assessment of potential injury and mortality effects to fishes from exposure to	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 et al. 2014). Sound exposure guidelines proposed in Popper et al. (2014), which indicated that TTS may occur at SEL_{cum} levels >186 dB re 1 µPa²·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).

	Mortality/Potential Mortal Injury		Recoverable Injury		TTS	
	underwater noise from marine seismic surveys.					
	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-hours is applied to the SEL_{cum} metric.					
Relevance of thresholds adopted	Based on the literature review presented in **Appendix G**, 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 and rays) [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	70 m MOD 80 m seafloor	50 m MOD Not exceeded at seafloor	70 m MOD 80 m seafloor	50 m MOD Not exceeded at seafloor		6.6 km MOD 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	130 m MOD 210 m seafloor	50 m MOD Not exceeded at seafloor	130 m MOD 210 m seafloor	70 m MOD 60 m seafloor		6.6 km MOD 6.2 km seafloor

	Mortality/Potential Mortal Injury		Recoverable Injury		TTS	
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	130 m MOD 210 m seafloor	50 m MOD Not exceeded at seafloor	130 m MOD 210 m seafloor	70 m MOD 60 m seafloor		6.6 km MOD 6.2 km seafloor
Threshold Adopted for Assessment	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), 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 smaller than those estimated using the PK-based metric. Therefore, in line with the conditions of the criteria as per Popper et al. (2014), the PK 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] 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.

[3] 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.

6.3.2.7.4 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 G**);
- 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 a risk scores of 'high' for demersal finfish and 'negligible' for pelagic finfish. Santos notes that the DPIRD risk assessment was undertaken at the level of *individual* finfish and assumed that an individual remains stationary (i.e. does not flee) while positioned directly in the path of the seismic source. Therefore, the WA DPIRD risk assessment represents a conservative scenario that is not necessarily representative of real-life exposures to fish.
- 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 to fishes without a swim-bladder connection involved in hearing are assessed as high within tens of metres of the seismic source and moderate within hundreds of metres from the 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 may occur in the Operational Area do not possess a mechanical connection between swim bladder and ears. These species have also 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). Note that demersal rock cods are not true cods (Gadidae) and so are not considered to have the same specialised hearing sensitivity. Therefore, these species of fish are considered to belong to the group of fishes that are primarily sensitive to particle motion with some limited sensitivity to sound pressure (Group II fishes according to the Popper et al. 2014 classification).

As shown in **Table 6-9**, fish with a swim bladder not involved in hearing could reach mortality/Potential Mortal Injury (PMI) and recoverable injury thresholds at 130 m from the seismic source within the entire water column, and 210 m at the seafloor, based on the single pulse PK thresholds. Therefore, injury effects could occur to demersal fishes in close proximity to the seismic source within or adjacent to the Active Source Zone. The maximum predicted distance to TTS thresholds were 6.6 km within the water column and 6.2 km the seafloor, based on the cumulative SEL_{24h} threshold. However, this SEL_{24h} threshold typically represents an unlikely worst-case scenario, as more realistically fish would not stay in the same location or at the same range for a period of 24-hours.

In his expert review of the TTS effects to demersal fishes for the Santos Bethany 3D MSS, located north-east of the Petrel Sub-Basin SW 3D MSS Operational Area, Popper (2018) 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 metres).
+ Most fishes in the Bethany region (and given the similarity in fish species, therefore can be applied for the Petrel 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.

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. 2000a, 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.

Mortality/PMI and recoverable injury thresholds for fish with no swim bladder (Group I) and fish with a swim bladder not involved in hearing (Group II) are 70 m and 130 m from the seismic source, respectively, within the water column (**Table 6-9**). Therefore, injury effects could occur to pelagic fishes in close proximity to the seismic source within or adjacent to the Active Source Zone. The maximum predicted distance to TTS thresholds were 6.6 km within the water column, based on the cumulative SEL_{24h} threshold.

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).

Sharks and rays (including sawfish)

There are 13 listed threatened or migratory shark and ray species that may be present in the Operational Area and EMBA during acquisition of the survey including sharks, whale sharks, manta rays and four species of sawfish (refer to **Table 3-10**).

No sound exposure thresholds currently exist for acoustic impacts from seismic sources to sharks and rays, which are sensitive only to particle motion. However, as a conservative approach the Popper et al. (2014) guidelines for fish with no swim bladder have been used for this assessment.

As shown in **Table 6-9**, fish with no swim bladder could reach mortality/PMI and recoverable injury thresholds at 70 m and 50 m from the seismic source within the entire water column and at the seafloor, respectively. Therefore, injury effects could occur to sharks and rays in very close proximity to the seismic source within or adjacent to the Active Source Zone. The maximum predicted distance to TTS thresholds were 6.6 km within the water column, and 6.2 km at the seafloor based on the cumulative SEL_{24h} threshold.

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).

The presence of sharks and rays (including whale sharks and sawfish) within the Operational Area during acquisition of the survey is likely to be limited to occasional transits of isolated individuals or small groups. Shark species are highly vagrant and naturally cover large distances, and 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.

During stakeholder consultation for this EP, the NPFI noted that sub-adult and adult sawfishes have been inadvertently caught in the offshore waters of Operational Area. As described in **Section 3.7.5**, all four listed threatened and/or migratory sawfish species are associated with shallow, nearshore waters. Juvenile sawfish (i.e. pups) generally inhabit river and estuarine environments in shallow, nearshore waters and these environments are known sawfish nursery habitats. Therefore, pups are unlikely to occur within the Operational Area but may be present in the shallower waters of the EMBA.

The nearest known location for sawfish pupping (dwarf sawfish – pupping likely to occur) is over 100 km south of the Operational Area, in Cambridge Gulf (DoE 2015f). Green sawfish and narrow sawfish adults have been reported to occur in water depths of over 70 m (Stevens et al. 2005) and 40 m (Last and Stevens 2009) respectively. Dwarf sawfish and freshwater sawfish adults are found in shallower coastal waters (DoEE 2019a). The presence of sawfish in the Operational Area is, therefore, likely to be limited to occasional transient adult or sub-adult individuals and most likely green or narrow sawfish.

Sawfish are recognised as primarily bottom dwellers, therefore they are expected to be present at the seafloor. Based on the modelling results presented in **Table 6-9**, sawfish would have to be within 50 m of the seismic source to experience mortality/PMI or recoverable injury. Similarly, a behavioural response is expected to occur within tens of metres to hundreds of metres. Therefore, impacts to sawfish as a result of the seismic survey are likely to be limited to localised and temporary behavioural disturbance. No impacts to key life stages or nursery habitats are expected, and there will be limited impact to their food sources as outline above and in **Section 6.3.2.6** (invertebrates).

Potential site-attached fish assemblages

For the purposes of the risk assessment, site-attached fishes are defined as fishes that rely on the benthic habitat and demonstrate a very high degree of site fidelity to the extent that they are unlikely or unable to flee an approaching seismic source and are instead likely to remain and/or seek refuge within habitat structures.

The biomass, diversity and abundance of fishes is typically greatest in the photic and upper meso-photic zones (<60 m depth) where biota such as hard corals are most abundant. The disappearance of live coral cover and corresponding lower fish diversity is often reported in water depths greater than 60 m (Lesser et al. 2009; Kahng et al. 2010, 2014; Lindfield et al. 2016; Fukunaga et al. 2016; Abdul Wahab 2018), including at other banks and shoals within the carbonate bank and terrace system of the Sahul Shelf KEF (Heyward et al. 2011 and ERM 2012). The banks and shoals within the carbonate bank and terrace system of the Sahul Shelf KEF have the greatest potential for supporting diverse site-attached fish assemblages is greatest in water depths of 30 – 45 m or less due to the increased presence of photosynthetic biota such as hard corals. However, these habitats become increasingly sparse with depth until approximately 60 – 80 m depth when hard corals are absent and dominant habitat types give way to rubble, sponges and filter feeders (Heyward et al. 2011 and ERM 2012). At these depths, fish species diversity and the potential for site-attached fishes is significantly reduced.

The Operational Area (including Full-fold Acquisition Area B and the Active Source Zones for Areas A and B) overlaps with bank features that are included within the carbonate bank and terrace system of the Sahul Shelf KEF. Banks in the KEF that rise to within 45 m water depth support more biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans (Brewer et al. 2007; Nichol et al. 2013). The Operational Area (and Area A Active Source Zone) also includes two small pinnacle features within the pinnacles of the Bonaparte Basin KEF. Pinnacles provide areas of hard substrate in an otherwise soft sediment environment.

The bank features in the Operational Area represent approximately 4.4% of the total designated area of the carbonate bank and terrace system of the Sahul Shelf KEF. The two pinnacles in the Operational Area each occupy an area of less than 5 km^2, which represents approximately 1.6% of the designated area of the pinnacles of the Bonaparte Basin KEF.

The banks located within the Operational Area rise to approximately 62 m. The pinnacles located within the Operational Area rise to approximately 75 m. At these water depths, there is limited potential for any significant coverage of photosynthetic organisms such as hard corals to occur, but sponges and soft octocorals may still be present at these depths. Consequently, significant site-attached fish assemblages are unlikely to occur at these depths.

Based on the modelling results presented in **Table 6-9**, potential injury or mortality to fishes may occur within 80 – 210 m of the seismic source, depending on the type and sensitivity of the fishes. Significant site-attached fish assemblages are unlikely to occur on the banks and pinnacles in the Operational Area due to the water depths. No banks, shoals or pinnacles within the KEFs which are shallower than 60 m and likely to support site-attached fish assemblages will be exposed to injurious sound levels from the Petrel Sub-Basin SW 3D MSS.

TTS effects at the seafloor may occur up to 6.2 km from sail lines (refer to **Table 6-9**). There is the potential for some fishes at the seafloor within the KEFs to experience TTS effects. The potential for TTS to occur is not the same for all fish species. The Popper et al. (2014) threshold is based on exposure experiments to different types of fish including sensitive fishes with a swim bladder mechanism involved in hearing. Most marine fish species do not have this hearing mechanism and are less sensitive to sound pressure. Therefore, some types of fish may not begin to experience TTS until sound exposure levels are higher. As Popper (2018) summarises, if TTS takes place in site-attached fishes, its level is likely to be sufficiently low that it may not be possible to easily differentiate it from normal variations in hearing sensitivity, and recovery will start as soon as the most intense sounds end and is likely to occur within 24 hours.

The potential for such effects to have significant implications on the fishes' fitness and survival is low. For example, fishes exposed during the Woodside Maxima 3D survey at Scott Reef were examined for evidence of TTS. This included four species of tropical reef fishes, including the pinecone soldierfish (a sound pressure-sensitive species which has a swim bladder connection with the inner ear). None of the four species experienced any TTS following close-range exposure to 190 dB re 1 $\mu Pa^2 \cdot s$ SEL_{cum} (Hastings et al. 2008; Hastings and Miksis-Olds 2012). No significant decreases were detected in the diversity and abundance of either sound pressure-sensitive or non-pressure sensitive fish species after the seismic survey compared to the long-term temporal trend before the survey (Woodside 2011b; Miller and Cripps 2013). Therefore, while TTS effects in site-attached fishes at the banks and pinnacles in or adjacent to the Operational Area may occur, the potential for impacts to individuals' fitness and survival is limited and impacts to fish community structure on the banks and pinnacles are not expected.

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).

The following assessment considers the potential magnitude of effects to fish spawning behaviours, and therefore the potential influence of the survey on recruitment success and the sustainability of key indicator fish species. The assessment considers:

+ Spatial-temporal analysis – to provide context on the proportion of the spawning biomass that may be exposed to sound during the Petrel Sub-Basin SW 3D MSS;
+ Consideration of the natural variability in fish distribution, spawning biomass and recruitment; and
+ Consideration of the sustainability status of the relevant WA and NT fish stocks and fisheries.

While the focus of the assessment is on the key indicator species, the status of the key indicator fish stocks is also used as a robust indicator of the sustainability status within the broader suite of demersal scalefish species within Australian fisheries management units.

Spatial-Temporal Analysis

A spatial-temporal analysis has been conducted to determine the overlap between the survey and the principal spawning ranges and periods of key commercial indicator species. The analysis provides an indication of the proportion of the spawning area and the proportion of the spawning period for each species that may be exposed to sound from the survey.

The following assessment focuses on the following commercial key indicator fish species:

+ Goldband snapper (WA and NT);
+ Red emperor (WA);
+ Saddle-tail snapper (NT);
+ Crimson snapper (NT); and
+ Spanish mackerel (WA and NT).

It is understood from DPIRD (2019) that all of these species and other species in the same families undergo group spawning throughout their ranges, rather than aggregating at specific locations.

The spatial-temporal analysis is not intended to provide an exact estimate of how much of each species' spawning success rate will be impacted. Instead, this method demonstrates how the proportion of fishes that may be affected is relatively small compared to the larger overall spawning biomass, spawning area and spawning periods of each stock, which is important context for the assessment. It is important to note that a number of assumptions have been applied to the analysis in order to address uncertainty about behavioural effects to spawning fishes and provide a highly conservative and more precautionary estimate of the proportion of spawning fish stocks that may be exposed and potentially affected during the survey. These assumptions are outlined below:

+ **Spatial overlap is based on a week (seven days) of acquisition lines with a 5 km buffer applied to the racetrack formation to account for possible uncertainty about the range to disturbance to fish.** This approach accounts for an area that will be encircled during a typical racetrack line acquisition and therefore subject to sound exposure from the seismic source. A week of racetrack was selected as this reflects an area where the seismic survey vessel will acquire consecutive, adjacent lines within proximity to the same general area of seabed and groups of demersal fishes. The seven-day timeframe is also precautionary in order to account for scientific uncertainty in relation to the duration and recovery of behavioural disturbances in fishes; it provides a conservative reflection of the longest duration changes in fish behaviour or fish distribution (approximately five days, as noted by Slotte et al. (2004); Engås et al. (1996); Engås & Løkkeborg (2002), noting that such changes are limited to studies that focused primarily on migrating sound pressure-sensitive types of fish with a swim bladder-ear connection (Clupeidae, Gadidae). Behavioural changes in demersal fish species typically return to normal within minutes or hours following exposure, although noting that during the racetrack formation, the same groups of fish may be exposed again when the seismic source returns to acquire an adjacent line nearby. Within any seven-day period, the seismic survey vessel (travelling at a speed of approximately 4.5 knots [8.3 km/hr]) will cover a distance of approximately 1,400 km.

It is also appropriate to consider a week of acquisition lines, given that over the duration of each survey, the seismic survey vessel would gradually move across the survey area; following a week, the racetrack would have progressed sufficiently far that it would no longer disturb the same areas and groups of demersal fishes as may be disturbed at the start of the racetrack. Therefore, this seven-day scenario already provides a highly conservative reflection of the spawning area that may be exposed at any time during the survey, and accounting for a larger area would significantly over-represent this area.

To apply an additional level of conservatism and account for possible uncertainty about the exact range over which fish may be disturbed, a 5 km buffer has been applied to the racetrack formation. This allows to account for potential variability in the hearing of different fish species and to broadly represent where some fishes may have some awareness of sound pressure changes; noting that the key indicator demersal fish species are primarily sensitive to particle motion effects more so than sound pressure and significant behavioural effects are more likely to be limited to within tens or hundreds of metres of the seismic source (Popper et al. 2014). Overall, the seven-day scenario and 5 km sound exposure buffer would result in an area of disturbance of approximately 1,470 km^2.

+ **The spatial extent of the spawning areas for each key indicator fish species has been estimated based on each species' depth range (as advised by DPIRD 2019) and the Kimberley and NT fishery management areas.** As described in **Section 3.8.1.4**, genetic connectivity and the biological stocks have been confirmed across significantly larger areas (hundreds of thousands of square kilometres compared with the tens of thousands of square kilometre spawning areas considered in the analysis). The biological stocks of the key indicator species generally extend across northern Australia, usually covering the waters of WA, the NT and Queensland. The biological stock areas may be more relevant to the impact assessment from a biological perspective. However, the boundaries of the biological stocks are not clearly defined and it is noted that genetic connectivity and recruitment within the biological stock ranges occurs over multiple years of spawning and dispersion of eggs and larvae (Martin et al. 2014; Gaughan et al. 2018). In any given year or a single spawning season, the genetic connectivity between the area of seabed exposed to disturbances from the survey depends on the duration of the egg and larval dispersion phase and the oceanographic currents. Connectivity and recruitment in a single season may therefore occur within and well beyond the limits of the fishery management units, but potentially not across the entire biological stock area.

  Therefore, to address any potential uncertainty in the biological stock ranges, fishery management areas have been selected by Santos to provide a conservative indication of the proportion of the stocks that may be affected in a single spawning season. Referencing the fishery management units also allows the results to be considered in relation to the annual fish stock status assessments, which are also reported per fishery management area (an approach that is recognised as being a conservative approach for fishery management purposes [Gaughan et al. 2018]). As a result, the spatial overlaps accounted for in the spatial-temporal analysis are likely to significantly overestimate the percentage of spawning area available to each species.

+ **The spatial-temporal analysis is a simplistic approach that assumes that fish spawning in the area and period of exposure will definitely be compromised**. In reality, it is possible that fishes may continue to spawn regardless, may move away from the seismic source and spawn nearby, or, given that fish behaviours may return to normal within minutes or hours of exposure, spawning may be delayed but may occur a short time later. In either of these cases, the impact on spawning success may be negligible. However, given uncertainty about how the spawning behaviours of individual fishes and populations may be affected in response to seismic sound exposure, it is conservatively assumed that cessation of spawning will occur.

Therefore, the following analysis provides a highly conservative indication of the proportion of each indicator fish stock that may be exposed in a 7-day period. This provides useful context for the impact assessment, but the extent and duration of actual impacts will likely be significantly smaller.

Table 6-10 presents the spatial and temporal overlaps with the spawning areas and spawning periods of key indicator species based on each species' principal depth range and the Kimberley and/or NT management units. The maximum spatial-temporal overlap of the 100-day duration Petrel Sub-Basin SW 3D MSS ranges from 0.0% to 0.19%.

Given there is either negligible or no overlap with the NT stocks and Spanish mackerel, the remainder of the assessment is focused on the WA (Kimberley) demersal fish stocks.

Table 6-10: Spatial and temporal overlap of the Petrel Sub-Basin SW 3D MSS with the spawning range and spawning periods of key indicator fish stocks

Key Indicator Fish Stock	Maximum spatial overlap with the Petrel Sub-Basin SW 3D MSS		Maximum temporal overlap with fish spawning period[+]		Combined spatial-temporal overlap with fish spawning period and principal depth range
	km^2	%	Days	%	%
Goldband snapper (Kimberley)					
Principal depth range: 50 – 200 m Spawning Area (area within depth range) in the Kimberley Management Area*: 274,856 km^2 Spawning period: 243 days (Oct-May)	1,458	0.46%	100	41.2%	0.19%
Goldband snapper (NT)					
Principal depth range: 50 – 200 m Spawning Area (area within depth range) in the NT Management Area*: 318,885 km^2 Spawning period: 243 days (Oct-May)	260	0.08%	100	41.2%	0.03%
Red emperor (Kimberley)					
Principal depth range: 10 – 180 m Spawning Area (area within depth range) in the Kimberley Management Area*: 345,982 km^2 Spawning period: 303 days (Sept-Jun) Spawning Area (area within depth range) in the Kimberley Management Area*: 338,110 km^2 Spawning period: 245 days (June-Dec, Mar)	1,470	0.34%	62	25.3%	0.08%
Saddle-tail snapper (NT)					
Principal depth range: 5 – 100 m	260	0.06%	90	59.6%	0.04%

Key Indicator Fish Stock	Maximum spatial overlap with the Petrel Sub-Basin SW 3D MSS		Maximum temporal overlap with fish spawning period+		Combined spatial-temporal overlap with fish spawning period and principal depth range
	km^2	%	Days	%	%
Spawning Area (area within depth range) in the NT Management Area*: 429,225 km^2					
Spawning period: 151 days (Oct-Feb)					
Crimson snapper (NT)					
Principal depth range: 5 – 100 m	260	0.06%	100	66.2%	0.04%
Spawning Area (area within depth range) in the NT Management Area*: 429,225 km^2					
Spawning period: 151 days (Oct-May)					
Spanish mackerel (Kimberley)					
Principal depth range: 0 – 50 m	12	0.007%	62	40.5%	0.003%
Spawning Area (area within depth range) in the Kimberley Management Area*: 88,694 km^2					
Spawning period: 153 days (Sept-Jan)					
Spanish mackerel (NT)					
Principal depth range: 0 – 50 m	0	0.0%	62	40.5%	0.00%
Spawning Area (area within depth range) in the NT Management Area*: 169,832 km^2					
Spawning period: 153 days (Sept-Jan)					

*Spawning areas have been estimated based on each species' depth range and the relevant management area (Kimberley and/or NT). It is important to note that genetic connectivity and the biological stocks have been confirmed across significantly larger areas, however, the fishery management areas are a useful and conservative indicator for assessment purposes and allows the results to be directly related to annual stock status assessments, which are also reported per fishery management area.

+ The temporal overlap is based on the number of days of acquisition coinciding with the days that each species is known to spawn.

Natural Variability in Fish Distribution, Spawning Biomass and Recruitment

In addition to the above spatial-temporal analysis, it is important to note that fishes may not be evenly distributed throughout their range. The spatial-temporal analysis accounts for disturbance to fish throughout the entire duration of the survey (up to 100 days), whereas the natural variability in the distribution of fish means that areas of high fish abundance may be exposed for a limited period of time, while the seismic survey vessel is operating in that area. At other times of the survey, while the seismic survey vessel is operating in areas of lower fish abundance, fewer fish may be exposed.

To provide further context, Santos has considered the natural levels of variability in spawning and recruitment. Spawning biomass and recruitment rates fluctuate annually, with years of elevated or reduced recruitment influencing the overall stock population (Marriott et al. 2014). Newman et al. (2003) and Marriott et al. (2014) suggest that both spawning and recruitment success can vary depending upon both environmental (e.g. water temperature, cyclones, El Nino-La Nina cycles) and anthropogenic influences (e.g. fisheries catch levels over and above natural mortality rates).

Extended periods of high exploitation by fisheries can result in decreases in the spawning stock biomass and effective spawning (Newman et al. 2003). For example, between 1980 and 2013, red emperor spawning biomass in the Kimberley management unit generally decreased to approximately 35% of unfished (pre-1980) levels, while recruitment success fluctuated inter-annually between a minimum of approximately 150 million fish and 400 million fish (a fluctuation of approximately 250%) (Refer to **Figure 6-3**). Similarly, goldband snapper spawning biomass declined steadily while recruitment success fluctuated inter-annually between a minimum of approximately 250,000 fish and 900,000 fish (a fluctuation of 350%) (Refer to **Figure 6-4**). This provides an indication of the high natural inter-annual variability in the spawning and recruitment of these indicator species. The trends in spawning biomass and recruitment do not clearly reflect one another, indicating that there may also be significant variation in spawning biomass and stock recruitment success as a result of other natural factors.

In the context of this large natural variability, the potential for approximately 0.19% or less of the spawning biomass of each species in the Kimberley management unit to be disturbed is expected to have a negligible effect. The effects of the survey are unlikely to be discernible from natural variation, given that it is only the groups of fishes exposed at a particular site and point in time that may be affected; spawning will continue undisturbed elsewhere throughout the stocks' ranges and the majority of spawning groups in the region at any point in time will be undisturbed. The affected groups of fishes will also spawn again at multiple other times during the spawning season and so discernible impacts to recruitment and populations are not expected.

The serial, broadcast spawning strategies of the indicator demersal fish species, by their very nature, offsets potential high natural embryo and larval mortality as a result of predation or other environmental factors and thereby spreads the risk or potential opportunity for larval settlement over large areas and long timeframes. Subsequent recruitment of fishes to the adult stock also occurs over extended timeframes and is ongoing. For example, with reference to goldband snapper stocks, the Australian Government's FRDC has previously noted that moderate or 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 a seismic survey would have impacts many orders of magnitude smaller than regional scale environmental/climatic events that would affect entire stocks.

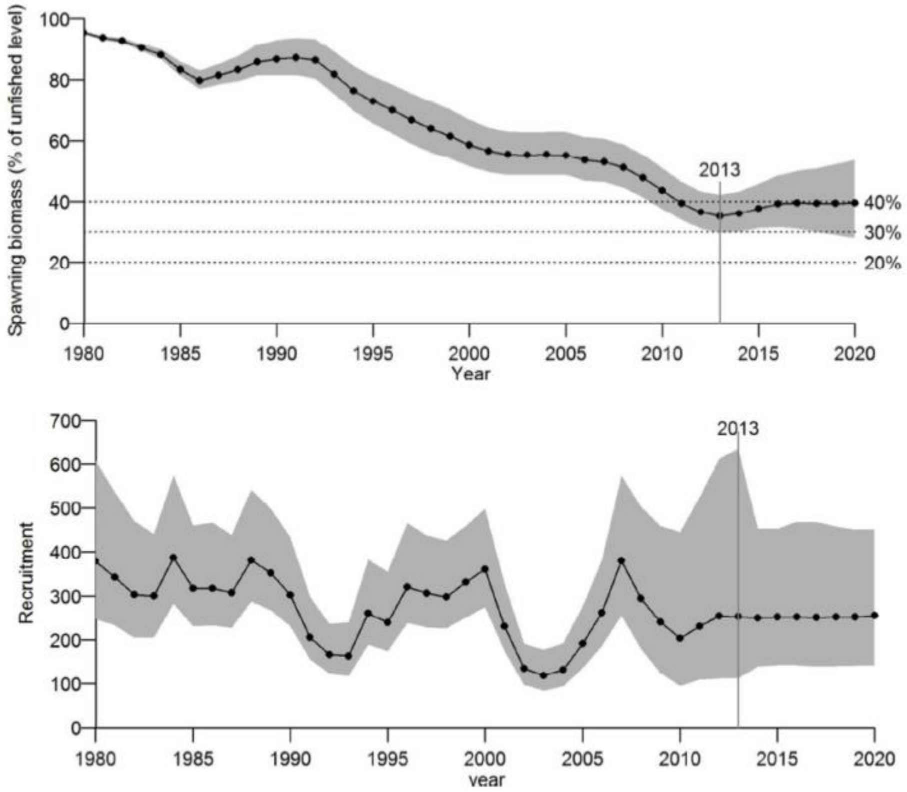


Figure 6-3: Red emperor spawning biomass as a percentage of unfished levels (top) and recruitment (millions of fish) (bottom) (source: DoF 2015a)*

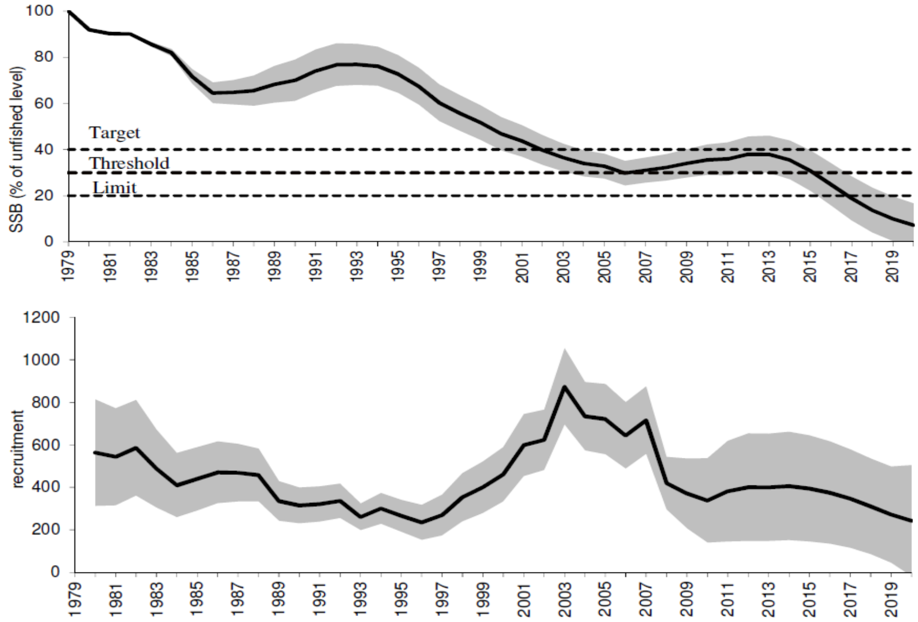


Figure 6-4: Goldband snapper spawning biomass as a percentage of unfished levels (top) and recruitment (thousands of fish) (bottom) (source: DoF 2015a)*

* Levels after 2015 are predictions made in 2015 based on different fishing and stock scenarios, and do not represent real levels.

<u>Fish stock assessments and sustainability status</u>

The monitoring and assessment of commercial fish stocks in WA and elsewhere in Australia is undertaken by the relevant Commonwealth or State Government agency for fisheries. Each fishery and its target species are assessed in accordance with stock sustainability reference levels and in many cases, fishery harvest strategies are developed in accordance with the DOF (2015b) Harvest Strategy Policy. The stock assessment process and objectives are consistent with the principles of ecologically sustainable development as it aims to maintain spawning stock biomass, high productivity and recruitment, as well as to ensure that impacts do not result in serious or irreversible environmental harm (DoF 2015b). Any stock size at or above the threshold level is consistent with meeting the objectives for biological sustainability and is also sufficient to meet the stock status certification requirements under the Marine Stewardship Council's standard for sustainability (DPIRD 2017).

The main commercial fish species that are present and spawn within the Acquisition Areas are the suite of demersal scalefish. Assessment and management of the north coast demersal scalefish resource is undertaken by DPIRD for the Kimberley management unit. As outlined in the North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017), assessment of the sustainability of the fisheries and fish stocks is undertaken by DPIRD based on two assessment processes. The first is a formal resource-level review, which is undertaken every 3-5 years and assesses the current status of the resource (the overall stock abundance and spawning biomass, and fish mortalities from fishing catch) against defined biological reference levels (target, threshold and limit) to determine whether management arrangements are appropriate (DPIRD 2017).

Spawning biomass is estimated based on abundance, sex and age composition derived from catch data. The target, threshold and limit levels in each stock correspond with 40%, 30% and 20% of the virgin spawning biomass (unfished levels) respectively. The target level is an aspirational and acceptable level based on stock biomass and the fishing mortality rate that fisheries managers aim to achieve to be protective of the stock. Due to natural variability in the sizes of fish populations, DPIRD set a target range of 30-40% of unfished biomass (DPIRD 2017).

The second process involves an annual, fishery-level review, which determines whether the current catch/effort is consistent with the reference levels and the status of the resource defined during the resource-level review process. (DPIRD 2017). The last available published integrated assessment (both processes) was undertaken in 2015.

Table 6-11 outlines the stock assessments of these key indicator fish species, as published online by the FRDC. Overall, all indicator species are classed as sustainable and all evidence indicates that the biomass of the stocks is unlikely to be depleted and that recruitment is unlikely to be impaired.

Table 6-11: Stock assessments of key indicator fish species

Fish Species	Stock Assessment*
Red emperor (Newman et al. 2020)	The spawning biomass level of red emperor was estimated to be approximately 30 per cent in the NDSMF in 2017. This indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. An assessment of fishing mortality derived from representative samples of the age structure of red emperor has also been undertaken for the NDSMF. The fishing mortality based assessments indicated that the fishing level on Red Emperor is at or below the limit level in 2017. This indicates that fishing is not having an unacceptable impact on the age structure of the population. Catch levels of Red Emperor in the NDSMF over the last 10 years (2010–19) have ranged from 128–192 tonnes, with a mean annual catch of 141 tonnes. The above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. Based on the evidence provided above, the Kimberley (Western Australia) management unit is classified as a **sustainable** stock.
Goldband snapper (Trinnie et al. 2020)	The spawning biomass of goldband snapper was estimated to be approximately 30 per cent of the unfished level in the Kimberley management unit (i.e. at the threshold reference level) in 2017 (the year the last integrated assessment was undertaken). This indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. Goldband snapper catches from the NDSMF (Kimberley management unit) over the last 10 years (2010–19) have ranged from 400–602 tonnes, with a mean annual catch of 490 tonnes. The above evidence indicates that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. On the basis of the evidence provided above, the Kimberley (Western Australia) management unit is classified as a **sustainable** stock.

*Stock assessments are based on FRDC (2019) stock assessment data.

In comparison with fishing mortalities (which DPIRD considers to be acceptable and sustainable) and the normal variability in the fish biomass and recruitment levels (250-350%), the survey is not expected to result in any direct reduction in the spawning biomass through fish mortalities. Furthermore, the potential spatial-temporal overlap of the survey with the spawning fish stocks (maximum of 0.19%) will be negligible. Therefore, the survey will not result in a serious or irreversible impact to the sustainability of key indicator commercial fish stocks.

It is acknowledged that the Petrel Sub-Basin SW 3D MSS may affect spawning fish and the fish stocks in addition to other natural influences and commercial fishing pressures placed on the stocks. However, the proportion of the spawning biomass exposed to the seismic source is negligible. 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 survey is not expected to result in any direct reduction in the spawning biomass through fish mortalities;
+ 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 very short ranges to injury thresholds for fish eggs and larvae shown in in **Table 6-5** (160 m from the seismic source) and negligible impacts in the context of natural turnover;
+ Localised (tens to hundreds of metres) and short-term (minutes, hours, days) behavioural disturbances resulting from a transient seismic source are unlikely to result in a discernible impact to demersal fish populations given that spawning and stock connectivity occurs over significantly larger geographic areas, over protracted spawning periods of several months, and involves the production of millions of eggs over multiple spawning events;
+ A small spatial-temporal overlap of the survey with the spawning areas in the Kimberley and NT management units and spawning periods of key indicator fish species (maximum spatial-temporal overlap of 0.19%, based on highly conservative spatial-temporal analysis);
+ The approach to assessing the spatial-temporal overlap of the survey includes a significant level of conservatism due to the assumptions outlined previously;
+ The level of disturbance and spatial-temporal overlap (maximum of 0.19%) with the key fish stocks is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250-350%);
+ Key indicator species in the Kimberley management unit have been assessed annually as 'sustainable', the biomass of the stocks is unlikely to be depleted and recruitment is unlikely to be impaired despite a history of ongoing commercial fishing and seismic surveys across the fisheries. The sustainability status is based upon the target and threshold levels for spawning biomass, which DPIRD note in their Harvest Strategy is a conservative approach, as well as being consistent with the principles of ESD;
+ Adult stocks comprise fish that are recruited over many years and are unlikely to be affected by seasonal disturbances, even at a regional scale (Martin et al. 2014). Therefore, in comparison, the occasional, short-term, transient and localised disturbances to groups of fish as a result of a seismic survey are not expected to impact recruitment;
+ DPIRD Status of the Fisheries reports indicate that fish catches have remained stable or increased despite a history of ongoing commercial fishing and seismic surveys across the fisheries, with evidence that fish abundance is increasing and stocks are rebuilding; and

- DPIRD Status of the Fisheries reports also considers other activities in the region, including oil and gas activities and seismic surveys. DPIRD consider the risk status of oil and gas activities to be 'Low' and states that 'While there are a number of specific oil and gas related offshore developments that are proposed in this region, at the overall ecosystem level there is only a low risk that the ecosystem will be altered measurably'. The Status of the Fisheries assessments are undertaken by DPIRD's principal research scientists, responsible for assessing risks to the stocks and maintaining suitable management measures.

6.3.2.7.5 Summary

Based on the impact assessment no long term or population impacts to individual fish, sharks and rays or commercial fish stocks, thus the consequence level is assessed as minor.

6.3.2.8 Cetaceans

6.3.2.8.1 Receptors

As described in **Section 3.7.3,** there are seven listed threatened of migratory cetacean species that may be present in the Operational Area and EMBA during acquisition of the survey including sei, fin, killer and Bryde's whales. The presence of these cetacean species within the Operational Area during acquisition of the survey is likely to be limited to occasional transits of isolated individuals or small pods.

There are no cetacean BIAs located within or adjacent to the Operational Area. The closest cetacean BIA to the Operational Area is an Australian snubfin dolphin breeding/calving BIA near Cape Londonderry and King George River (located approximately 23 km from the Operational Area). The BIA is utilised throughout the year. Other breeding/calving/resting and foraging BIAs are located further west along the north Kimberley coastline, as well as around Ord River and Cambridge Gulf approximately 70 km south from the Operational Area.

6.3.2.8.2 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 6-12** 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 6-13**, further detail on relevant scientific studies and research undertaken used to inform this impact assessment is included in **Appendix G.**

Table 6-12: Marine mammal functional hearing groups (NMFS 2018)

Functional Hearing Group	Generalised Hearing Ranges
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 6-13: 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,

Impact Pathway	Summary
	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 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'). 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.

Santos

6.3.2.8.3 Thresholds

The threshold criteria in **Table 6-14** 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 or TTS 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 6-14** 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 6-14: 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 (NOAA 2019). 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. 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; 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 (NMFS 2019).		

	Potential Impacts					
	Impairment - PTS		Impairment - TTS		Behavioural	
	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]	NOAA (2019) does not define an SEL exposure criteria for behaviour for cetaceans.
Modelled Distance	N/A	N/A	N/A	N/A	NA	
	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]	NOAA (2019) does not define an SEL exposure criteria for behaviour for cetaceans.
Modelled Distance	Not exceeded	Not exceeded	20 m MOD	40 m MOD	8.46 km MOD	
	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]	NOAA (2019) does not define an SEL exposure criteria for behaviour for cetaceans.
Modelled Distance	30 m MOD	4.89 km MOD	70 m MOD	62.2 km MOD	8.46 km MOD	

NB. Model does not account for shutdowns. HF cetaceans are unlikely to be present in the Operational Area and therefore distance to thresholds have not been modelled.

[1] NMFS (2018) – Table 4

[2] NMFS (2018) – Table AE-1

[3] NOAA (2019)

6.3.2.8.4 Impact Assessment

The type and scale of the effect of seismic sound on cetaceans will depend on a number of factors. These include 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.

High-frequency (HF) cetaceans (i.e. beaked whales) are unlikely to be present in the Operational Area and surrounding waters, and accordingly the impact assessment is focused on low-frequency (LF) cetaceans (i.e. baleen whales) and mid-frequency (MF) cetaceans (i.e. toothed whales and dolphins). It is noted that while dugongs were identified as potentially occurring in the EMBA through a PMST search, they are not expected to occur in or around the Operational Area due to the absence of suitable shallow water habitats (<10 m). Impacts to dugong as a result of underwater from the seismic source are therefore not expected and are not addressed in this assessment.

The Operational Area is not known to support significant numbers of any cetacean species and it does not provide unique habitat for any aggregations or sensitive life stages. The pygmy blue whale migration BIA is located 317 km north-west from the Operational Area. Humpback whale migration, breeding, calving, nursing and resting BIAs are all located 385 km south-west from the Operational Area. Therefore, no impacts are expected to these species in the BIAs. Instead, any cetaceans within the Operational Area are expected to be transient.

As shown in **Table 6-14**, LF cetaceans (such as pygmy blue whales and humpback whales) are predicted to have potential to experience PTS at a maximum predicted distance of 4.89 km from the nearest survey line, based on application of the multiple pulse SEL_{24h} threshold across all water depths modelled (maximum-over-depth: MOD). It is predicted however that PTS may be experienced within less than 30 m based on the single pulse PK metric. For MF cetaceans, the single pulse PK metric and multiple pulse SEL_{24h} threshold was not exceeded.

The maximum predicted distance to the TTS thresholds for LF cetaceans is 62.2 km from the nearest survey line, based on application of the multiple pulse SEL_{24h} threshold and within 70 m based on the single pulse PK metric. This zone of potential TTS effects does not overlap any of the LF cetacean BIAs within the JBG. For MF cetaceans the maximum predicted distance to TTS effects reduces to 20 m, based on the application of the single pulse PK metric and 40 m based on the multiple pulse SEL_{24h} threshold. Therefore, there is no potential for PTS or TTS to occur in the coastal BIAs for Australian snubfin dolphin, 23 km from the Operational Area.

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. The modelling results show that the corresponding SEL_{24h} radii for LF cetaceans were considerably 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 for 24 hours. This would particularly be the case for an animal migrating through offshore waters that don't represent critical habitat or a narrow restricted migratory pathway. 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 (Koessler and McPherson 2021). The concept of an individual whale remaining within a range of 4.89 km (maximum predicted distance for PTS, based on the SEL_{24h} metric) from the operating seismic source (which is moving) for a full 24-hour period, or even for a few hours, is not credible. Should an individual remain within the range for potential impact, some recoverable TTS could occur. However, the likelihood of TTS occurring is reduced by the implementation of control measures including a shut-down zone of 500 m and a low-power zone of 2 km under Part A of EPBC Policy Statement 2.1.

Behavioural impacts, such as behavioural avoidance, are more likely to occur if cetaceans 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 all types of cetacean, is approximately 8.46 km, across all water depths modelled. The received levels in the Australian snubfin dolphin BIA near Cape Londonderry, 23 km from the Operational Area, are predicted in the modelling to be approximately 130 dB re 1 µPa SPL from the closest modelling site. Ambient background noise levels in the nearshore waters of the Kimberley consistently between 85 – 110 dB re 1 µPa SPL, increasing at times to in excess of 130 dB re 1 µPa SPL as a result of biological noise, tidal currents and movement of sediment, and occasionally other anthropogenic noise sources (McCauley 2011, 2012; McPherson et al. 2016). Distant pulses of sound may therefore be audible to dolphins in the BIA when the seismic source is operated in the western part of the Operational Area but behavioural responses are not expected to be significant. The survey is not expected to be audible to dolphins in any of the other BIAs along the Kimberley coast.

6.3.2.8.5 Summary

Overall, the potential impacts of noise emissions from the seismic source on cetaceans at any one time during acquisition are considered to be temporary behavioural changes (e.g. avoidance) by transient individuals. Potential TTS effects may also occur to a few individuals, but long term or ecologically significant effects are highly unlikely.

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

6.3.2.9 Marine Turtles

6.3.2.9.1 Receptors

Six threatened and migratory marine turtle species were identified in the PMST search as having the potential to occur in the Operational Area and EMBA: flatback, green, loggerhead, hawksbill, leatherback and olive ridley turtles (**Section 3.7.4**). There are several BIAs for marine turtle species in the region, including those along the coastline in the JBG, in close-proximity to the Operational Area. The Operational Area overlaps with the year-round foraging BIAs for the loggerhead, flatback, olive ridley and green turtle.

Additionally, an internesting BIA for the flatback turtle is located adjacent to the Operational Area. The nearest habitat critical area is for the flatback turtle located at Cape Domett, 24 km from the Operational Area. The Cape Domett stock nest year-round with a peak between July and September.

6.3.2.9.2 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).

6.3.2.9.3 Thresholds

As described above and in **Appendix F** and **Appendix G**, the threshold criteria in **Table 6-15** have been adopted for the assessment of noise impacts to marine turtles. **Table 6-15** 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 6-15**. 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. (2000a) found that marine 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 2017) 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 6-15: Sound level threshold criteria and values for mortality, impairment and behaviour in marine turtles

	Turtles				
	Mortality/Potential Mortal Injury		Recoverable Injury, PTS 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 marine turtles at 166 dB SPL, as referenced by NSF 2011 and in the Recovery Plan for Marine Turtles in Australia (DoEE 2017).
Relevance of thresholds adopted	There is limited information on marine 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]	Behavioural response†: 166 dB SPL Behavioural disturbance‡: 175 dB SPL
Modelled Distance	110 – 160 m MOD	50 m MOD	PTS: Not exceeded TTS: Not exceeded	PTS: 50 m MOD TTS: 2.37-2.72 km MOD	Behavioural response†: 4.59-5.06 km MOD Behavioural disturbance‡: 1.71-1.97 km MOD

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000a, 2000b).

‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

[1] Popper et al. (2014)

[2] Finneran et al. (2017)

6.3.2.9.4 Impact Assessment

As shown in **Table 6-15**, the Finneran et al. (2017) PK marine turtle injury (PTS) and TTS threshold criteria of 232 dB re 1 µPa (PTS) and 226 dB re 1 µPa (TTS) were not exceeded at a distance greater than 20 m from the centre of the seismic array. Because the array is not a point source (measuring approximately 14 x 8 m in the horizontal plane), the actual effect range from the edge of the array will be less than 20 m. Therefore, it is highly unlikely that a marine turtle would be exposed at such close range given that the source is towed directly behind the seismic vessel and some attempt to swim away from the approaching vessel and/or increasing sound levels from the seismic source is likely.

Based on the more conservative Popper et al. (2014) thresholds injury to marine turtles could potentially occur up to 160 m from the seismic source.

The NMFS criterion (NSF 2011) for a behavioural response in marine turtles (166 dB re 1 µPa SPL) could be exceeded within a distance of approximately 5 km of the operating seismic source. The McCauley et al. (2000a, 2000b) threshold (175 dB re 1 µPa SPL) for a behavioural disturbance (i.e. increase in swimming behaviour) could also be exceeded within approximately 1.7-2 km from the operating seismic source.

Behavioural disturbances to marine turtles are expected to be temporary and localised and affect a relatively small number of the species. These disturbances are not expected to affect a significant proportion of populations in the JBG or occur in habitat of any particular significance to key life stages. Based on the distances to internesting BIAs and habitat critical areas, and the control measures proposed, predicted noise levels from seismic acquisition are not considered likely to cause PTS effects, displace any individuals from these areas, or result in any ecologically significant impacts at a population level for any species of turtle that may be present within or adjacent to the Operational Area.

No seismic acquisition will occur within the defined internesting BIA or habitat critical for the flatback turtle, consistent with recommendations in the Recovery Plan for Marine Turtles in Australia. The habitat critical area is 24 km from the Operational Area and, therefore, internesting turtles will not be disturbed.

It is noted that the Operational Area overlaps with foraging BIAs for flatback, loggerhead, green and olive ridley turtles (refer to **Section 3.7.4**). No information regarding the reasons for the foraging BIAs being defined in the JBG is published by the DAWE. Given the water depths in this area (>40 m) and the limited occurrence of benthic epifauna in the predominantly soft sediment environment, it seems unlikely that the whole JBG represents important foraging habitat for these species.

In addition, a study of the marine turtle bycatch of the NPF, which included the waters of the southern JBG, recorded five species: flatback (59% of the total), loggerhead (10%), olive ridley (12%), green (8%) and hawksbill (5%). They identified that marine turtle catches varied with water depth: the highest catch rates were from trawls in water between 20 and 30 m deep, relatively few turtles (10%) were captured in water deeper than 40 m (Poiner and Harris 1996). Thus, it is unlikely that the Active Source Zones (water depth range of 45 - 105 m) is a significant foraging area for marine turtles. Marine turtles encountered in the Operational Area are more likely to be transient individuals. However, should behavioural disturbance occur to foraging marine turtles, it will likely be limited to one-off disturbances to the affected individuals given the transient nature of both the seismic vessel and marine turtles. No long term or widespread disturbances to foraging populations of marine turtles are expected.

6.3.2.9.5 Summary

Based on the impact assessment no long term or population impacts to marine turtles are predicted. No seismic acquisition will be undertaken in an internesting BIA and the effects of sound emitted during the survey will not extend into any habitat critical to the survival of marine turtles. Behavioural effects to transient marine turtles may occur. Thus, the consequence level is assessed as minor.

6.3.2.10 Seabirds and Migratory Shorebirds

6.3.2.10.1 Receptors

There are 23 bird species considered to be ecologically significant to the NWMR; that is, they are either endemic to the region, have a high number of interactions with the region (nesting, foraging, roosting or migrating) or have life history characteristics that make them susceptible to population decline. In addition, there are 11 bird species considered to be ecologically significant to the NMR, due to the presence of important feeding sites in the NMR.

The Operational Area overlaps with the breeding BIA for the lesser crested tern (**Figure 3-12**). No other BIAs for seabird and migratory shorebird species overlap with the Operational Area.

There is no emergent land within the Operational Area to support breeding colonies of seabirds. The closest known breeding sites occur at the three estuaries at the head of the JBG (located approximately 150 km from the Operational Area) (the Keep, Victoria and Fitzmaurice rivers). Shorebird species may fly over the Operational Area during migrations, given nearby coastal habitats support larger migratory populations.

6.3.2.10.2 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 the fact 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.

6.3.2.10.3 Thresholds

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

6.3.2.10.4 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 2017) 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 small pelagic fishes 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 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 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 forage 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. It is expected that lesser crested terns will not be displaced from the wider areas of the breeding and foraging BIAs in the JBG.

The behaviour and distribution of some fishes may be affected for short periods during and after exposure to the seismic source, which may result in short-term and localised changes in the distribution of target prey species for some species. 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 in the Operational Area. Therefore, impacts to seabird populations are highly unlikely to occur.

6.3.2.10.5 Summary

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

6.3.2.11 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.

6.3.2.11.1 Receptors

The following key fisheries that have historic fishing effort within the Operational Area have been identified for this assessment:

+ Commonwealth Northern Prawn Fishery (NPF);
+ WA Northern Demersal Scalefish Managed Fishery (NDSMF);
+ WA Mackerel Managed Fishery (MMF – Area 1);
+ NT Demersal Fishery (DF);
+ NT Spanish Mackerel Fishery (SMF); and
+ NT Offshore Net and Line Fishery (ONLF).

6.3.2.11.2 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 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. 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. 2016): *"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 (Przeslawki 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.

6.3.2.11.3 Impact Assessment

As assessed in **Section 6.3.2.7**, the effects of sound produced by the seismic source during the Petrel Sub-Basin SW 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 (refer to **Section 6.3.2.7**). 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 (refer to **Section 6.3.2.7**). Changes in behaviour may last for minutes or hours, while the distribution of fishes may take hours or days to return to normal.

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 temporary as the seismic vessel traverses each survey line. As described above, significant behavioural responses in the key indicator demersal fish species (which primarily detect particle motion, with limited, or no sensitivity to sound pressure changes at distance from a seismic source) will be limited to distances of a few hundreds of metres from the operating seismic source. Overall annual catch levels throughout the fisheries are not expected to be significantly impacted.

As described in **Section 6.3.2.6**, no behavioural effects are expected to prawns. Exposure of prawns within a few hundred metres of the seismic source may result in sub-lethal effects such as reduced reflexes. However, this is not expected to impact catchability or fishery catch rates.

To provide further context on the proportion of the fisheries that may be affected by the Activity, **Table 6-15** presents the areas of overlap with commercial fisheries based upon 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 finfish behaviour and distribution may be affected by the active source. 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 highly conservative, given that target demersal and pelagic fish species (as well as prawns) 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 6-16 shows that relatively large areas of the fisheries will be available for fishing outside of the survey area, with the conclusion based on previously presented evidence (**Appendix G**) that any fish behavioural affects within these areas should be localised and temporary.

Santos

Table 6-16: Overlap with commercially important fisheries

Fishery	Area of Fishing Effort (km^2)*	Spatial Overlap (km^2)	Spatial Overlap (%)
Northern Prawn Fishery – Entire fishery	151,232	1,288	0.85%
Northern Prawn Fishery – JBG area	13,748	1,288	9.37%
WA Northern Demersal Scalefish Managed Fishery	142,173	354	0.25%
WA Mackerel Managed Fishery (Area 1)	55,375	306	0.55%
NT Demersal Fishery	315,310	274	0.09%
NT Spanish Mackerel Fishery	337,351	274	0.08%
NT Offshore Net and Line Fishery	326,966	274	0.08%
* Based on coarse resolution 60 nm blocks. Area of fishing effort and % overlap for these fisheries; therefore, may be overestimated.			

Santos has assumed that past fishing activity is representative of future target areas, fish presence and fishery catch. The % impacts calculation in **Table 6-16** is based on the fishing effort area of the fishery and excludes any closure areas where fishing is not permitted to take place.

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;
+ No mortality or behavioural effects are expected to prawns;
+ 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 (more than 90%) are out of range of predicted sound levels that could disturb fish or crustaceans and affect catchability at any one time (refer to **Table 6-16**);
+ 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; and
+ Santos will have a commercial fisher's payment claim protocol in place. Should a loss of catch be demonstrated as a result of the survey then commensurate make good payments will be made.

6.3.2.11.4 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.

6.3.2.12 AMP Values

The Petrel Sub-Basin SW 3D MSS Operational Area is not located within an AMP. At its closest points, the Petrel Sub-Basin SW 3D MSS Operational Area is located 10 km from the Oceanic Shoals AMP (Multiple Use Zone) and 12 km from the Joseph Bonaparte Gulf AMP (Special Purpose Zone). The Active Source Zones, at their closest points, are located approximately 18 km from the Oceanic Shoals AMP (Multiple Use Zone) and 23 km from the Joseph Bonaparte Gulf AMP (Special Purpose Zone).

Given the potential for underwater sound to propagate towards the AMPs and for sound levels to be audible above ambient levels within the AMP boundaries, the following assessment has considered the potential for impacts to the values of the Oceanic Shoals and the Joseph Bonaparte Gulf AMPs.

6.3.2.12.1 Receptors

As summarised in **Section 3.5.1**, the AMP values considered in this assessment are summarized below.

Oceanic Shoals AMP:

+ Examples of ecosystems representative of the Northwest Shelf Transition. The pinnacles, carbonate banks and shoals within the AMP are sites of enhanced biological productivity.
+ Four KEFs, namely:
  - Carbonate bank and terrace systems of the Van Diemen Rise;
  - Carbonate bank and terrace system of the Sahul Shelf;
  - Pinnacles of the Bonaparte Basin; and
  - Shelf break and slope of the Arafura Shelf.
+ Foraging and internesting BIAs for marine turtles.
+ Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing.
+ Commercial fishing and mining are important activities in the AMP.

Joseph Bonaparte Gulf AMP:

+ Ecosystems representative of the Northwest Shelf Transition.
+ The presence of the carbonate bank and terrace system of the Sahul Shelf KEF.
+ Foraging and internesting BIAs for marine turtles and the Australian snubfin dolphin.
+ Sea country within the marine park is valued for Indigenous cultural identity, health and wellbeing.
+ Tourism, commercial fishing, mining and recreation (including fishing) are important activities in the AMP.

6.3.2.12.2 Impact Assessment

Oceanic Shoals AMP

Received sound levels at the AMP are predicted to be approximately 140 dB re 1 µPa SPL at times when the seismic source operates at a point within the Active Source Zones closest to the AMP. For the majority of the survey, when the seismic vessel and seismic source will be transiting at greater distances from the AMP, the received sound levels will be less. These received sound levels are below any threshold for physical or significant behavioural impacts for any marine fauna.

The potential impacts to the values of the Oceanic Shoals AMP are summarised as follows.

Marine ecosystems and Key Ecological Features (KEFs):

The Petrel Sub-Basin SW 3D MSS does not overlap with the carbonate bank and terrace system of the Sahul Shelf KEF or the pinnacles of the Bonaparte Basin KEF within the boundaries of the AMP and, as such, no impacts to the KEF within the AMP are expected.

Outside of the AMP, the Active Source Zones for the survey have limited overlap with the KEFs (1.5% of the carbonate bank and terrace system of the Sahul Shelf and 1.2% of the pinnacles of the Bonaparte Basin). The survey primarily occurs over featureless shelf and basin features and soft-sediment habitats. Carbonate banks in the KEF that rise to within 45 m water depth support the greatest biodiversity, such as communities of sessile benthic invertebrates including hard and soft corals, sponges, whips, fans and bryozoans. The carbonate banks located within the Operational Area rise to approximately 62 m water depth and pinnacles located within the Operational Area rise to approximately 82 m water depth. At these greater depths, there is limited potential for extensive coverage of photosynthetic organisms such as hard corals to occur, although sponges, soft octocorals and filter-feeders may still be present at these depths.

As previously assessed in **Section 6.3.2.6**, the habitat structure and condition of the carbonate bank and terrace system of the Sahul Shelf KEF and pinnacles of the Bonaparte Basin KEF will not be impacted. No impacts will occur to soft corals, sponges or filter-feeders. While a range of effects to some benthic invertebrate organisms such as crabs, molluscs and echinoderms (including sub-lethal effects and chronic mortality in some organisms) may occur in close proximity to the operating seismic source, changes to these communities are unlikely to be discernible from natural variation. Impacts to the fish communities associated with carbonate banks and pinnacles are primarily expected to be behavioural and temporary.

As previously assessed in **Section 6.3.2.5**, impacts to zooplankton will be localised and limited to tens of metres from the seismic source; no long term impacts to plankton communities or fauna dependent on plankton as a food or recruitment source are predicted.

Therefore, the ecological function and values of the KEF (within the AMP or outside of the AMP boundary) will not be impacted.

BIAs for foraging and internesting marine turtles:

No seismic acquisition will occur near the defined Tiwi Islands turtle internesting BIAs within the Oceanic Shoal AMP, therefore, internesting turtles will not be disturbed in the AMP. The potential for behavioural effects to marine turtles is predicted to extend up to 5 km from the seismic source. As the Active Source Zones are located approximately 18 km from the AMP, no impacts to turtles within the AMP are predicted.

The Operational Area overlaps the Sahul Shelf where BIAs are defined for foraging marine turtles. As previously assessed in **Section 6.3.2.9**, given the water depths of the Active Source Zones range from 45 m to 105 m, and the predominantly soft sediment environment, the area overlapped by the survey may not represent significant foraging habitat compared with other shallower and more productive areas of the Sahul Shelf. Marine turtle bycatch by fisheries in this region also suggest that turtles are more abundant in water depths less than 30 m, while relatively few turtles occur in water deeper than 40 m. Given the transient nature of both foraging marine turtles and the seismic vessel, impacts to foraging turtles may include short-term disturbances, however, no long term or population level impacts are predicted.

Cultural, heritage, social and economic values:

The main commercial fishery operating in the same waters as the Petrel Sub-Basin SW 3D MSS is the Northern Prawn Fishery. The survey is planned to occur at a time that avoids the Northern Prawn Fishery's operations, and no significant impacts to prawn stocks are predicted (refer to **Section 6.3.2.6**). Sea country and other cultural values associated with the marine park are not expected to be affected by underwater sound emissions. No disturbance to traditional fisheries or other traditional practices will occur within the AMP.

Joseph Bonaparte Gulf AMP

Received sound levels at the AMP are predicted to be approximately 140 dB re 1 µPa SPL at times when the seismic source operates at a point within the Active Source Zones closest to the AMP. For the majority of the survey, when the seismic vessel and seismic source will be transiting at greater distances from the AMP, the received sound levels will be less. These received sound levels are below any threshold for physical or significant behavioural impacts for any marine fauna.

The potential impacts to the values of the Joseph Bonaparte Gulf AMP are summarised as follows.

Marine ecosystems and Key Ecological Features (KEFs):

The Petrel Sub-Basin SW 3D MSS does not overlap with the carbonate bank and terrace system of the Sahul Shelf KEF within the boundaries of the AMP and, as such, no impacts to the KEF within the AMP are expected.

As summarised above for the Oceanic Shoals AMP, impacts within the KEF (outside of the AMP) will be limited and the ecological function and values of the KEF will not be impacted.

BIAs for foraging and internesting marine turtles:

The potential for behavioural effects to marine turtles is predicted to extend up to 5 km from the seismic source. As the Active Source Zones are located approximately 23 km from the AMP, no impacts to turtles within the AMP are predicted.

No seismic acquisition will occur within the defined internesting BIA or the habitat critical for flatback turtles at Cape Domett, consistent with recommendations in the Recovery Plan for Marine Turtles in Australia. The habitat critical area is 24 km from the Operational Area and, therefore, internesting turtles will not be disturbed. It is also noted that turtles may nest year-round, with peak nesting activity occurring between July and September. Therefore, the proposed timing of the survey (1 December to 31 March) avoids the period when peak nesting occurs in the region.

As summarised above for the Oceanic Shoals AMP, impacts to foraging turtles may include short-term disturbances to transient individuals, however, no long term or population level impacts are predicted.

BIA for Australian snubfin dolphin:

The potential for significant behavioural effects to cetaceans is predicted to extend up to approximately 8.5 km from the seismic source. As the Active Source Zones are located approximately 23 km from the AMP, no impacts to snubfin dolphins within the AMP are predicted.

As previously assessed in **Section 6.3.2.8**, the received levels in the Australian snubfin dolphin BIA outside of the AMP, at its closest point near Cape Londonderry, are predicted to be approximately 130 dB re 1 µPa SPL from the closest modelling site. Distant pulses of sound may be audible to dolphins in the BIA when the seismic source is operating in the western part of the Operational Area but behavioural responses are not expected to be significant.

Cultural, heritage, social and economic values:

The main commercial fishery operating in the same waters as the Petrel Sub-Basin SW 3D MSS is the Northern Prawn Fishery. The survey is planned to occur at a time that avoids the Northern Prawn Fishery fishing operations, and no impacts to prawn stocks are predicted. Sea country and other cultural values associated with the marine park are not expected to be affected by underwater sound emissions. No disturbance to tourism, recreation, traditional fisheries or other traditional practices will occur within the AMP.

6.3.2.12.3 Summary

Received sound levels in the Oceanic Shoals AMP and Joseph Bonaparte Gulf AMP will be below any threshold for physical or significant behavioural impacts for any marine fauna.

No impacts to AMP values within the Oceanic Shoals AMP or Joseph Bonaparte Gulf AMP are predicted to occur.

The above assessment has also considered potential impacts to values, where they occur outside of AMP boundaries, in order to account for potential impacts to the values of the broader Marine Park Network as a whole. No significant, long term or population levels impacts are predicted.

The objectives of the North Marine Parks Network Management Plan are to provide for:

a) The protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North Network; and

b) Ecologically sustainable use and enjoyment of the natural resources within marine parks in the North Network, where this is consistent with objective (a).

Based on the predicted levels of impact to values of the AMPs, the Petrel Sub-Basin SW 3D MSS is expected to be undertaken in a manner that is not inconsistent with the management objectives for the Marine Park Network.

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

A seismic survey vessel and two support vessels (one supply and one chase) will be employed for the survey. Vessel noise comprises a combination of continuous noise generated by engine and machinery noise, and modulated, broadband noise produced by propeller rotation and cavitations (Richardson et al. 1995; Southall 2007; Jensen et al. 2009; Wales and Heitmeyer, 2002; Hildebrand, 2009). Vessel noise emissions varies with the size, speed, and engine type and the activity being undertaken. Noise levels for a range of vessels have been measured at 164-182 dB re µPa at 1 m (SPL) at dominant frequencies between 50 Hz and 7 kHz (Wyatt 2008; Simmonds et al. 2004).

In addition, a helicopter may be employed for the survey for the purpose of crew changes. Crew changes are expected to occur every 35 days (via helicopter or support vessel). The main source of noise from a helicopter is the main rotor. Dominant tones from helicopters are generally below 500 Hz (Richardson et al. 1995). The penetration of noise into the ocean is dependent on the angle of the aircraft and its distance from the sea surface. Typically, noise does not transmit well from air into water due to impedance at the air-water interface. Noise levels from a Bell 212 helicopter flying at altitudes of 610 to 152 m respectively were measured at 101 – 109 decibels (dB) at 3 m water depth (Richardson et al. 1995). This provides an indication of the low received level noise that may be expected from a helicopter.

In general, exposure to helicopter sound emissions is of short duration, peaking as the helicopter passes directly overhead. Received levels are expected to be low during transit when helicopter altitude is greatest and disturbance to marine fauna is not expected. The highest received levels will occur at lower altitudes on approach to landing. Some minor behavioural disturbance may occur for short periods if marine fauna are present near the surface in the vicinity of helicopters landing on the seismic survey vessel. This would be limited to a temporary change in behaviour due to avoidance of the area, but is not expected to have any longer term impacts.

The potential receptors of sound produced by vessels and helicopters are cetaceans, marine turtles, seabirds and migratory shorebirds.

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 600 m (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 (1995) 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. (1983) 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, seabirds and migratory shorebirds 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. Some transient individuals may avoid the immediate proximity of a vessel or helicopter, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations.

6.3.4 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ EPO-3: Commercial fishing licence holders are no worse off as a result of the seismic survey.
+ EPO-5: Undertake seismic acquisition in a manner that prevents serious or irreversible impacts to plankton communities or fauna dependent on plankton as a food source within the Operational Area.
+ EPO-6: No serious or irreversible impacts to listed marine fish, sharks and rays due to noise associated with the operation of seismic source, consistent with the MNES Significant Impact Guideline 1.1.
+ EPO-7: 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 source.
+ EPO-8: No injury to cetaceans due to noise associated with the operation of seismic sources.
+ EPO-9: No injury to turtles due to noise associated with the operation of seismic sources.
+ EPO-10: Undertake seismic acquisition in a manner consistent with the Recovery Plan for Marine Turtles in Australia 2017-2027.
+ EPO-11: No serious or irreversible impact to the sustainability of indicator commercial fish stocks for the following commercial fisheries due to noise associated with the operation of the seismic source:
  - Commonwealth Northern Prawn Fishery (NPF);
  - WA Northern Demersal Scalefish Managed Fishery (NDSMF);
  - WA Mackerel Managed Fishery (MMF);
  - NT Demersal Fishery (DF);
  - NT Spanish Mackerel Fishery (SMF); and
  - NT Offshore Net and Line Fishery (ONLF).
+ EPO 12: Far-field source levels for the selected seismic source for the Petrel Sub-Basin SW 3D MSS are consistent with levels assessed in this EP.
+ EPO-13: Protect and maintain biological diversity and other natural, cultural and heritage values of the North and North-west Marine Parks Network.

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-11	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-12	Implementation of EPBC Policy Statement 2.1 (Part A): + Pre start-up visual observation + Soft start procedures + Start-up delay procedure + Operations procedure + Shut-down procedure + Night-time and low visibility procedures	Minimise acoustic impacts to cetaceans 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 outweigh the costs incurred by Santos. MFOs will be on the seismic survey vessel.
CM-13	Marine fauna observations undertaken to minimise the disturbance to fauna caused by the Activity.	Reduces risk of physical impacts to marine fauna 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.
CM-14	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 Santos. Costs of	**Adopted** – benefits in reducing impacts to marine fauna outweigh the costs incurred by Santos.

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	employing MFOs and personnel costs involved in reporting sightings to authorities. Employment of experienced MFOs is not considered a significant additional cost.	
Additional control measures General / Non-receptor specific				
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 maximum volume of 3,480 in^3 has been identified for this purpose. Reducing the source volume further 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 in **Appendix F** or for the Santos Petrel Sub-Basin SW 3D MSS EP, then additional source modelling will be undertaken to confirm whether the sound levels are consistent with levels	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.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
		assessed as acceptable under this EP. Sound propagation modelling (**Appendix F**) and the risk assessment was based upon a 3,480 in^3 source with a far-field source specification of 248.6 dB re 1 µPa m PK in the broadside direction. Therefore, if modelling of the selected seismic source confirms that it does not exceed peak source pressure levels of 250 dB re 1 µPa m PK in the horizontal plane, it can be concluded that the acoustic output is consistent with the seismic sources already evaluated and provides reasonable confidence that propagated sound levels will be comparable to those assessed and found to be acceptable in this EP. This provides confidence in the impact assessment which was based on the acoustic modelling results.		

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
N/A	Baseline monitoring prior to the survey and monitoring for potential impacts within the Oceanic Shoals AMP and Joseph Bonaparte Gulf AMP during and after the survey (as per recommendation from DNP).	The received sound levels in the AMPs are predicted to be below levels that result in any physical effects or significant behavioural impacts to any marine fauna within the AMPs. No impacts to habitats within the AMPs will occur. No significant long term or population level impacts to AMP values are predicted to occur. Therefore, monitoring within the AMPs is not expected to provide a material environmental benefit.	Baseline monitoring and impact monitoring campaigns have the potential to cost millions of dollars to implement, given reliance on survey vessels, multiple survey events and subsequent analysis and reporting.	**Not adopted** – Baseline monitoring and monitoring during and after the survey will not be undertaken, given that the Petrel Sub-Basin SW 3D MSS will not be undertaken within an AMP and no significant impacts are predicted within the AMPs or to AMP values more widely. The costs associated with monitoring programmes is grossly disproportionate to the limited benefit that would be gained.
Megafauna (cetaceans, dugong, turtles, whale sharks)				
N/A	Pre-survey research would involve sending a dedicated research vessel to the planned 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)	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 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.	**Not Adopted** – Given the lack of spatial overlap of the Operational Area with cetacean BIAs, Santos considers the presence of cetaceans in the survey area to be limited to transient individuals/small groups. 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

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				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 and 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 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	**Not Adopted** – Costs outweigh benefits given the relatively low densities of whales expected in the Operational Area during survey acquisition, and the absence of any overlap between critical habitats (i.e. feeding, breeding, calving areas) or a constricted migratory pathway and the Acquisition Area.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			on board additional vessels/airplanes.	
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 and 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, given the lack of spatial overlap cetacean BIAs, Santos considers the presence of cetaceans in the survey area during the Activity to be limited to transient individuals/small groups. 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 MSS is not being completed in a key breeding or resting area for cetaceans and other fauna, they will only be passing through the area.
N/A	Thermal Imaging camera can be used to detect cetaceans and blows during daylight and low visibility/night-time by detecting heat signatures. Can detect cetaceans at night which reduces the risk of impacts if undertaking seismic	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 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.	**Not Adopted** – the observer must be focusing the thermal imaging camera on the cetacean when it surfaces to enable a positive verification to be 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

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
	acquisition due to no MFO observations			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.
Cetacean 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 does not overlap with any cetacean BIAs.	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.
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	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	**Not Adopted** – Consideration was given to the other controls provided for in Part B of the EPBC Policy Statement 2.1, including the use of PAM. The additional management measures described in Part B are designed to ensure that impacts and interference to whales are avoided/and or minimised for seismic surveys operating in areas where the likelihood of encountering whales is moderate to high. There are no known aggregation areas for foraging, breeding, calving or resting habitat for cetaceans within or in close proximity to the Operational Area. Although PAM can be used to supplement visual observations made by the MFO, the method is dependent upon animals vocalising.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
	survey operations (EPBC Policy Statement 2.1 – Part B.5)		required, with a dedicated vessel thus increasing cost.	Costs for engaging a trained PAM operator for the survey are approximately US$40,000. The significant additional cost of having a qualified PAM operator on board for the duration of the survey when few or no detections are expected was determined to outweigh any limited additional benefit that PAM might provide, particularly given the proposed soft-start, night time and low visibility procedures. MFOs may be trained in the operation of the PAM system on board the vessel, however, MFOs on board the vessel will be present to undertake observational duties on deck and therefore additional MFOs would need to be engaged at a similar cost. Given that the Operational Area is not significant for cetaceans, and the limited detections expected from the use of PAM, the cost of this option is considered to outweigh the limited potential for any further reduction to an already low level of risk.
N/A	Implementation of EPBC Policy Statement 2.1 (partial part B.6 – adaptive management)	Adaptive management of shutdowns based on sightings of cetaceans rather than a fixed date optimises the time for seismic acquisition without increasing the risk to cetacean species.	Given that the Operational Area is not significant for cetaceans, the costs to implement adaptive management measures are grossly disproportionate to the limited environmental benefit gained.	**Not Adopted** – Potential impacts to whales are already reduced to an acceptable level, given Part A of EPBC Policy Statement 2.1 will be applied in full and that low densities of whales are expected in the Operational Area , and the absence of any overlap with critical habitats or a constricted migratory pathway. The costs to implement adaptive management measures are grossly disproportionate to the limited environmental benefit gained.
N/A	No start up or operations at night-time / low visibility	Would reduce probability of a cetacean occurring within the low power/shutdown	Increases time of MSS as operations only continue for ~10 hours/day. Increase cost due to	**Not Adopted** – Cost outweighs the environmental benefit given the low numbers of marine fauna that reside in the area as opposed to transiting through. Given the lack of spatial overlap with

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
	(EPBC Policy Statement 2.1 – Part B.2)	zone and not being detected.	increased MSS time (more than double the cost). Survey objectives would not be met in available timeframe.	humpback whale and pygmy blue whale migration BIAs, 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.
Marine turtles				
CM-16	Shutdown procedures for turtles	Minimise potential for acoustic impacts to turtles.	Increased costs of the survey through additional shutdowns, prolonging the survey duration.	**Adopted** – Small numbers of turtles may be transiting through the survey area. Thus, EPBC Act Policy Statement 2.1 – Interaction between Offshore seismic exploration: Part A will be applied to turtles as a control to minimise impacts to turtles. In order to reduce the potential risks to turtles, a 250 m shut-down zone is considered to be a practicable measure to implement. A 250 m shutdown zone is considered to be conservative given that PTS and TTS effects are predicted to be limited to less than 20 m from the seismic source, and exceedance of a more precautionary injury threshold (Popper et al. 2014) is predicted up to a maximum of 160 m distance from the source. Observing for turtles at distances greater than 250 m from the source (which itself is towed a short distance behind the vessel) is unreliable due to the small size of turtles' heads above the surface, even in calm conditions, and is not considered practicable. The seismic source will be shut down, or start-up will be delayed, if a turtle is observed within the shut-down zone. Operation of the seismic source using soft-start shall only resume after the turtle has

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				been observed to move outside the shut-down zone or the survey vessel has proceeded more than 250 m from the last turtle sighting (approximately 4 minutes sail time at 4.5 knots). Given that turtles are slow swimming relative to the survey vessel and due to their limited sensitivity to sound (impairment impacts limited to <20 m form the seismic source), the shut-down and start-up delay is considered appropriate. Further start up delay is not considered practicable, as it could result in significant periods of shut-down when turtle are not close enough to the seismic source to experience hearing impairment impacts. Multiple shut-downs and delays could extend the overall survey duration at significant cost (tens of thousands of dollars per day that the survey is extended). The benefit is considered to outweigh the cost.
N/A	Adaptive management methods for marine turtles: + Increased shutdown zone + No night-time/low visibility operations	Minimise potential for acoustic impacts to turtles.	Increased observation zones for turtles are not considered to be feasible. Observing for turtles at distances greater than 250 m from the source (which itself is towed a short distance behind the vessel) is unreliable due to the small size of turtles' heads above the surface, even in calm conditions, and is not considered practicable. No night-time or low-visibility operations has the potential to significantly extend the duration of the survey and may mean the	**Not Adopted** – Turtles in the area are expected to be transitory, with the exception of foraging turtles. Due the small area where acquisition will be undertaken, and the fact that waters of the Operational Area are unlikely to represent significant foraging habitat for any turtle species, it is unlikely that significant numbers of turtles will be encountered. The potential for PTS and TTS effects in turtles is limited to less than 20 m (i.e. in direct proximity to the source array) and, therefore, the existing 250 m shut down zone combined with soft-start procedures will be effective in protecting marine turtles from potential physical effects and significant

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			planned acquisition cannot be completed within the already limited window (1 December to 31 March).	behavioural responses. Observing turtles at greater distances than 250 m from the seismic source is not considered practicable. Thus the implementation of adaptive management, such as an increased shut down zone or no night-time/low visibility operations is not considered to provide significant environmental benefit.
CM-17	No operation of the seismic source within the internesting BIA for flatback turtles during the nesting season.	Minimise potential for acoustic impacts to turtles.	None. The survey and Operational Area are already designed to exclude the internesting BIA for flatback turtles.	**Adopted** – The Recovery Plan for Marine Turtles in Australia (DoEE 2017) states that a precautionary approach should be applied to seismic surveys, such that surveys should not occur inside important internesting habitat during nesting season. The Operational Area abuts the internesting BIA for flatback turtles. The seismic source will not be operated outside of the Operational Area (and therefore, not within the internesting BIA).
N/A	Exclude seismic acquisition within turtle foraging BIAs.	Minimise potential for acoustic impacts to turtles.	The entire Operational Area overlaps with turtle foraging BIAs. Avoiding these BIAs would mean the survey would not be able to go ahead.	**Not Adopted** – The combined foraging BIAs for flatback, loggerhead, green and olive ridley turtles in the JBG overlap the entire Acquisition Areas and Operational Area. Therefore, it is not possible to exclude the BIAs from seismic acquisition. Complete exclusion of the BIAs is not considered feasible as the loss in data would be too significant and the survey would not be able to acquire the clients' (block titleholders) required line kilometre commitments under their permit to NOPTA. The waters of the Operational Area are unlikely to represent significant foraging habitat for any turtle species. Two individual pinnacles (associated with the pinnacles of the Bonaparte Basin KEF) are located within the Operational Area. Water depths

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				on the tops of these pinnacles are in the range of approximately 82 – 90 m, and therefore are highly unlikely to represent foraging habitats for any turtle species. Given that only short-term and localised behavioural impacts are predicted in response to the transient seismic source, displacement from critical foraging habitat or population level impacts is not likely to occur and the risk to turtles is already low. Therefore, the cost of excluding the BIAs far outweighs the small environmental benefit that would be gained from doing so.
Socio-economic				
CM-9	Commercial fishery payment claims (further details are provided in **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 and financial loss. 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	Reduce 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** – Santos would not be able to obtain the data for the identified hydrocarbon prospects being targeted. While it is acknowledged that this would provide a reduction in risk to the commercial

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				fishing industry, it is not practicable or feasible to implement. As assessed, acquisition has the potential to disrupt up to just 9.37% of NPF fishing activities in the JBG and for a small proportion of the fishing season. Overlap with other commercial fisheries is less (<1%).
N/A	Avoidance of prawn spawning and/or migration periods	Ensures no impacts to prawn spawning and recruitment. However, limited impacts to prawn spawning and recruitment are currently predicted and so limited benefit would be gained.	Survey would not be able to occur due to spawning occurring year round and peak spawning periods for different prawn species occurring at different times of year. Even if avoiding red-legged banana prawn spawning and migration the survey would not be able to be undertaken within the necessary timeframes. The 1 December to 31 March survey window has been identified such that it already limits overlap with commercial fishing activities and other key environmental sensitivities. The proposed timing is also key to Santos for operational and commercial reasons, with the timing intended to allow for the contracted to seismic vessel to transition to/from the Petrel Sub-Basin SW 3D MSS to other Santos seismic surveys that could potentially occur off northern	**Not Adopted** – Given the exact timing of the survey will be subject to vessel availability and a number of other commercial, operational and environmental factors, some level of flexibility is required for the survey window. Reducing the survey window could prevent Santos from being able to complete the survey or it could mean the survey is not financially feasible, if contracting of a seismic vessel cannot align with other potential Santos surveys in Australian waters. Given limited additional benefit can be gained for commercial fisheries by altering or reducing the survey window, the potentially significant cost to Santos means that this option is not practicable.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			Australia during the same periods allowed for under this EP (e.g. phases of the Keraudren Extension 3D MSS from 1 February to 31 July in 2021 or 2022). The commercial viability of the Petrel Sub-Basin SW 3D MSS depends on the ability to utilise a single seismic vessel contract and acquire these surveys consecutively. The cost of contracting and mobilizing a separate seismic vessel for the Petrel Sub-Basin SW 3D MSS or to cover the cost of periods of vessel downtime if scheduling of the various surveys cannot align, can be several millions of dollars. This would mean that the Petrel Sub-Basin SW 3D MSS is not financially feasible and it is likely it could not go ahead.	
N/A	Avoidance of spawning times for commercially targeted key indicator finfish species.	Minimise the potential impacts to spawning fish or commercial importance and their fish eggs and larvae.	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.	**Not Adopted** – Combined spawning periods for the key indicator species covers all 12 months of the year, and therefore the survey could not be acquired. Santos has considered in detail fish spawning periods. Significant disturbance to groups of spawning fishes are limited to short periods while the seismic source is passing within hundreds of metres of their location, however this is not expected to have a significant impact on the stocks.

REF	Control measure	Environmental benefit	Potential cost/issues	Evaluation
				The costs are grossly disproportionate to any potential environmental benefit gained.
N/A	No helicopter operations	Minimise acoustic disturbance to marine fauna from helicopter operations	Vessel would be required to return to port (approximately every five 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.

6.3.5 Impacts and Consequence Ranking

Receptor	Consequence Level
Noise from operation of the 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 Any mortality effects to zooplankton resulting from seismic noise emissions are likely to be highly localised and inconsequential compared to natural mortality rates. Given the currents in the area aiding natural replenishment, plankton depletion is not expected to have ecosystem-wide impacts, 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 ***Negligible***. Invertebrates Based on the impact assessment no long term or population impacts to invertebrates (crustaceans, molluscs, corals, filter-feeders) are predicted. Thus, the consequence level for benthic invertebrates is assessed as negligible. No effects to benthic invertebrates are expected within the pinnacles of the Bonaparte Basin and the carbonate bank and terrace system of the Sahul Shelf KEFs. The potential risk to commercial prawns within the JBG is also considered to be limited. Thus, the consequence level for crustaceans and molluscs is assessed as ***Minor***. Fish, sharks and rays 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/elasmobranchs 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 likely to be limited to tens or hundreds of metres of the seismic source, which pelagic and demersal fish can avoid. Based on the impact assessment no long term or population impacts to individual fishes (including sawfish) or fish stocks 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. Given that the Operational Area does not overlap with any cetacean BIAs, the presence of cetaceans is expected to the limited to transient individuals/small groups. 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***. Marine turtles 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. Although the Operational Area overlaps with a number of marine turtle foraging BIAs, given the water depths and distance from nesting beaches, the Operational Area is unlikely to represent significant foraging habitat for these species. Based on the impact assessment, no long term or population impacts to turtles are predicted. Thus, the consequence level is assessed as ***Minor***. Seabirds and migratory shorebirds Diving seabirds and migratory shorebirds 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	Not applicable – no impacts to corals, filter-feeders or the physical habitat structure of the seabed are predicted to occur.
Threatened Ecological Communities	Not applicable – no threatened ecological communities are identified in the area over which noise emissions are expected to occur.
Protected Areas	The closest protected areas are the Oceanic Shoals AMP, located 10 km north of the Operational Area, and the JBG AMP, located 12 km from the Operational Area. Received sound levels at the AMP will be below levels that may result in impacts. The physical environment/habitat and marine fauna are included as values of the AMPs and the consequence of potential impacts to these receptors is discussed above. As no long term or population level impacts are predicted, the Petrel Sub-Basin SW 3D MSS will not impact upon the values of the AMP or the wider Marine Parks Network. The consequence level is assessed as ***Negligible.***
Socio-economic receptors – Commercial fisheries	Potential impacts to fish from noise levels exceeding exposure thresholds may have direct effects on commercial fisheries. Population level impacts to fish or prawns 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 fishes, 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. The consequence to commercial fisheries has been assessed as ***Minor***.
Overall worst case consequence	II – 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 operation from vessels and helicopters	
Threatened/Migratory/ Protected Fauna	Noise generated from vessels and helicopters may result in momentary behavioural effects to marine fauna. However, acoustic emissions from vessels and helicopters will be less than that of the seismic source.
Physical Environment/Habitat	Not applicable
Threatened Ecological Communities	Not applicable – no threatened ecological communities are identified in the area over which noise emissions are expected to occur.
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 – Commercial fisheries	Due to 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	I - Negligible Considering the levels of received noise from operating vessels and helicopters, potential impacts will be restricted to temporary behavioural responses and are expected to have negligible consequence on populations or ecosystem function.

6.3.6 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 December to 31 March).

No additional control measures to those provided in **Section 6.3.4** were identified to further minimise impacts to prawn and fish spawning and recruitment, commercial fishers, invertebrates and plankton. The survey is unable be timed to avoid all spawning periods due to the species present.

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.

6.3.7 Acceptability Evaluation

Is the consequence ranked as I (Negligible) or II (Minor)?	Yes – Maximum consequence from noise emissions is II (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. 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 is 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 as having the potential to be impacted by noise emissions.
	EPBC Policy Statement 1.1. – Significant Guidelines Yes – The overall worst-case consequence for noise emissions has been determined to be ***Minor*** and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
	Recovery Plan for Marine Turtles in Australia (DoEE 2017) Yes – The Recovery Plan states that a precautionary approach should be applied to seismic surveys, such that surveys should not occur inside important internesting habitat during the nesting season. Consistent with this approach, the Petrel Sub-Basin SW 3D MSS is located 24 km from any habitat critical for the survival of marine turtles, as defined in the Recovery Plan. The Operational Area is adjacent to an internesting BIA for flatback turtles, however, studies indicate that the Operational Area will not provide important habitat for turtles. The Recovery Plan states that in accordance with EPBC Act Policy Statement 2.1 – Interactions between Offshore Seismic Exploration and Whales, all seismic survey vessels operating in Australian waters must undertake a soft start during surveys irrespective of location and time of year of the survey. Soft-starts (as well as shut-down procedures, which exceed this requirement) will be implemented during the seismic survey. The Recovery Plan also recognises that activities resulting in impacts to foraging habitats may indirectly contribute to a decreased viability of marine turtle stocks by reducing food availability. The impacts of the seismic survey on the behaviours of marine turtles is expected to include short term, transient disturbances to marine turtles. The survey is not expected to result in the decreased availability of prey and is not expected to result in the displacement of turtles from foraging BIAs. Therefore,

	the survey is not expected to indirectly impact the viability of any marine turtle stocks.
	North Marine Parks Network Management Plan Yes – The objectives of the North Marine Parks Network Management Plan are to provide for: a) the protection and conservation of biodiversity and other natural, cultural and heritage values of marine parks in the North Network; and b) ecologically sustainable use and enjoyment of the natural resources within marine parks in the North Network, where this is consistent with objective (a). Based on the predicted levels of impact to values of the Oceanic Shoals and the Joseph Bonaparte Gulf AMPs, the Petrel Sub-Basin SW 3D MSS is expected to be undertaken in a manner that is not inconsistent with the management objectives for the AMPs and the North Marine Park Network.
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 – Commercial fisheries stakeholders have raised concerns regarding potential impacts to fish and prawn stocks. Santos has therefore assessed the potential for such impacts in detail. NPFI recommended that Santos take measures to minimise and mitigate impacts on both NPF fishing operations and prawn stocks in the area as much as possible. The timing of the Petrel Sub-Basin 3D MSS (1 December to 31 March) was defined in order to prevent overlap with NPF fishing activities. It is noted, however, that this timing also reduces seismic acquisition during peak prawn spawning periods and so indirectly reduces the potential for impacts to prawns as well. WAFIC requested that population level effects to fishes and marine invertebrates be assessed in the EP. Potential impacts to commercial fish stocks, prawn stocks and benthic communities have been assessed in detail in this section of the EP. DNP requested that potential impacts to AMP values are assessed in the EP. The potential impacts to AMP values, both within and outside of the AMP boundaries, have been assessed. Mitigation and monitoring suggestions made by the DNP have been considered in **Section 6.3.4**. Detailed responses have been provided to stakeholders, as detailed in **Section 4.4**. Relevant fishery stakeholders were also 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 survey, control measures and performance standards, and will continue to engage with stakeholders as committed.
Are control measures and performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).

Defined Acceptable Levels				
Does the predicted impact meet defined acceptable levels of impact (refer to **Section 5.1.5**)?	Receptor Category	Defined Acceptable Level	Comparison with Predicted Levels of Impact	EPO
	EPBC Act-listed threatened and migratory cetaceans	Seismic activities are not inconsistent with a recovery plan or wildlife conservation plan/ advice that is in force for a species of cetacean. This includes no injury to a cetacean and no displacement of foraging, aggregating, calving/breeding, or migrating cetaceans from identified BIAs.	Santos considers the level of impact to cetaceans to be of an acceptable level. Potential impacts of noise emissions from the seismic survey have been evaluated against the requirements within relevant conservation management plans and approved conservation advice. With control measures implemented, no injury to a cetacean is expected.	EPO-3 EPO-5 EPO-6
	EPBC Act-listed threatened and migratory marine turtles	Seismic activities are not inconsistent with the Recovery Plan for Marine Turtles. This includes no acquisition inside important internesting habitat during the nesting season.	Santos considers the level of impact to marine turtles to be of an acceptable level. Potential impacts of noise emissions from the seismic survey have been evaluated against the requirements within the Recovery Plan for Marine Turtles in Australia. No seismic acquisition will occur within defined habitat critical for the survival or marine turtles, and soft-starts (as well shut-down procedures) will be implemented. Disturbance to internesting turtles is therefore not expected.	EPO-11 EPO-12

	EPBC Act-listed threatened and migratory fish, sharks and rays	Seismic activities are not inconsistent with the conservation advice that is in force for whale sharks and the MNES Significant Impact Guideline 1.1, including no serious or irreversible impacts to listed marine fish (including sharks) due to noise associated with the operation of seismic source.	Santos considers the level of impact to fish, sharks and rays (including whale sharks and sawfish) to be of an acceptable level. Potential impacts of noise emissions from the seismic survey have been evaluated against the requirements within the conservation advice that is in force. Given the control measures to be implemented for the seismic survey, which include shut-down procedures for whale sharks, no injury is expected and the potential for disturbance or serious or irreversible impacts is limited.	EPO-7
	Non-EPBC Act-listed species and ecological communities	Given the widespread distribution of non-EPBC listed marine fauna species and ecological communities, and that non-EPBC listed species and communities are not formally managed, Santos considers it acceptable to have a Negligible (I) or Minor (II) consequence. As defined within Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004), a Minor consequence is defined as a 'Detectable but insignificant change to a local population, industry or ecosystem factor. Localised effect,	Santos considers the level of impact to non-EPBC Act-listed species and ecological communities to be of an acceptable level. The consequence of potential impacts to such marine fauna and ecological communities (including plankton and benthic invertebrate communities) from noise emissions has been assessed to be Negligible (I) to Minor (II).	EPO-6 EPO-8

		lasting weeks up to 12 months.		
	Commercial fisheries	No serious or irreversible impact to the sustainability of key indicator commercial stocks within the: • Commonwealth Northern Prawn Fishery; • WA Northern Demersal Scalefish Managed Fishery; • NT Demersal Fishery; • NT Spanish Mackerel Fishery; and • NT Offshore Net and Line Fishery. Commercial fishing license holders are no worse off as a result of the seismic survey.	Santos considers the level of impact to commercial fisheries and fishers to be of an acceptable level. The seismic survey is not expected to result in any direct reduction in the spawning biomass through fish mortalities. Therefore, the survey is not expected to result in a serious or irreversible impact to the sustainability of key indicator commercial fish stocks. 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 are expected return to typical catch levels relative to fishing effort.	EPO-3 EPO-13
	Australian Marine Parks (AMPs)	Protect and maintain biological diversity and other natural, cultural and heritage values in accordance with the conservation objectives of the North-west Marine Parks Network Management Plan (2018) and North Marine Parks Network Management Plan (2018).	Santos considers the level of impact to AMPs to be of an acceptable level. The activity is consistent with AMP management prescriptions, IUCN conservation objectives and the ecological use of the AMPs.	EPO-18

6.4 Cumulative and Additive Seismic Impacts

6.4.1 Description of Event

Cumulative and Additive Seismic Impacts
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 Petrel Sub-Basin SW 3D MSS. The two types of impacts 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 the predicted impacts from the Petrel Sub-Basin SW 3D MSS. Cumulative impacts will only occur where the effects of previous surveys overlap the same area and receptors, and when recovery of the impacts from previous seismic surveys has not occurred prior to the Petrel Sub-Basin SW 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 Petrel Sub-Basin SW 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 within the footprint of 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 Petrel Sub-Basin SW 3D MSS. It is not possible to anticipate what surveys will be planned after the Petrel Sub-Basin SW 3D MSS and it is the responsibility of future seismic survey proponents to assess the potential cumulative impacts in their EPs.
Operational Area (cumulative impacts) North West Marine Region and North Marine Region (additive impacts)
For the duration of the Activity as described in **Section 2**.

6.4.2 Nature and Scale of Cumulative Impacts

A review of data available on the National Offshore Petroleum Information Management System (NOPIMS) and Seisintel websites identified four 3D and one 2D seismic surveys that have been undertaken in the waters of the JBG, either overlapping or adjacent to the Petrel Sub-Basin SW 3D MSS Operational Area, in the past five years (since 2016). These surveys are presented in **Figure 6-5** and summarised in **Table 6-17**.

6.4.2.1 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 Petrel Sub-Basin SW 3D MSS commencing or not. As described in **Section 6.3**, 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 (including eggs and larvae) 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 (e.g. McCauley et al. 2017; Richardson et al. 2017), 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 variability in 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 and sublethal effects to some immobile benthic invertebrate communities considered to have the longest population recovery period. Longer term, only sublethal impacts to some benthic invertebrate organisms may persist but would not inhibit reproductive potential or community structure (refer to **Section 6.3.2.6** and **Appendix G**).

Based on these recovery periods, an assessment of the potential cumulative impacts to ecological receptors is included in **Table 6-17**.

Given the time that has elapsed since previous surveys were undertaken in this area, all receptors are expected to have recovered from the effects of previous surveys prior to commencement of the Petrel Sub-Basin SW 3D MSS. Therefore, cumulative impacts to ecological receptors are not expected to occur as a result of any of the identified previous seismic surveys in the region and the proposed Petrel Sub-Basin SW 3D MSS.

Santos

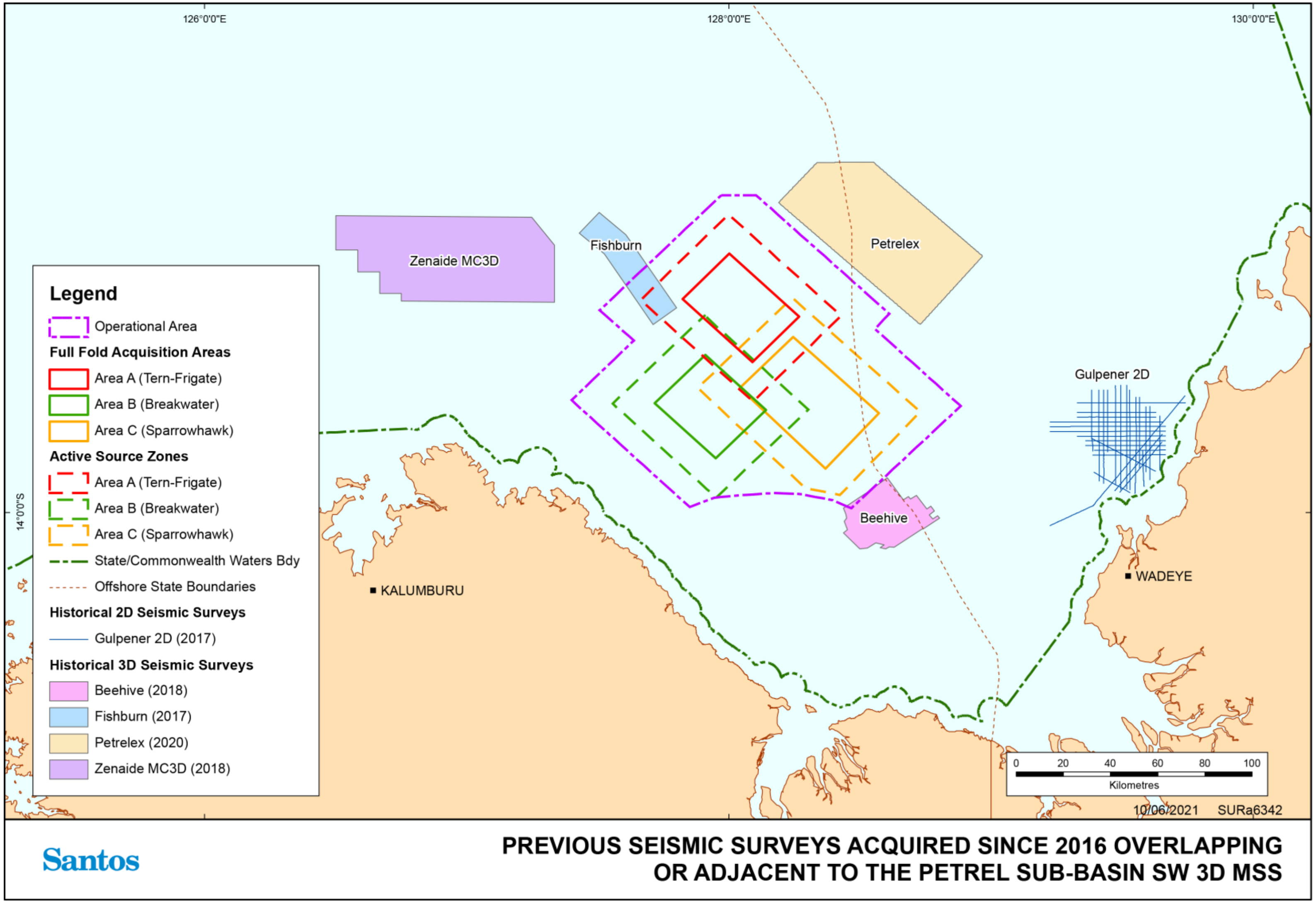


Figure 6-5: Previous seismic surveys acquired since 2016 overlapping and adjacent to the Petrel Sub-Basin 3D MSS

Santos

Table 6-17: Previous seismic surveys acquired in the JBG since 2016 overlapping or adjacent to the Petrel Sub-Basin SW 3D MSS

Survey Name	Company	Year	Survey Location	Survey Status and Timing	Potential Cumulative Impacts to Ecological Receptors
Fishburn WA-459-P Seismic Survey	Santos Limited	2017	The survey overlaps with the Operational Area, as well as the Full-fold Acquisition Area and Active Source Zone for Area A (Tern-Frigate) of the Petrel Sub-Basin SW 3D MSS. Maximum of 3,150 km^2 of 3D seismic acquisition in exploration permit WA-459-P.	Completed 27/06/2017 – 11/07/2017. 15 days acquisition.	The Fishburn survey was completed >4 years prior to the earliest potential start date for the Petrel Sub-Basin SW 3D MSS and recovery of all impacts, including to benthic communities, is expected to have occurred. No cumulative impacts to ecological receptors are expected to have occurred.
Gulpener 2D MSS	Origin Energy Resources Limited	2017	Located approximately 40 km east of the Operational Area. Maximum of 2,850 km^2 of 2D seismic acquisition in permit NT/P84.	Completed 24/06/2017 – 05/07/2017. 12 days acquisition.	There is no spatial overlap with the Petrel Sub-Basin SW 3D MSS. The Gulpener 2D MSS was completed > 4 years prior to the earliest potential start date for the Petrel Sub-Basin SW 3D MSS and recovery of all impacts, including to benthic communities, is expected to have occurred. No cumulative impacts to ecological receptors are expected to have occurred.
Zénaïde 3D MSS	Polarcus	2018	Located approximately 25 km north-west from the Operational Area. Maximum of 2,850 km^2 of 3D seismic acquisition in exploration permit WA-552-P.	Completed 18/01/2018 – 18/04/2018. Maximum of 60 days of acquisition.	There is no spatial overlap with the Petrel Sub-Basin SW 3D MSS. The Zénaïde 3D MSS was completed >3 years prior to the earliest potential start date for the Petrel Sub-Basin SW 3D MSS and recovery of all impacts, including to benthic communities, is expected to have occurred. No cumulative impacts to ecological receptors are expected to have occurred.

Santos

Survey Name	Company	Year	Survey Location	Survey Status and Timing	Potential Cumulative Impacts to Ecological Receptors
Beehive 3D MSS	Santos Limited	2018	The survey overlaps with the southern boundary of the Operational Area. Acquisition took place approximately 6 km from the Active Source Zone for Area C (Sparrowhawk) of the Petrel Sub-Basin SW 3D MSS. Maximum of 975 km^2 of 3D seismic acquisition in exploration permit WA-488-P.	Completed 23/07/2018 – 11/08/2018. 20 days of acquisition.	There is no spatial overlap with the Active Source Zones of the Petrel Sub-Basin SW 3D MSS, but a small (<10 km^2 overlap with the Operational Area). The Beehive 3D MSS was completed >3 years prior to the earliest potential start date for the Petrel Sub-Basin SW 3D MSS and recovery of all impacts, including to benthic communities, is expected to have occurred. No cumulative impacts to ecological receptors are expected to have occurred.
Petrelex 3D Marine Seismic Survey	Polarcus	2019	Located approximately 6 km north-east from the Operational Area. Approximately 2,900 km^2 of 3D seismic acquisition.	Completed 01/12/2019 – 16/01/2020. 46 days of acquisition.	There is no spatial overlap with the Petrel Sub-Basin SW 3D MSS. The Petrelex survey was completed more than 20 months prior to the earliest potential start date for the Petrel Sub-Basin SW 3D MSS and recovery of all impacts, including to benthic communities, is expected to have occurred. No cumulative impacts to ecological receptors are expected to have occurred.

6.4.2.2 Cumulative effects on commercial fisheries

A separate assessment has been undertaken on the potential cumulative impacts to commercial fisheries. Consultation with commercial fishery stakeholders, in particular the NPF, has highlighted concerns regarding seismic surveys taking place within the fishery, including surveys that have taken place in past years.

Of particular concern to NPF stakeholders was that catch in JBG was significantly lower in 2015 and 2016 compared to long term historical catches. Whilst there may be a number of influencing factors, stakeholders are concerned that impacts resulting from seismic exploration have been a contributing factor. Confidential catch and effort data provided by NPFI for the JBG in 2019 (provided to NOPSEMA in the Sensitive Information Report) confirms that banana prawn catch levels (the main component of the JBG section of the fishery) during 2015 and 2016 was low.

Therefore, to address these concerns, Santos has assessed the potential cumulative impacts from previous seismic surveys on the NPF. Noting that the Petrel Sub-Basin 3D MSS has had limited overlap with historical fishing effort by the WA and NT-managed fisheries, no further detailed assessment of cumulative impacts has been undertaken for these fisheries.

Santos has reviewed historical seismic surveys within the JBG based on survey data on the National Offshore Petroleum Information Management System (NOPIMS) database and compared these with the NPF catch and effort data for the JBG. No seismic surveys were undertaken in the JBG between 2015 and 2016 when catch levels were reportedly low, therefore, direct interference from seismic surveys on NPF fishing activities could not have been a contributing factor to the reduced banana prawn catch levels in those years.

It is noted from the confidential catch and effort data provided by NPFI for the JBG that in addition to banana prawn catch being low in 2015 and 2016, fishing effort during the banana prawn season in these years was also lower than normal. Catch per unit effort (CPUE) was actually comparable to other years.

Noting the ~6 month timescale of recruitment (from spawning of eggs to recruitment of juveniles to the adult stock in the JBG) and the 1-2 year life cycle of prawns, it is also unlikely that reduced catches during the 2015-2016 fishing seasons (2-3 years after the last seismic survey prior to this in the region) are the result of seismic impacts to the recruitment of the prawn stocks. As noted in **Section 6.3.2.6,** the potential effects of seismic to prawn spawning and recruitment are likely to be negligible in the context or natural variability. It is also consistently noted in each annual fishery status report published by ABARES that annual catches are variable from year to year because of natural variability in the banana prawn component of the fishery.

Santos has also reviewed banana prawn catch and effort data for the broader NPF for the years 2010-2019 (**Table 6-18**). Relatively low catch levels are evident in 2015 and 2016 (albeit less pronounced than the JBG, probably because banana prawns make up a relatively larger proportion of the catch in the JBG compared with the wider fishery). The low catch levels in 2015 and 2016 resulted in the assessment of the banana prawn stock biomass being classified as uncertain in 2016. Given that low banana prawn catch levels evident across the entire fishery in 2015 and 2016, and not just in the JBG, external factors other than seismic surveys need to be considered.

Table 6-18: NPF Banana prawn catch and effort data, 2010-2019 (Source: ABARES)

Year	Banana Prawn Catch (Tonnes)	Banana Prawn Season Effort (Days)	Banana Prawn CPUE	Red-legged Banana Prawn Biomass Status
2010	5642	3146	1.793	Not overfished
2011	7141	3440	2.076	Not overfished
2012	4901	2526	1.940	Not overfished
2013	3094	2192	1.411	Not overfished
2014	6245	2476	2.522	Not overfished
2015	3931	2249	1.748	Not overfished
2016	2877	2302	1.250	Uncertain
2017	5045	2304	2.190	Not overfished
2018	4708	2506	1.879	Not overfished
2019	5640	2392	2.358	Not overfished

The annual fishery status report for 2017 (Larcombe and Bath 2017) provides some explanation for the very low catch and effort levels in 2015 and 2016:

'The Northern Prawn Resource Assessment Group (NPRAG) analysed the anomalously low JBG catches of red-legged banana prawns in 2015 and 2016 (Plagányi et al. 2017). One hypothesis is that recruitment or availability was lower in 2015 and 2016 as a result of anomalous environmental factors. Preliminary work by Plagányi et al. (2017) found an association between catch rates and different combinations of El Niño conditions (Southern Oscillation Index) and seasonal rainfall. The model predicted low catch rates in both 2015 and 2016 as a result of El Niño conditions and below-median rainfall.

Another hypothesis for the low JBG catches is the potential existence of more favourable fishing opportunities in other parts of the multispecies NPF, particularly for tiger prawn fishing in the Gulf of Carpentaria, thereby leading to low fishing effort in JBG. Preliminary analysis found some association between lower JBG catches and higher catch rates in the tiger prawn fishery, which would contribute to low effort in JBG during years of unfavourable environmental factors, as explained above. So, low JBG catches may result from a combination of both poor environmental conditions in JBG and better fishing opportunities elsewhere.'

It was subsequently confirmed that extensive marine environmental impacts occurred in the region as a result of an unprecedented marine heat wave (Nohaïc et al. 2017). The event, linked to a record El Niño, resulted in coral bleaching and impacts to marine species throughout Australia. The heatwave primarily affected the Kimberley region of WA (including the JBG) and effects were also documented far south in the Tasman Sea. The heat wave was also farther reaching than Australia, with the El Niño being documented as the third global mass coral bleaching event on record (Nohaïc et al. 2017). The reduced catch and effort in 2015 and 2016 can therefore be attributed to unprecedented environmental factors.

Santos also notes that prior to the decrease catch levels in 2015 and 2016, between 2007 and 2014, catch per unit effort (CPUE) in the JBG banana prawn fishery was relatively high compared with other years, increasing from a typical CPUE in 2007 by as much as 30 – 100% for the next seven years. This same period coincided with a period of seismic surveys in the JBG, including the Petrel 3D MSS (2007), the Bernier 2D MSS (2008), Penguin 2D MSS (2010), Falcon 2D MSS (2011) and the Petrel Sub-Basin CO_2 MSS (2012). Seismic surveys occurred again in the JBG in 2017 and 2018 (Gulpener 2D MSS, Fishburn 3D MSS, Beehive 3D MSS) when banana prawn CPUE was once again at or above average.

If seismic surveys do have an effect on prawns, the CPUE data assessed above suggests that they have not previously resulted in impacts on the JBG stocks at a population level and that larger scale environmental factors have a greater influence on recruitment, prawn biomass and CPUE.

Based on the above assessment, there is no correlation between past seismic surveys and changes in prawn catch or fishing effort in the JBG or broader NPF. Occasional interactions between seismic vessels and fishing vessels may have taken place, resulting in relocation by fishing vessels, but this appears not to have a longer term impact on overall catch levels in any year.

6.4.3 Nature and Scale of Additive Impacts

During the same years that the Petrel Sub-Basin SW 3D MSS may be acquired (2021 – 2023), no other seismic surveys are currently proposed in the JBG. Santos has reviewed what other seismic surveys may be proposed in the wider region that:

+ May occur within the same EP timeframes (2021 – 2023); and
+ Either have an EP accepted by NOPSEMA or have submitted an EP to NOPSEMA for public comment or assessment.

The criteria were applied to a region that included the entire Bonaparte Basin, as well as the extent of the Kimberley (WA) and NT fishery management areas.

Currently, only one other seismic survey may take place, the INPEX 2D Seismic Survey, located in permit areas WA-532-P, WA-533-P and WA-50-L (**Figure 6-6**). The INPEX 2D Seismic Survey is located 335 km west from the Petrel Sub-Basin SW 3D MSS Operational Area, off the north-west Kimberley coast. The key characteristics of the survey are as follows:

+ Acquisition Area: Approximately 70,000 km^2
+ Total 2D line kilometres: 10,000 – 12,000 kms
+ Total acquisition duration: Up to 140 days
+ Schedule: Between 1 November and 31 May of any year the EP is valid (2021 – 2023):
  - 1 November 2021 – 31 May 2022
  - 1 November 2022 – 31 May 2023
  - 1 November 2023 – 31 December 2023

For the most part, the INPEX 2D Seismic Survey is likely to affect different receptors from the Petrel Sub-Basin SW 3D MSS. However, the following assessment provides a summary of the potential additive impacts to relevant key receptors.

In addition to INPEX 2D Seismic Survey, from review of work programs for other exploration permits in the Bonaparte Basin published on the NOPTA National Electronic Approvals Tracking System (NEATS), Santos is aware that there is the potential for other seismic surveys to take place in two key areas, the Vulcan Sub-Basin (approximately 220 km to the north-west of the Operational Area) and in exploration permits located north of the Tiwi Islands (approximately 280 km north-east from the Operational Area) (**Figure 6-6**). Although no details are yet known about potential surveys in these areas, the following assessment provides some high-level consideration of what additive impacts could occur, should these surveys go ahead.

Note, the following assessment does not consider cumulative or additive impacts from seismic surveys in the region that occur after the Petrel Sub-Basin SW 3D MSS or that have not yet submitted an EP to NOPSEMA, as it is the responsibility of that titleholder to assess the cumulative impacts.

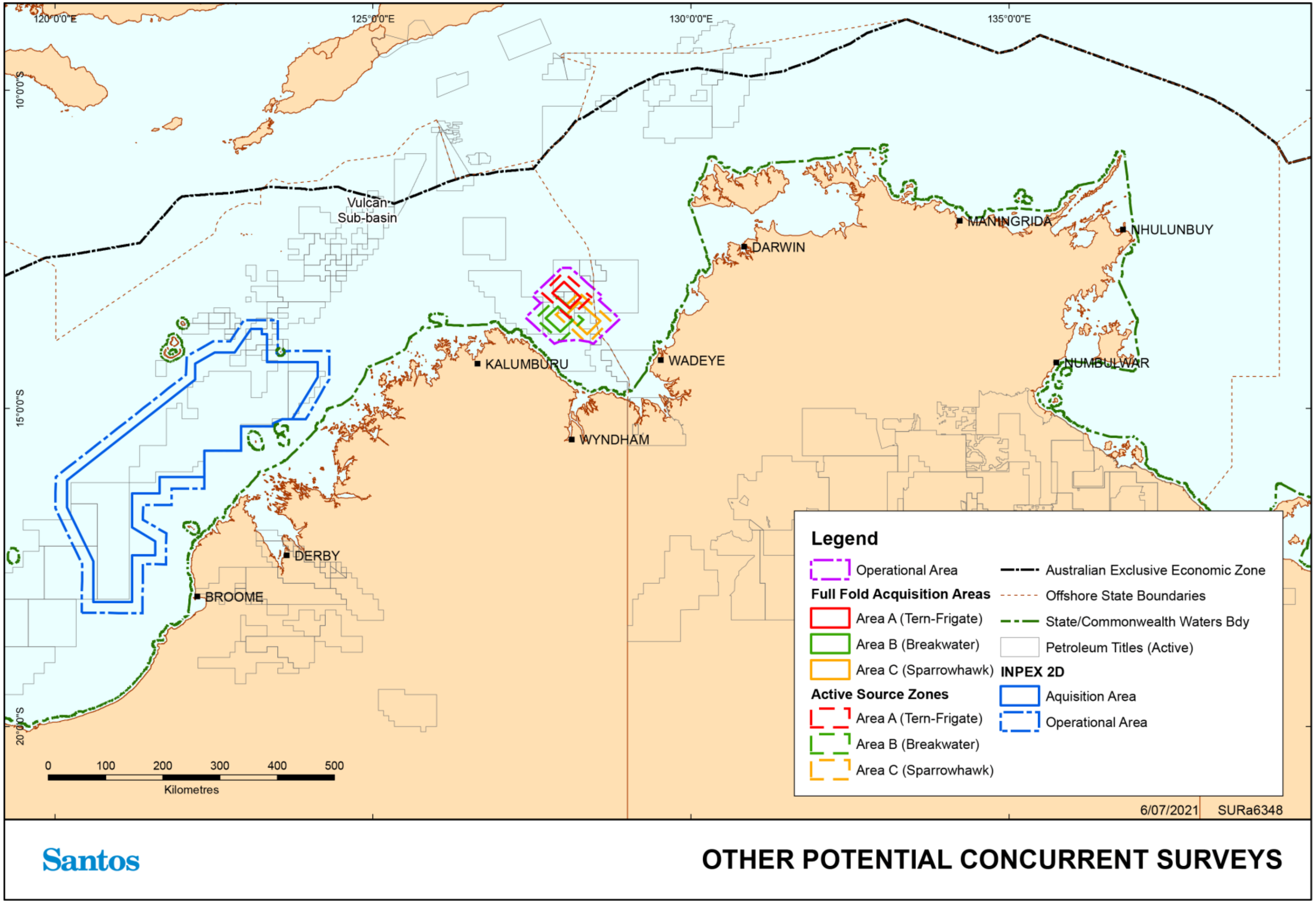


Figure 6-6: Other potential seismic surveys with the potential for additive impacts with the Petrel Sub-Basin SW 3D MSS

6.4.3.1 Sound fields from multiple seismic surveys

The individual sound fields produced by separate concurrent seismic surveys has the potential to interact where sound waves from the separate seismic sources may be received either in synchrony ("in synch") or out of synchrony ("out of synch"). How these sound waves might interact has previously been considered by JASCO Applied Sciences and ERM for the Santos Keraudren Extension 3D MSS EP (Santos 2020). 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.

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. Pulses may still line up occasionally for a brief moment at some locations, and where they do, the amplitudes will then be too unequal for the sum level to differ much from the stronger of the two components. However, in the unlikely case that two pulses interact and are exactly synchronised with each other, then the combined SPL would be 3 dB higher than the individual SPL, which represents a doubling of sound energy. Further explanation is provided in Santos (2020).

Santos will endeavour to minimise the potential for interaction between any concurrent seismic surveys to minimise both potential disruptions to operations as well as potential cumulative sound impacts to the marine environment and impacts to other marine users.

For operational reasons (to prevent acoustic interference and preserve seismic data integrity) a minimum separation distance of at least 40 km will be maintained between the Petrel Sub-Basin SW 3D MSS seismic source and any other concurrently operating seismic sources during data acquisition activities. Given this separation distance, underwater sound from the seismic sources is not anticipated to combine to significantly raise the sound pressure levels to which receptors may be exposed. In the unlikely event that two pulses interact and are exactly synchronised with each other, a 3 dB increase in SPL (doubling) may occur. Modelling of the seismic source for the Petrel Sub-Basin SW 3D MSS (Koessler and McPherson 2021) demonstrates that sound levels will be below 150 dB re 1µPa at 20 km from the source (half way between two seismic sources at their minimum separation distance) and in many cases will be below 140 dB re 1µPa. A combination of seismic sound from two similar seismic sources at this distance would therefore be expected to result in an SPL of no greater than 153 dB re 1 µPa, which is below the defined behavioural response thresholds for marine fauna (e.g. 160 dB re 1 µPa for cetaceans).

While overall sound levels are not expected to be significantly elevated, it is acknowledged that the result of multiple seismic vessels operating concurrently will represent a wider spatial area of potential exposure to seismic sound for receptors, as well as the potential for receptors to be exposed to separate sound fields from multiple surveys.

Given that the INPEX 2D Seismic Survey is located 335 km west from the Petrel Sub-Basin SW 3D MSS Operational Area and other potential surveys in the region are located over 200 km from the Operational Area, no effects are expected to receptors as a result of the sound fields from the two surveys interacting.

6.4.3.2 Additive impacts to plankton

No significant additive effects to plankton communities are expected from the INPEX 2D Seismic Survey or other surveys given the range to impact is typically tens of metres (**Section 6.3.2.5**) 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 within 15 km of the survey is expected to return to ambient levels due to recruitment from unimpacted areas within 3 days (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 at each of the adjacent 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.

6.4.3.3 Additive impacts to benthic invertebrates (including commercial prawn stocks)

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 6.3.2.6**). Such impacts are expected to occur at close range to the seismic source (i.e. tens or hundreds of metres) in each of the surveys' respective survey areas. In the context of natural mortality, recruitment and recovery rates, recovery is expected in the weeks and months following the surveys. Impacts to overall benthic communities are expected to be negligible and population level effects are not expected (**Section 6.3.2.6**).

The above assessment is also expected to be true of commercial prawns stocks targeted by the NPF, given that studies have found no mortality to adult crustaceans or their eggs. There is the potential for mortality of dispersed eggs and larvae in the water column during the seismic survey, but again, this is expected to be negligible in the context of natural variability in larvae mortality and larvae settlement rates (**Section 6.3.2.6**).

The INPEX 2D MSS does not overlap with the NPF. Therefore, while prawns could occur in the INPEX 2D Seismic Survey area, they will not be the same stocks as targeted by the NPF in the JBG. Should seismic surveys go ahead in the Vulcan Sub-Basin or north of the Tiwi Islands, the surveys are unlikely to be within the core range of banana prawns or tiger prawns. Therefore, no additive impacts are expected.

6.4.3.4 Additive impacts to fish, sharks and rays (including sawfish and commercial fish stocks)

Significant behavioural impacts in most demersal and pelagic fish, as well as sharks and sawfish, are likely to be limited to distances of tens or hundreds of metres from the seismic source, returning to normal within minutes or hours (**Section 6.3.2.7**). 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 6.3.2.7**).

A similar level of disturbance to fishes may occur at each individual survey area in the region. However, given the separation distance between the seismic surveys, no additive impacts to the same groups of fishes are expected.

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 6.3.2.7**).

As assessed in **Section 6.3.2.7**, the Petrel Sub-Basin 3D MSS could affect between 0.005% and 0.32% of the spawning biomass of indicator pelagic and demersal species in the Kimberley fisheries management area. The Petrel Sub-Basin 3D MSS could affect up to 0.04% of the spawning biomass of indicator species in the NT fisheries management area.

A similar assessment in the INPEX 2D Seismic Survey EP indicates that less than 1% of the spawning biomass of indicator species in the Kimberley fisheries management area will be affected. Should seismic surveys take place in the Vulcan Sub-Basin or north of the Tiwi Islands, then a small proportion of the fish stocks will be affected by these surveys too.

The combined disturbance to key indicator species is therefore expected to be less than 5% of the spawning biomass of key indicator species in both the Kimberley and NT fisheries management area. As previously discussed in **Section 6.3.2.7**, the analysis is simply an indication of the area where, and period when, potential spawning aggregations may be influenced and does not necessarily represent the actual reduction in spawning success or subsequent recruitment to the stocks.

It is acknowledged that in addition to natural factors and fishing catches, the proposed seismic surveys may contribute to some small, localised reduction in spawning success in disturbed areas. However, these effects are considered to be temporary, and relatively minor compared with normal variations in spawning success and fish recruitment, which have fluctuated by approximately 250% and 350% respectively, as a result of fishing and natural factors (refer to **Section 6.3.2.7**).

Potential additive impacts to spawning and recruitment within commercially significant fish stocks are, therefore, expected to be 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;
+ There will not be any reduction in the total adult spawning biomass as a result of seismic surveys, as the effects are expected to be behavioural and fish are unlikely to be lost from the stock (i.e. killed) as a result of the seismic surveys;
+ Localised (tens to hundreds of metres) and short-term (minutes, hours, days) behavioural disturbances resulting from a transient seismic source are unlikely to result in a discernible impact to demersal fish populations given that spawning and stock connectivity occurs over significantly larger geographic areas, over protracted spawning periods of several months, and involves the production of millions of eggs over multiple spawning events;

+ The level of disturbance and maximum cumulative spatial-temporal overlap (less than 5%) with the key fish stocks during any spawning season is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250-350%);
+ Key indicator species in the Kimberley and NT fisheries management unit have been assessed annually as Sustainable, the biomass of the stocks is unlikely to be depleted and recruitment is unlikely to be impaired despite a history of ongoing commercial fishing and seismic surveys across the fisheries;
+ Adult stocks comprise fish that are recruited over many years and are unlikely to be affected by seasonal disturbances, even at a regional scale (Martin et al. 2014). Therefore, in comparison, the occasional, short-term, transient and localised disturbances to groups of fish as a result of a seismic survey are not expected to impact recruitment.

Therefore, the additive effects from concurrent seismic surveys are not expected to result in a serious or irreversible impact to the recruitment or sustainability of key indicator commercial fish stocks.

6.4.3.5 Additive impacts to cetaceans

As described in **Section 6.3.2.8**, behavioural disturbances from seismic surveys may result in cetaceans deviating from their course and avoiding the seismic source in proximity to individual survey areas. However, given the separation distance between the seismic surveys, no additive impacts to the same groups of cetaceans are expected.

The Petrel Sub-Basin SW 3D MSS will not impact the same humpback whale and pygmy blue whale migration and aggregation BIAs as the INPEX 2D Seismic Survey or other potential areas in the wider region where seismic surveys may be acquired. Therefore, no additive impacts to these cetacean species are expected.

It is noted that both the Petrel Sub-Basin SW 3D MSS and the INPEX 2D Seismic Survey are located offshore from BIAs for inshore dolphin species in the coastal waters of the Kimberley. However, as noted in **Section 6.3.2.8**, sound levels received in coastal waters from the Petrel Sub-Basin SW 3D MSS when the seismic source is operating closest to the coast are not expected to result in significant behavioural disturbances. This relates to a single BIA for Australian snubfin dolphins located near Cape Londonderry. This particular BIA will not be exposed to elevated sound levels from the INPEX 2D Seismic Survey.

The INPEX 2D Seismic Survey EP notes that when the seismic source is operating in parts of the survey area closest to the coast, dolphin BIAs located on the north Kimberley coast may receive sound levels between approximately 100 and 125 dB re 1 µPa, which is not expected to result in significant behavioural disturbances.

The additive effects of the two surveys on inshore dolphin species in the Kimberley region are not expected to result in any impacts at the population level.

6.4.3.6 Additive impacts to marine turtles

The Petrel Sub-Basin SW 3D MSS will not be acquired within important turtle internesting habitats.

Behavioural disturbances to transient turtles may occur in close proximity to each individual survey area. However, given the separation distance between the seismic surveys the INPEX 2D Seismic Survey or other potential areas in the wider region where seismic surveys may be acquired do not overlap the same internesting or foraging BIAs and no additive impacts to the same turtles stocks are expected.

6.4.3.7 Additive impacts to commercial fisheries

The Petrel Sub-Basin SW 3D MSS is located in the JBG where fishing activity is primarily limited to the NPF. However, the proposed timing of the Petrel Sub-Basin SW 3D MSS (1 December to 31 March) avoids the banana prawn and tiger prawn fishing seasons. Banana prawns have historically accounted for the majority of the catch in the JBG. As of 2021, a new closure area that encompasses all of the JBG fishing grounds will also be implemented during the main banana prawn fishing season (1 April to 15 June). NPF fishing activities in the JBG will now be limited to the tiger prawn fishing season (1 August to 1 December) and tiger prawn fishing effort has historically been limited. Given the Petrel Sub-Basin SW 3D MSS will not coincide with banana prawn or tiger prawn fishing in the JBG, the seismic survey is predicted to have limited, if any impacts on the NPF. The INPEX 2D Seismic Survey does not overlap with the NPF. Permit areas in the Vulcan Sub-Basin also do not overlap with the NPF. Should any seismic surveys be planned for exploration permits north of the Tiwi Islands these are located further offshore than the key areas where the NPF normally trawls (refer to **Figure 3-14**). It is possible that a seismic survey could overlap waters that are fished infrequently (i.e. less than 5 vessels per year) or near an area at the outer edge of the AFZ where the fishery may target small quantities of the non-target species, scampi, during the prawn closure seasons. However, given the limited NPF fishing effort in this area, the potential additive impacts to the NPF would be negligible.

The INPEX 2D Seismic Survey overlaps with areas where the NDSMF and the MMF (Area 1) fish. It is noted that the Petrel Sub-Basin SW 3D MSS also overlaps an area where the NDSMF and MMF have historically fished, although these areas represent very low and infrequent fishing (refer to **Figure 3-17**). The INPEX 2D Seismic Survey occurs in areas that have historically been subjected to significant fishing effort by both fisheries. The Vulcan Sub-Basin is also located in an area where significant NDSMF activity occurs. Therefore, there is the potential for additive impacts to these fisheries, but given how infrequently fishing effort has occurred in the Operational Area previously (refer to **Section 6.1.2.2**and **Section 6.1.2.3**), the Petrel Sub-Basin SW 3D MSS contributes to negligible additive impacts to these fisheries.

Exploration permits to the north of the Tiwi Islands primarily overlap with the NT Timor Reef Fishery and the NT Demersal Fishery. The Petrel Sub-Basin SW 3D MSS does not overlap with the Timor Reef Fishery and so no additive impacts will occur. As described in **Section 6.1.2.4**, the overlap between the Petrel Sub-Basin SW 3D MSS and the NT Demersal Fishery is negligible (only three days of fishing over a 5-year period). Therefore, additive impacts to this fishery will also be negligible.

6.4.3.8 Additive impacts to other marine users

Given the separation distance between surveys, no additive impacts to commercial shipping are expected given that different vessel traffic and vessel routes are associated with Operational Area than the other survey area. Therefore, no additive impacts are expected.

6.4.4 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes (EPOs) and Control Measures for managing the interaction with other marine users (including commercial fishers) and noise emissions are described in **Section 6.1.3**, **Section 6.2.3** and **Section 6.3.4**, and are not restated in this section.

An additional Environmental Performance Outcomes (EPOs) relating specifically to the management of cumulative and additive seismic survey impacts is:

+ EPO-14: Potential cumulative and additive impacts resulting from the Petrel Sub-Basin SW 3D MSS and other seismic survey operations are identified and reduced as far as reasonably practicable.

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-18	Management of concurrent seismic surveys within commercial fisheries.	Commercial fishing operators may be frustrated by concurrent seismic survey vessels operating within their fishery. To this end, prior to commencing the Petrel Sub-Basin SW 3D 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 because of potential additive impacts to spawning periods of commercially significant prawns and fishes.	Santos intends to acquire the full survey during the period 1 December to 31 March. Reducing the number of months that the Petrel Sub-Basin 3D MSS can be acquired in any year may minimise potential additive impacts from multiple seismic surveys on spawning prawns and fishes. However, the impacts to the spawning and recruitment of prawn and fish species is predicted to be negligible.	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 (December to March) 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. 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 naturally high levels of variability in spawning and recruitment.
Marine Fauna				
CM-19	Seismic source separation distance during concurrent surveys: minimum 40 km while operating.	The Bureau of Ocean Energy Management (BOEM 2014) published an environmental review of geological and geophysical survey activities in the south Atlantic Ocean. To minimise impacts to marine life by providing a ‘corridor’ between vessels, the environmental impact statement from this review included a requirement for a 40 km geographic separation distance (based on worst case scenarios) between the sources of simultaneous seismic surveys.	In the event that another seismic survey occurs, a 40 km separation distance 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. A separation distances of 40 km is also consistent with some other seismic survey environment plans in Australia.

Santos

6.4.5 Impact and Consequence Ranking

Receptor	Consequence Level
Cumulative and Additive Seismic Impacts	
Threatened / Migratory Fauna	Plankton Multiple surveys 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*.** Benthic invertebrates Some sublethal effects and chronic mortality may occur to a small proportion of the benthic invertebrates in each survey area, however, benthic communities are expected to recover in the weeks and months following the surveys. No significant discernible additive impacts to prawn spawning and recruitment are expected, given high natural variability and the limited effects of seismic to crustaceans and eggs. The consequence level is assessed as ***Negligible*.** Fish No significant discernible additive impacts to fish are expected, given the separation distances between survey vessels. 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 recover 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, the high natural variability in spawning and recruitment success of these species and the 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 ***Negligible***. Sharks Based on the impact assessment no long term or population impacts to whale sharks, sawfish or other shark species, are predicted thus the consequence level is assessed as ***Negligible***. Marine turtles Due to the separation distance between potential surveys, the same internesting or foraging BIAs for marine turtles are not expected to be exposed to sound from different seismic surveys, and no additive impacts to the same turtles stocks are expected. The consequence level is assessed as ***Negligible*.** Cetaceans Due to the separation distance between potential surveys, the same species and populations are not expected to be exposed to sound from different seismic surveys. The consequence level is assessed as ***Negligible*.**
Physical Environment/ Habitat	Not applicable
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 due to absence of overlap with any AMPs and the Petrel Sub-Basin SW 3D MSS, and the separation distance between potential surveys. 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. However, based on the limited shared overlap between the seismic activity and commercial fisheries, the consequence level is assessed as ***Negligible***. Should a loss of catch be demonstrated as a result of the Petrel Sub-Basin SW 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	I – Negligible Based on the maximum consequence ranking by receptor, the overall consequence is Negligible.

6.4.6 ALARP Evaluation

Santos has adopted a 40 km seismic source separation control to avoid increased behavioural responses from 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 December to 31 March).

A further 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. A further reduction in survey area and duration would mean that the survey objectives would not be met.

In the event that other surveys occur concurrently with the Petrel Sub-Basin SW 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.

Therefore, the proposed control measures are considered appropriate to manage the consequence of cumulative and additive acoustic impacts to ALARP.

6.4.7 Acceptability Evaluation

Is the consequence ranked as I (Negligible) or II (Minor)?	Yes – Maximum consequence from cumulative and additive noise emissions is I (Negligible).
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 based on a maximum credible scenario. 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 Petrel Sub-Basin SW 3D MSS. As such, no further information is currently required.
Are control measures and 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.
	EPBC Policy Statement 1.1. – Significant Guidelines Yes – The overall worst-case consequence for cumulative and additive seismic impacts has been determined to be Minor and are not predicted to have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
	Conservation Advices, Recovery Plans and Other Guidelines Yes – As described in **Section 6.3**, the activity will be undertaken in a manner consistent with the applicable objectives and actions of Conservation Advice, Recovery Plans or Guidelines in relation to seismic sound emissions. No specific Conservation Advice, Recovery Plans or Guidelines have been identified for managing cumulative impacts from seismic sound.
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 has attempted to understand these concerns and has included them in the assessment.
Are control measures and performance standards such that	Yes (see ALARP evaluation above).

the impact or risk is considered to be ALARP?				
Defined Acceptable Levels				
Does the predicted impact meet defined acceptable levels of impact (refer to **Section 5.6**)?	Receptor Category	Defined Acceptable Level	Comparison with Predicted Levels of Impact	EPO
	EPBC Act-listed species (cetaceans; marine turtles; fish, sharks and rays)	Seismic activities are not inconsistent with the requirements of a recovery plan or wildlife conservation management plan/ advice that is in force for an EPBC Act-listed species. No injury to a cetacean and no displacement of foraging, aggregating, calving/breeding, or migrating cetaceans from identified BIAs. No injury to a turtle and no seismic surveys inside critical internesting habitat during the nesting season. No serious or irreversible impacts to listed marine fish due to noise associated with the operation of seismic source.	Santos considers the level of impact to EPBC Act-listed species to be of an acceptable level. Noise-related impacts are described in **Section 6.3** and cumulative and additive seismic surveys will not significantly change the predicted level of impacts (**Section 6.4**). A precautionary 40 km separation distances between seismic surveys has been applied to address potential additive impacts. Given the separation distance between potential surveys, no additive impacts to the same BIAs or populations/stocks are expected.	EPO-6 EPO-7 EPO-8 EPO-9 EPO-10 EPO-16
	Non-EPBC Act-listed species and ecological communities	Given the widespread distribution of non-EPBC listed marine fauna species and ecological communities, and that non-EPBC listed species and communities are not formally managed, Santos considers it acceptable to have a Negligible (I) or Minor (II) consequence. As defined within Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-	Santos considers the level of impact to non-EPBC Act-listed species and ecological communities to be of an acceptable level. The maximum consequence from cumulative and additive noise emissions have been assessed as Negligible (I).	EPO-5 EPO-7 EPO-16

		91-IG-00004), a Minor consequence is defined as a 'Potentially detectable but insignificant change to a local population, industry or ecosystem factor. Localised effect, lasting weeks up to 12 months.		
	Commercial fisheries	No serious or irreversible impact to the sustainability of key indicator commercial stocks within the: • Commonwealth NPF; • WA NNDSMF; • WA MMF; • NT DF; • NT SMF; and • NT ONLF. Commercial fishing license holders are no worse off as a result of the seismic survey.	Santos considers the level of impact to commercial fisheries and fishers to be of an acceptable level. Impacts to prawn and fish stocks in terms of spawning and recruitment are expected to be negligible and stocks within the Operational Area will have had >2 years to recover from historical seismic surveys over the same area. Significant percentages of commercially important key indicator prawn and fish stocks have not been exposed to, and are not expected to be exposed to seismic surveys on an annual basis.	EPO-3 EPO-11 EPO-16
	Australian Marine Parks (AMPs)	Protect and maintain biological diversity and other natural, cultural and heritage values in accordance with the conservation objectives of the North-west Marine Parks Network Management Plan (2018) and North Marine Parks Network Management Plan (2018).	Santos considers the level of impact to AMPs to be of an acceptable level. The activity is consistent with AMP management prescriptions, IUCN conservation objectives and the ecological use of the AMPs.	EPO-15 EPO-16

6.5 Light Emissions

6.5.1 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 as described in **Section 2**.

6.5.2 Nature and Scale of Environmental Impacts

Potential adverse impacts on marine fauna from artificial lighting during seismic surveys are well understood and in WA there are guidelines for mitigating impacts from artificial lighting (WA EPA 2010). In addition, National Light Pollution Guidelines for Wildlife (NLPG) have also been published (Commonwealth of Australia 2020). According to the NLPG, 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 2020).

Artificial light is considered to potentially have a significant impact in areas adjacent to sensitive habitats, such as turtle and seabird nesting sites. Given the transient nature of the survey, the predominantly open oceanic location of the Operational Area and the minimum distance to known turtle nesting beach (105 km) and bird breeding colonies (150 km), marine fauna are unlikely to be impacted by artificial light. 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.

Potential receptors include fish, sharks and rays, marine turtles, seabirds and migratory shorebirds.

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 2020).

Fish, sharks and rays

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 result in an increase in predation from larger fish and sharks on prey species, or exclusion of nocturnal foragers/predators aggregating in the immediate vicinity of the vessels at night (Marchesan et al. 2006).

Overall, a short-term localised increase in fish activity as a result of vessel lighting is expected to occur, however, it will be limited to night-time operations and with negligible impacts. Sound emissions from the seismic survey vessel and support vessels and from the seismic source, are also expected to act as a localised and temporary deterrent to fish (refer to **Section 6.3**).

Marine turtles

Artificial light can disrupt marine turtles wherever it is stronger than natural light sources (DoEE 2017). For a vessel at sea, light is most likely to affect marine turtles at breeding sites through direct light shining on nesting beaches or nearshore dispersal areas (DoEE 2017). The Recovery Plan for Marine Turtles in Australia: 2017-2027 (DoEE 2017) 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).

The Operational Area is approximately 105 km north from the closest known turtle nesting beach (flatback turtle nesting at Cape Domett), and no seismic acquisition will occur within the internesting BIA for flatback turtles (adjacent to the Operational Area), therefore impacts to nesting turtles are not expected. Adult turtles that may be present within the Operational Area may be attracted to the seismic survey vessel and support vessel lighting. However, attraction of turtles to the vessels would be localised, short-term and affect a small proportion of the population due to the transient nature of the survey and the limited disturbance of visible light from the vessels and/or seismic equipment. In addition, during acquisition, sound emissions from the seismic survey and support vessels and from the seismic sound, are expected to act as a localised and temporary deterrent to approaching adult turtles.

The potential impacts of light emissions to turtles from the activities is considered to be minimal with no long term or residual impact due to the continual movement of the vessels and distance from known turtle nesting beaches. 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 and migratory shorebirds

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 when travelling within a radius of 3-5 km from the light source (Marquenie et al. 2008). The light sources associated with the vessels may also provide enhanced capability for seabirds to forage at night. The Operational Area is located approximately 150 km away from recognised important roosting sites for migratory birds (i.e. the Keep, Victoria and Fitzmaurice rivers at the head of the JPG).

Light emission effects to birds within the Operational Area (including those migrating) are expected to be localised and temporary based on the transient nature of the survey, limited duration of the survey (up to 100 days) and the limited distance of visible light from the seismic vessel. The minor radius of potential disorientation/attraction compared to the wide extent of known migratory routes further reduces the risk of impacts from light emissions on migratory birds present during the survey.

6.5.3 Environmental Performance Outcomes 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.	The vessel would need to depart from the Operational Area as lighting levels at night-time are a requirement so this is not feasible. This control 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 and seabirds/migratory shorebirds 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 peak 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** – The Petrel Sub-Basin SW MSS is scheduled to avoid the banana prawn fishing season (1 April - 15 June) and tiger prawn fishing season (1 August – 1 December). Turtle foraging in JBG does not have a seasonal period. Flatback turtles nest year-round at Cape Domett (located 105 km from the Operational Area), with a peak in Jul-Sep. There is generally less seasonality in zooplankton biomass in tropical regions and thus the time of the year that a survey is conducted is less important (from a zooplankton perspective: Richardson et al. 2017).

6.5.4 Impact 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 and migratory shorebirds. Given that the Activity will involve vessels that are continually moving, is for a limited duration, and the Operational Area is located 105 km from the nearest nesting beach (Cape Domett) and no seismic acquisition will occur within the internesting BIA for flatback turtles, at these distances lighting is unlikely to be at a level that could impact nesting turtles or hatchlings (Commonwealth of Australia 2020). 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 2020). Impacts to transient fish and seabirds and migratory shorebirds 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 critical habitats and/or 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	I – 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.

6.5.5 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 (DoEE 2017) 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. The Operational Area is 105 km from the nearest nesting beach (Cape Domett), which is considerably further than the EPA's estimated light influence distance of approximately 1.5 km (EPA, 2010). In addition, the distance of the Operational Area from the closest nesting beach is also much greater than the draft NLPG (Commonwealth of Australia 2020) precautionary threshold of 20 km. Therefore impacts are not expected on fauna including turtles at nesting beaches (inter/nesting adults or emerging hatchlings), with impacts 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. The implementation of these control measures would require a disproportionate level of cost/effort in order to reduce the level of impact or risk.

6.5.6 Acceptability Evaluation

Is the consequence ranked as I (Negligible) or II (Minor)?	Yes – maximum consequence from artificial light is I (Negligible).
Is further information required in the consequence assessment?	No – potential impacts and risks are well understood through the information available.
Are 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 (DoEE 2017) and NLPG (Commonwealth of Australia, 2020).
	EPBC Policy Statement 1.1. – Significant Guidelines Yes – The overall worst-case consequence for light emissions has been determined to be Negligible and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
	NLPG (including marine turtles, seabirds and migratory shorebirds) and Recovery Plan for Marine Turtles in Australia Yes – In January 2020, the Department of Agriculture, Water and the Environment released NLPG including marine turtles, seabirds and migratory shorebirds. The aim of the Guidelines is to manage artificial light so that wildlife is not disrupted, nor displaced from important habitat and is able to undertake critical behaviours such as foraging, reproduction and dispersal. The Recovery Plan for Marine Turtles in Australia (DOEE 2017) also identifies lighting as a threat to marine turtles. 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. 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 of moving marine vessels; the nature of the impact will generally be restricted to localised behavioural effects in the offshore waters of the Operational Area. The Operational Area is located approximately 105 km from the nearest nesting beaches (Cape Domett) and impacts to nesting marine turtles from artificial lighting are not expected. 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 National Light Pollution Guidelines and the Recovery Plan for Marine Turtles in Australia, and the impacts of lighting to the receiving environment are considered acceptable.
Are performance standards consistent with the Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.

Are performance standards such that the impact or risk is considered to be ALARP?	Yes – Based on available information and the proposed control measures, Santos considers artificial light impacts to marine fauna to be at an acceptable level.		
Defined Acceptable Levels			
Does the predicted impact meet the defined acceptable level of impact (refer to **Section 5.6**)?	Defined Acceptable Level of Impact	Comparison with Predicted Levels of Impact	EPO
	Light emissions are not inconsistent with recovery plans or wildlife conservation plans/ advice that are in force for protected EPBC Act listed threatened and migratory species. Santos considers it acceptable to have a Negligible (I) or Minor (II) consequence to a marine fauna population or ecological community. As defined within Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004), a Minor consequence is defined as a 'Potentially detectable but insignificant change to a local population, industry or ecosystem factor. Localised effect, lasting weeks up to 12 months.	Santos considers the level of impact from light emissions to be of an acceptable level. Given the temporary nature of the activity and because the survey vessels will be moving, lighting impacts will be Negligible. Potentially vulnerable wildlife to artificial light (e.g. turtles and seabirds) will not be disrupted, nor displaced from important habitat and will be able to undertake critical behaviours such as foraging, reproduction and dispersal. The Activity will not compromise the objectives set out in applicable recovery plans or wildlife conservation plans/advice that are in force for threatened and migratory species.	N/A

6.6 Planned Operational Discharges

6.6.1 Description of Event

Planned Operational Discharges	
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/greywater* 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 from domestic processes such as ablution, laundry and galley activities. Treated sewage will be disposed in accordance with MARPOL Annex IV and AMSA Marine Order 96. *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 workload 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* 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.

6.6.2 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.

The waters within and adjacent to the Operational Area are generally oligotrophic (i.e. low nutrient levels) except where localised and sporadic and short-lived upwellings occur in the region (e.g. at the shelf break, where deeper, cooler nutrient rich water is brought to the surface).

Potential receptors include water quality, fish (pelagic) and 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 will occur when vessels are transient, resulting in the discharges dispersing rapidly in the predominantly open oceanic location of the Operational Area. Discharges may result in localised increases in nutrient concentrations, exert 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 107 m dominated by open ocean currents, resulting in highly localised and 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.

Santos

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 (100 days), 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.

6.6.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ Discharges to sea meet legislated permissible discharge requirements (EPO-15).
+ No unplanned objects, emissions or discharges to sea or air (EPO-16).

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**.

Reference No	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-20	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-21	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-22	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-23	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.

Reference No	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-24	Oily water treatment system.	Reduces potential impacts of planned discharge of oily water to the environment. Ensure compliance with Marine Order 91 and MARPOL requirements as appropriate for vessel class.	Additional time and personnel costs in maintaining oil record book.	**Adopted –** benefits of ensuring vessel is compliant outweigh the minimal costs.
CM-25	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-26	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	**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
			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.	
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.

Reference No	Control measure	Environmental benefit	Potential cost/issues	Evaluation
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.

6.6.4 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 (100 days) from a moving discharge point, in deep waters (40 m – 107 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	I - Negligible Given the distance offshore, the small volumes discharged, the moving discharge point and the well-mixed waters of the Operational Area.

6.6.5 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 6.6.3**. 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 I (Negligible) or II (Minor)?	Yes – maximum planned operational discharge consequence is rated I (Negligible).
Is further information required in the consequence assessment?	No – potential impacts and risks well understood through the information available.
Are 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 and conservation advice. 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 – 107 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. The operational discharges are not expected to significantly impact the receiving environment with control measures proposed and compliance with legislative 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 3-11**). 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.
Are performance standards consistent with the Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.
Are performance standards such that the impact or risk is	Yes (see ALARP evaluation above).

considered to be ALARP?			
Defined Acceptable Levels			
Does the predicted impact meet the defined acceptable level of impact (refer to **Section 5.6**)?	Defined Acceptable Level of Impact	Comparison with Predicted Levels of Impact	EPO
	Operational discharges to sea meet legislated permissible discharge requirements. Operational discharges are not inconsistent with recovery plans or wildlife conservation plans/advice that are in force for protected EPBC Act listed threatened and migratory species. Santos considers it acceptable to have Negligible (I) or Minor (II) consequence to a marine fauna population or ecological community. As defined within Santos' Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004), a Minor consequence is defined as a 'Potentially detectable but insignificant change to a local population, industry or ecosystem factor. Localised effect, lasting weeks up to 12 months.	Santos considers the level of impact from operational discharges to be of an acceptable level. Potential impacts of typical marine vessel operational discharges to the sea are expected to be limited to temporary and insignificant localised water quality perturbations. Reduced water quality is not expected to be a threat to marine turtles, birds or shark species and will not be inconsistent with relevant recovery plans or approved conservation advice. Santos considers the application of internationally recognised legislative as appropriate to manage operational discharges and the receiving marine environment.	EPO-15 EPO-16

6.7 Atmospheric Emissions

6.7.1 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.

6.7.2 Nature and Scale of Environmental Impacts

The seismic survey vessel and support vessels present in the Operational Area will generate atmospheric emissions from power generation and waste incineration. 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.

Potential receptors include seabirds and migratory shorebirds, and humans

Atmospheric emissions have the potential to result in a temporary, localised reduction of air quality in the environment immediately surrounding the discharge point (e.g. vessel exhaust) 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.

As the activities will occur in offshore waters (approximately 28 km from the mainland coastline), any emissions from the combustion of fuels and incineration are expected to disperse rapidly in the open oceanic conditions and background levels of atmospheric pollutants are expected to be low. The quantities of gaseous emissions are relatively small and will quickly dissipate into the surrounding atmosphere. Emissions will not impact on the air quality in coastal towns given the distance offshore. Seabirds may traverse the Operational Area, however, are not expected in large numbers. Given the potential reduction in air quality will be highly localised, any impacts to individual or populations are not expected. Given the low level of emissions anticipated, survey emissions only represent a very small contribution to overall Australian and global GHG emissions to the 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.

6.7.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ No unplanned objects, emissions or discharges to sea or air (EPO-16).
+ Emissions to air meet legislated requirements (EPO-17).

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**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-27	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-28	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-29	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-30	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-31	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	**Not Adopted** – based on cost to replace all equipment and

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			replace for a short duration activity.	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.

6.7.4 Impact and Consequence Ranking

Receptor	Consequence Level
Air emissions	
Threatened / Migratory Fauna	Short term behavioural impacts to seabirds and migratory shorebirds 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 (28 km from the mainland coastline), 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	I – 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).

6.7.5 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 6.7.3**. 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.

6.7.6 Acceptability Evaluation

Is the consequence ranked as I (Negligible) or II (Minor)?	Yes – maximum consequence from atmospheric emissions is I (Negligible).		
Is further information required in the consequence assessment?	No – potential impacts and risks are well understood through the information available.		
Are 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. 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.		
Are performance standards consistent with the Environmental Management Policy?	Yes – Aligns with the Environmental Management Policy.		
Are performance outcomes and standards consistent with stakeholder expectations?	Yes – No concerns raised.		
Are performance standards such that the impact or risk is considered to be ALARP?	Yes (see ALARP evaluation above).		
Defined Acceptable Levels			
Does the predicted impact meet the defined acceptable level of impact (refer to **Section 5.6**)?	Defined Acceptable Level of Impact	Comparison with Predicted Levels of Impact	EPO
	Atmospheric emissions meet legislated permissible requirements. Santos considers it acceptable to have a Negligible (I) or Minor (II) consequence to a marine fauna population or ecological community. As defined within Santos' Offshore Division Environmental Hazard Identification and Assessment	Santos considers the level of impact from air emissions to be of an acceptable level. Atmospheric emissions will be standard marine vessel emissions, temporary, with the potential for localised reduction of air quality at the point source (e.g. engine exhaust).	EPO-16 EPO-17

	Guideline (EA-91-IG-00004), a Minor consequence is defined as a 'Potentially detectable but insignificant change to a local population, industry or ecosystem factor. Localised effect, lasting weeks up to 12 months.	Contribution to regional air emissions, including greenhouse gases, will be negligible. Santos considers the application of legislative requirements appropriate to manage air emissions and the receiving environment.	

7 Environmental 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)	III (Moderate)	a (Remote)	Very Low
Minor hydrocarbon release	I (Negligible)	b (Unlikely)	Very Low
Spill response operations	II (Minor)	b (Unlikely)	Very Low
Hazardous and non-hazardous unplanned discharges – liquid	I (Negligible)	b (Unlikely)	Very Low
Hazardous and non-hazardous unplanned discharges - solid	I (Negligible)	b (Unlikely)	Very Low
Marine fauna collisions	I (Negligible)	b (Unlikely)	Very Low
Introduction of invasive marine species	III (Moderate)	a (Remote)	Very 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 a result of 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 to be 1,062 m^3 of MDO/MGO. A tank rupture as a result of vessel grounding is not considered a credible scenario as the minimum water depth is approximately 40 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	Environment that May be Affected A hypothetical hydrocarbon spill scenario due to a seismic vessel tank rupture releasing 1,062 m^3 of MDO over six hours on the sea surface has been modelled at three release sites along the perimeter of the Operational Area, carefully selected based on proximity to shorelines and sensitive receptors. 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 100 different simulations for each of the three spill events (total of 300). An actual spill event is more realistically represented by only one of the simulations and hence, have a much smaller spatial footprint. Modelled Extend of Spill The potential extent of an MDO/MGO spill described here is based on the low hydrocarbon exposure values from the spill modelling for surface, total submerged (entrained), 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 predicted to be a maximum of approximately 40 km to the northwest. Total submerged hydrocarbons (entrained) in the water column above the low exposure value of 10 ppb is predicted to occur up to approximately 600 km to the west and 300 km to the east from the release locations. Dissolved hydrocarbons in the water column above the low exposure value of 10 ppb is predicted to occur up to approximately 120 km to the west and 50 km to the east from the release locations.

<table>
<tr><th colspan="2">Hydrocarbon spills from a ruptured vessel fuel tank as a result of collision, a refuelling incident and other minor MDO/MGO spills</th></tr>
<tr><td></td><td>No accumulation of hydrocarbon on shorelines at the low exposure value (10 g/m^2) is predicted from any of the release locations.
Refer to Table 7-3 for the exposure values used in the MDO/MGO Spill Modelling. Appendix H further describes the environmental significance of the selected exposure values.
Refer to MDO/MGO Spill Modelling Results summary (Section 7.1.2.4).</td></tr>
<tr><td>Duration</td><td>MGO/MDO 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.
Refer to MDO/MGO Spill Modelling Results summary (Section 7.1.2.4).</td></tr>
</table>

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 1,062 m^3. RPS (2021) used a marine diesel oil (MDO) to inform the hydrocarbon characteristics for the modelling. The characteristics of the MDO, selected as the analogue for the MDO/MGO release is presented in **Table 7-2**. Marine diesel 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%). Marine diesel has no residual persistent hydrocarbons after weathering. 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 (RPS 2021)

<table>
<tr><th rowspan="3">Oil Type</th><th rowspan="3">Initial density (kg/m^3)</th><th rowspan="3">Viscosity (cP)</th><th>Component</th><th>Volatiles (%)</th><th>Semi-volatiles (%)</th><th>Low Volatility (%)</th><th>Residual (%)</th></tr>
<tr><td rowspan="2">Boiling Points (°C)</td><td><180</td><td>180-265</td><td>265-380</td><td>>380</td></tr>
<tr><td colspan="3">NON-PERSISTENT</td><td>PERSISTENT</td></tr>
<tr><td>MDO</td><td>829.1</td><td>4.0</td><td>% of total</td><td>6</td><td>34.6</td><td>54.4</td><td>5.0</td></tr>
</table>

7.1.2.2 Modelling Inputs

To determine the spatial extent of a potential MDO/MGO hydrocarbon spill, RPS were commissioned to conduct modelling of a 1,062 m^3 MDO/MGO release. Modelling was conducted at three release sites along the perimeter of the Operational Area, which were carefully selected based on proximity to shorelines and sensitive receptors.

Key parameters considered for the MDO/MGO spill modelling are:

a. API gravity: 37.6°;

b. Pour point: -14°C;

c. Duration of spill: 6 hours

d. Location of release: Surface spill;

e. Volume of hydrocarbon: 1,062 m^3; and

f. Time of year: any month of the year (range of conditions representative of all 12 months).

Stochastic Modelling

Stochastic modelling was performed on a release of 1,062 m^3 of MDO/MGO over 6 hours at the sea surface, with a simulation period of 40 days 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 (100 runs per release location in total).

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 submerged hydrocarbons, dissolved hydrocarbons and shoreline accumulated hydrocarbons. It is noted that the 'total submerged hydrocarbons' is comprised of both entrained (or droplets) and dissolved hydrocarbons, and therefore provides a conservative (over) representation of entrained 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.

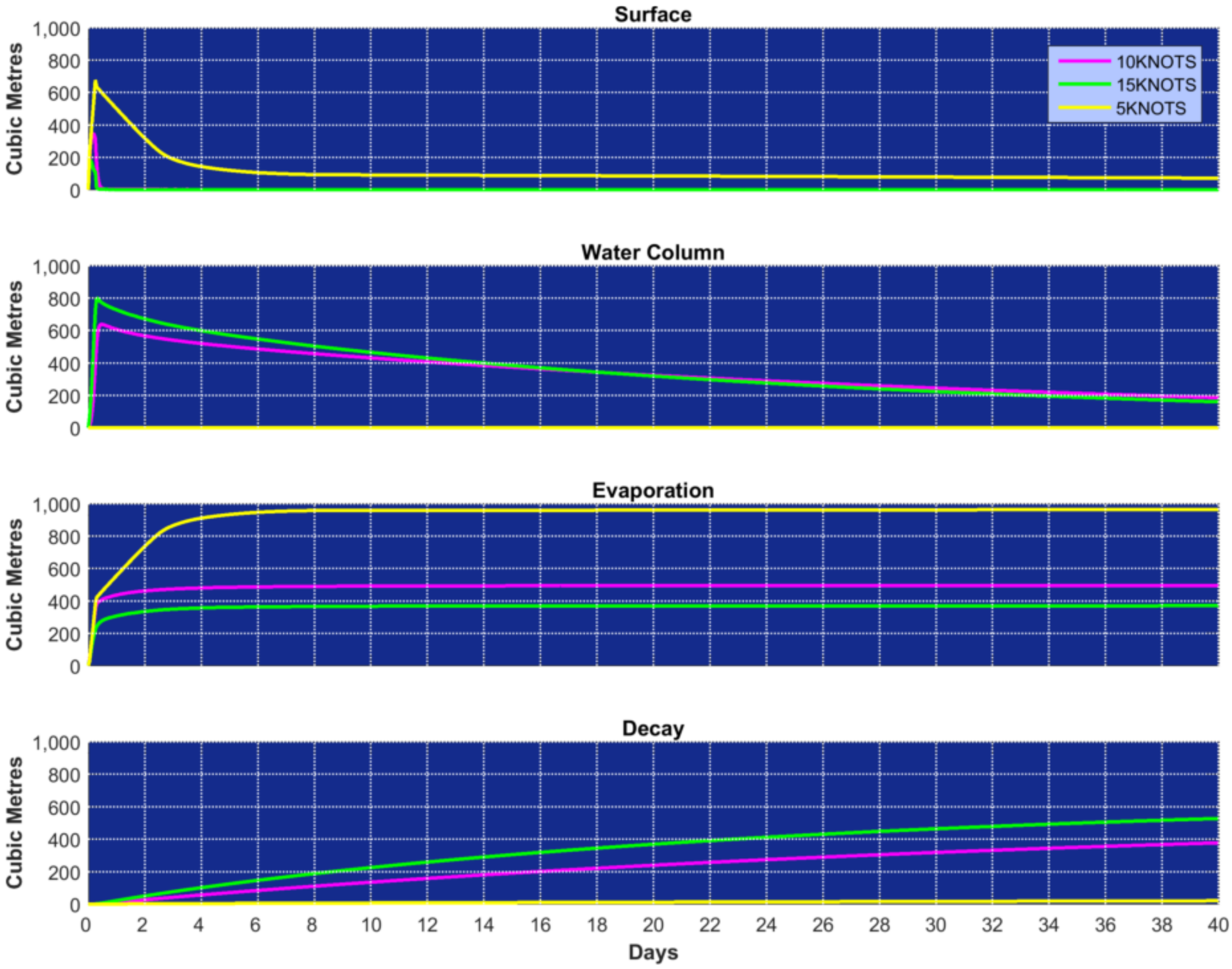
Exposure values applied for surface hydrocarbons, total submerged hydrocarbons (entrained), dissolved hydrocarbons and accumulated hydrocarbons ashore used in the modelling study are summarised in **Table 7-3.** The adopted exposure values are based primarily on the exposure values defined in NOPSEMA Bulletin #1 Oil Spill Modelling (April 2019). The environmental significance of these exposure values is described in **Appendix H**.

Table 7-3: Summary of the hydrocarbon exposure thresholds

Exposure Type	Potential Level of Exposure	Hydrocarbon Concentration	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 is indicative of perceived impacts and areas that may be temporarily closed as a precautionary measure. 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. It is the lowest "actionable" level where spill response may be possible.
	High	50	This value is the estimated minimum floating hydrocarbon threshold for containment and recovery and informs response planning.
Total submerged hydrocarbons (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 and life stages.
	High	-	N/A
Dissolved hydrocarbons (ppb) [1]	Low	10	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.
	Moderate	50	This represents potential toxic effects, particularly sublethal effects to highly sensitive species and life stages of fish and invertebrates (e.g. larvae, plankton).
	High	400	This value represents toxic effects including lethal effects to sensitive species.
Accumulated hydrocarbons (shoreline) (g/m^2) [1]	Low	10	This value represents light oiling (equivalent to 2 teaspoons of oil per m^2). It is indicative of perceived impacts and shorelines that may be temporarily closed as a precautionary measure, 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, shorebirds, mammals and reptiles) 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. Potential significant impacts to coastal vegetation including mangroves and marshes.
[1] Instantaneous exposure values sourced from NOPSEMA Bulletin #1 Oil Spill Modelling (April 2019)			

7.1.2.4 MDO/MGO Weathering Assessment

Figure 7-1 illustrates the weathering graph of a 1,062 m^3 of MDO spill over six hours under three static wind conditions. The graphs illustrate greater persistence of MDO on the sea surface with decreasing wind speeds, which coincided with increasing volumes of MDO forced into the water column with increasing wind speeds. Additionally, the loss to evaporation was greatest during the 5-knot static wind speed, allowing for the MDO to remain on the sea surface.



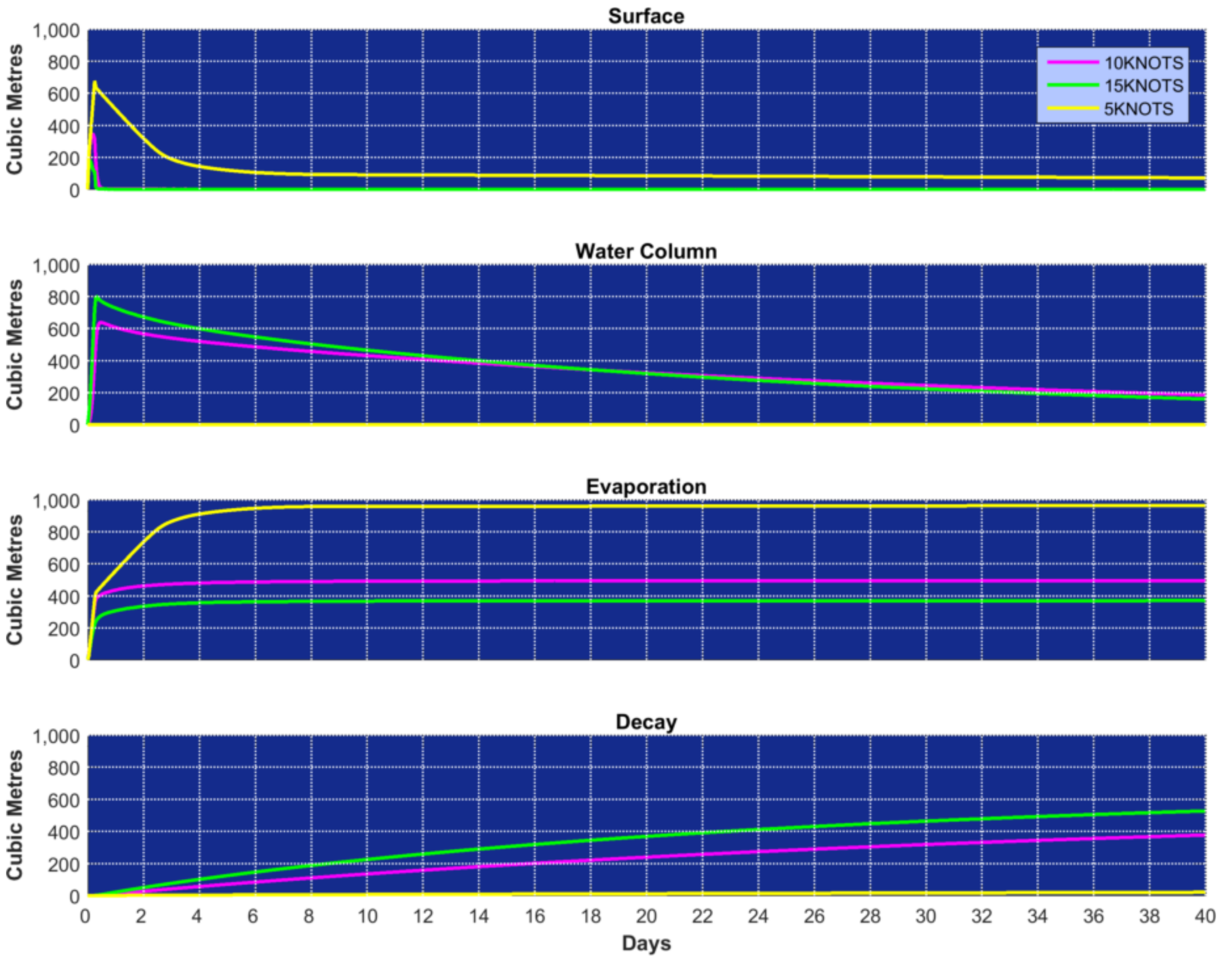


Figure 7-1: Weathering and fates graph, as a function of volume, under 5, 10 and 15 knot static wind conditions. Results are based on a 1,062 m^3 surface release of MDO over 6 hours (tracked over 40 days).

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 7-4** to **Table 7-6**. The modelled EMBA for surface, total submerged (entrained) and dissolved hydrocarbons for each spill release location is presented in **Figure 7-2** to **Figure 7-3**.

Sea Surface Hydrocarbons

Surface oiling was assessed at three exposure values representing low (1 g/m^2), moderate (10 g/m^2, and high (50 g/m^2) exposure levels. Modelling indicated in the event of a 1,062 m^3 spill of MDO, surface oil was predicted to extend up to a maximum of approximately 40 km, 27 km and 18 km from the spill release locations, for low, moderate and high exposure thresholds respectively.

The carbonate bank and terrace system of the Sahul Shelf KEF and JBG AMP were the only receptors predicted to be exposed to low, moderate and high threshold concentrations from spill trajectories. **Table 7-4** summarises the spill modelling results for surface hydrocarbons.

Table 7-4: Summary of oil spill modelling results for surface hydrocarbons, including sensitive receptors with predicted exposure above threshold concentrations.

Release Site	Distance and Direction to Sensitive Receptor	Areas of potential sea surface exposure		
		>1 g/m^2	>10 g/m^2	>50 g/m^2
1	Maximum distance from release site (km)	35.7	27.0	17.8
	Direction	ESE	WNW	ESE
	Probability of oil exposure to the carbonate bank and terrace system of the Sahul Shelf KEF (%)	98	91	71
	Minimum time before oil exposure to the carbonate bank and terrace system of the Sahul Shelf KEF (hrs)	1	1	1
	Probability of oil exposure to the JBG AMP (%)	-	-	-
	Minimum time before oil exposure to the JBG AMP (hrs)	-	-	-
2	Maximum distance from release site (km)	40.2	24.0	15.1
	Direction	NW	WNW	NW
	Probability of oil exposure to the carbonate bank and terrace system of the Sahul Shelf KEF (%)	2	-	-
	Minimum time before oil exposure to the carbonate bank and terrace system of the Sahul Shelf KEF (hrs)	51	-	-
	Probability of oil exposure to the JBG AMP (%)	-	-	-
	Minimum time before oil exposure to the JBG AMP (hrs)	-	-	-
3	Maximum distance from release site (km)	39.3	23.0	17.9
	Direction	SW	SE	SSE
	Probability of oil exposure to the carbonate bank and terrace system of the Sahul Shelf KEF (%)	-	-	-
	Minimum time before oil exposure to the carbonate bank and terrace system of the Sahul Shelf KEF (hrs)	-	-	-
	Probability of oil exposure to the JBG AMP (%)	17	10	1
	Minimum time before oil exposure to the JBG AMP (hrs)	6	9	10

A dash indicates that the threshold was not reached. The results were calculated from 300 possible spill trajectories and do not represent a single spill event.

Shoreline Accumulation

Shoreline oiling was assessed at three contact exposure values representing low (10 g/m^2), moderate (100 g/m^2), and high (1,000 g/m^2) exposure thresholds. No shoreline contact above the low exposure threshold was predicted from the modelling at any of the three locations. Therefore, shoreline accumulation is not discussed further in this EP.

Total Submerged Hydrocarbons (Entrained)

Total submerged hydrocarbons were assessed at two contact exposure values representing low (10 ppb) and moderate exposure (100 ppb) for entrained hydrocarbons. Modelling of entrained hydrocarbons considered exposure to receptors at 0-10 m and 10-20 m water depths.

A range of receptors were predicted to be exposed to entrained hydrocarbons above exposure value concentrations, including AMPs, reefs, shoals and banks. **Table 7-5** summarises the maximum entrained hydrocarbon exposure (over 1 hour) for each threshold to individual receptors in the 0-10m depth layer. There was no predicted exposure to any of the receptors from any release site within the 10–20 m water depth layer.

The carbonate bank and terrace system of the Sahul Shelf KEF recorded the greatest probability of exposure of any receptor at or above the low threshold (98% at Release Site 1 and 62% at Release Site 2). Note, the receptor is 615 m from Release Site 1.

Santos

Table 7-5: Maximum entrained hydrocarbon exposure levels and probability for each threshold to individual sensitive receptors in the 0-10 m depth layer (from Release Sites 1, 2 and 3)

Sensitive Receptor Location	Entrained hydrocarbon exposure (over 1 hour)					
	Total Contact Probability (%)					
	Release Location 1		Release Location 2		Release Location 3	
	>10 ppb	>100 ppb	>10 ppb	>100 ppb	>10 ppb	>100 ppb
Ashmore Reef AMP	1	-	-	-	-	-
Cartier Island AMP	1	-	1	-	-	-
JBG AMP	8	-	15	1	66	53
Kimberley AMP	35	16	40	7	12	-
Oceanic Shoals AMP	9	1	5	-	2	-
Ancient coastline at 125 m depth contour KEF	11	-	5	-	2	-
Ashmore Reef and Cartier Island and surrounding Commonwealth waters KEF	1	-	1	-	-	-
Carbonate bank and terrace system of the Sahul Shelf KEF	98	96	62	37	25	7
Continental slope demersal fish communities KEF	5	-	3	-	1	-
Pinnacles of the Bonaparte Basin KEF	2	-	1	-	-	-
Barracouta Shoal	1	-	2	-	1	-
Vulcan Shoal	1	-	4	-	-	-
Echuca Shoal	8	-	4	-	-	-
Eugene McDermott Shoal	6	-	4	-	-	-
Gale Bank	3	-	-	-	8	-
Heywood Shoal	2	-	2	-	-	-
Holothuria Banks	38	12	38	6	12	-
Penguin Shoal	20	-	5	-	11	-

Sensitive Receptor Location	Entrained hydrocarbon exposure (over 1 hour)					
	Total Contact Probability (%)					
	Release Location 1		Release Location 2		Release Location 3	
	>10 ppb	>100 ppb	>10 ppb	>100 ppb	>10 ppb	>100 ppb
Fantome Shoal	1	-	-	-	-	-
Van Cloon/Deep Shoals	9	-	5	-	1	-
Woodbine Bank	1	-	1	-	-	-
Vernon Islands CR	1	-	-	-	-	-
Beagle Gulf-Darwin Coast	4	-	-	-	1	-
JBG East Coast	4	-	5	-	13	2
JBG South Coast	2	-	11	-	13	-
JBG West Coast	11	4	13	5	4	-
Kimberley Coast PMZ	12	3	20	6	5	-
Browse Island	4	-	2	-	-	-

A dash indicates that the threshold was not reached. The results were calculated from 300 possible spill trajectories and do not represent a single spill event.

Dissolved Hydrocarbons

Dissolved hydrocarbons were assessed at three contact exposure values representing low (10 ppb), medium (50 ppb) and high (400 ppb) exposure thresholds. Modelling of dissolved hydrocarbons considered exposure to receptors at 0-10 m, 10-20 m and 20-30 m water depths.

In the 0-10 m depth layer, a total of five receptors were predicted to be exposed to concentrations above the low dissolved hydrocarbon exposure threshold (10-50 ppb).

The carbonate bank and terrace system of the Sahul Shelf KEF was predicted to be exposed to dissolved hydrocarbons at the low threshold concentration in 0-10 m layer from spills with probabilities of 50% (Release Site 1) and 3% (Release Site 2). Exposure at the moderate threshold was also predicted for the KEF, however only from spills originating from Release Site 1 (12% probability). The maximum exposure levels predicted at receptors ranged from 11 ppb to 186 ppb. The JBG AMP was predicted to be exposed to dissolved hydrocarbons at the low and moderate thresholds concentration in the 0-10 m layer from spills at Release Site 3 with probabilities of 5% and 1% respectively. No receptors were exposed at the high exposure threshold (>400 ppb) for the 0-10 m layer.

In the 10-20 m layer, the carbonate bank and terrace system of the Sahul Shelf KEF recorded a 2% probability of low dissolved hydrocarbon exposure from spills occurring at Release Site 1 and a 1% probability for Release Site 2. JBG AMP recorded a 2% probability of low exposure from spills originating from Release Site 3. The maximum predicted concentrations ranged from 12 ppb to 43 ppb. No receptors were predicted to be exposed at the moderate or high exposure thresholds for the 10-20 m layer.

No receptors were exposed above the low (10 ppb) exposure threshold for the 20-30 m depth layer.

Table 7-6 summarises the maximum dissolved hydrocarbon exposure (over 1 hour) and probability of exposure for each threshold to individual receptors in the 0-10m depth layers.

Table 7-6: Maximum dissolved hydrocarbon exposure levels and probability for each threshold to individual sensitive receptors in the 0-10 m depth layer (from Release Sites 1, 2 and 3).

Sensitive Receptor Location	Dissolved hydrocarbon exposure (over 1 hour)								
	Total Contact Probability (%)								
	Release Location 1			Release Location 2			Release Location 3		
	>10 ppb	>50 ppb	>400 ppb	>10 ppb	>50 ppb	>400 ppb	>10 ppb	>50 ppb	>400 ppb
JBG AMP	-	-	-	-	-	-	5	1	-
Kimberley AMP	1	-	-	-	-	-	-	-	-
Carbonate bank and terrace system of the Sahul Shelf KEF	50	12	-	3	-	-			
JBG West Coast	-	-	-	1	-	-	-	-	-

A dash indicates that the threshold was not reached. The results were calculated from 300 possible spill trajectories and do not represent a single spill event.

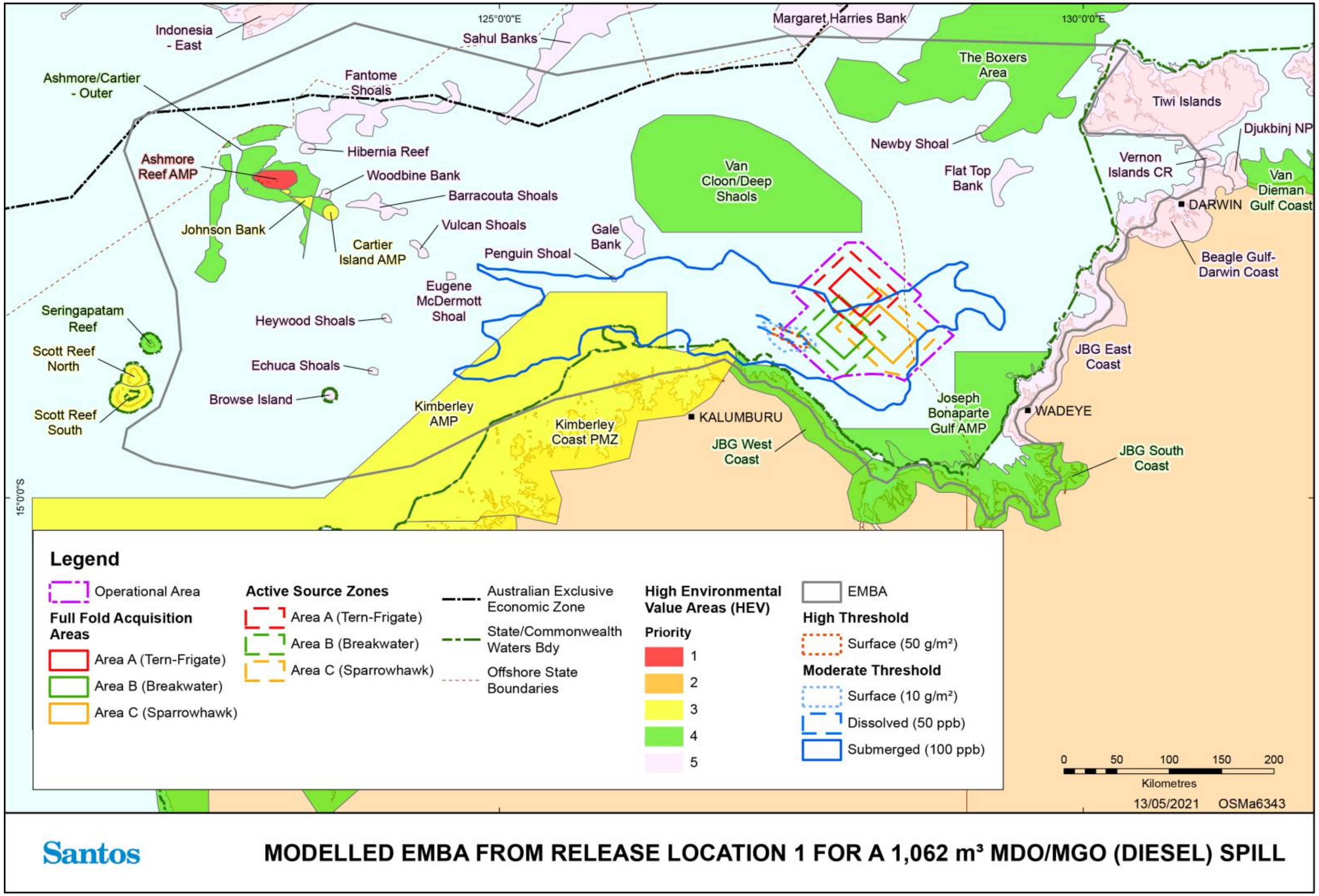


Figure 7-2: Modelled EMBA from Release Location 1 for a 1,062 m³ MDO/MGO (diesel) spill

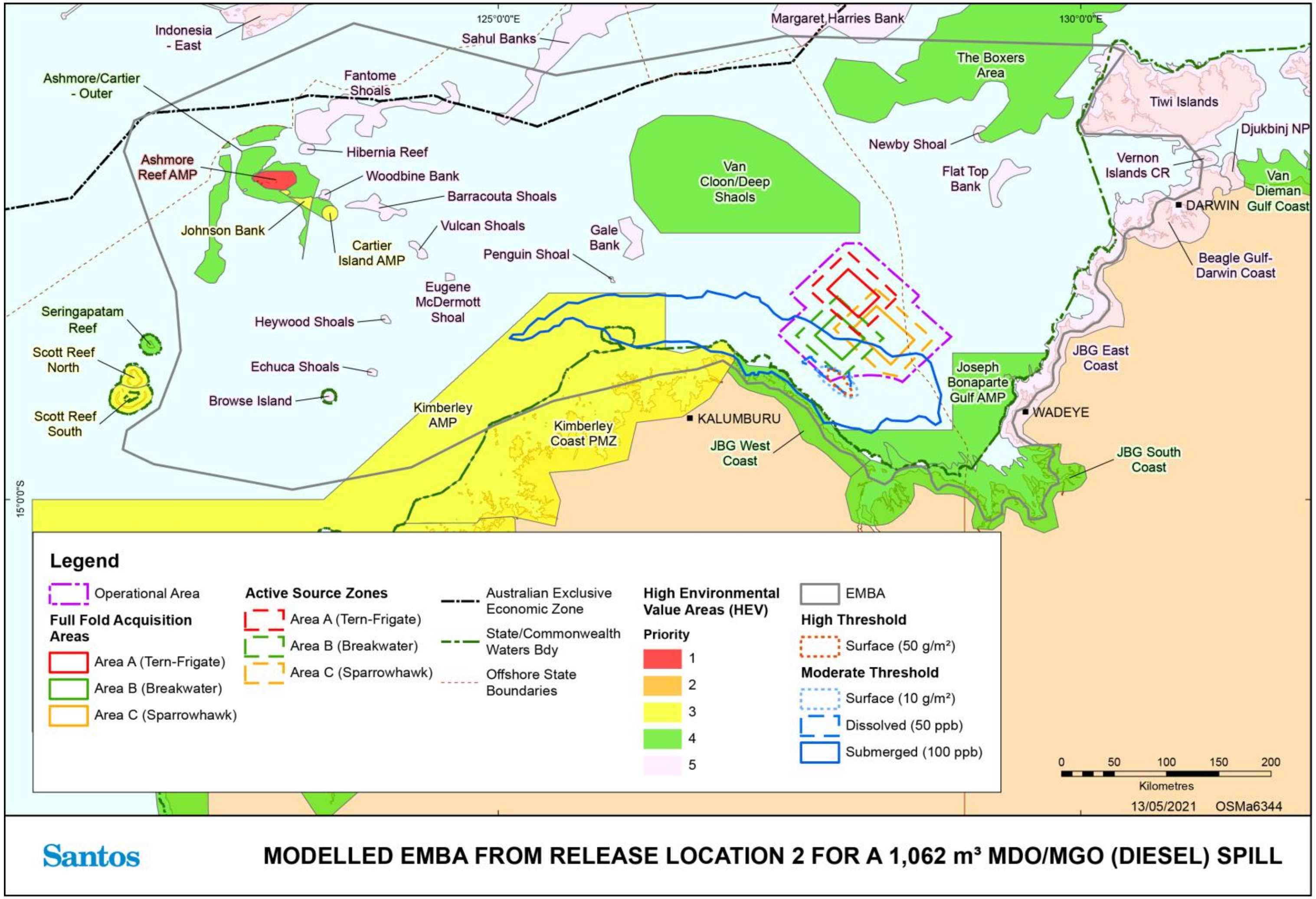


Figure 7-3: Modelled EMBA from Release Location 2 for a 1,062 m^3 MDO/MGO (diesel) spill

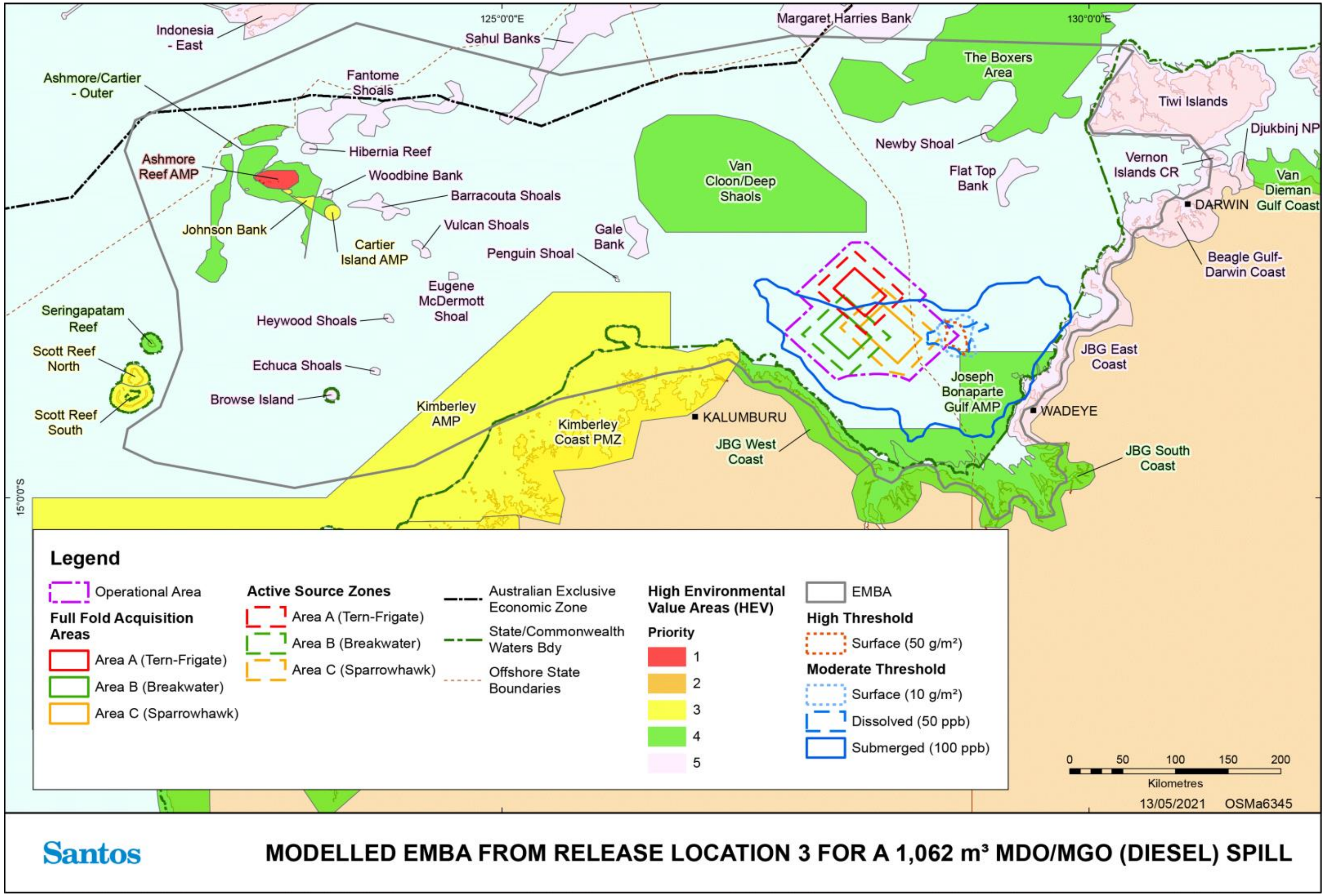


Figure 7-4: Modelled EMBA from Release Location 3 for a 1,062 m^3 MDO/MGO (diesel) spill

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 include marine mammals, marine reptiles, seabirds and shorebirds, fish, sharks and rays, plankton, fish eggs and larvae.

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 7-7** (refer to **Appendix H** 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 7-8**. 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 7-4**).

Table 7-7: **Physical and chemical pathways and oil impacts to marine organisms**

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
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. Reduced seed viability.	External contact by oil and adsorption across cellular membranes.	Yellowing of leaves. Defoliation. Increased sensitivity to stressors. Tree death. Reduced growth. Reduced reproductive output. 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.

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
				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 Behavioural 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. 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.

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
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 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 hatchling success. Reduced reproductive output. Growth abnormalities. Behavioural disruption.

Receptor	Physical pathway		Chemical pathway	
	Exposure	Potential impacts	Exposure	Potential impacts
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 7-8: 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 eggs and 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. Coral spawning also occurs in the region during the proposed Activity. There is potential for a hydrocarbon spill to result in localised mortality of plankton due to reduced water quality and toxicity from entrained hydrocarbons. Effects will be greatest in the upper 10 m of the water column and areas close to the spill source where hydrocarbon concentrations are likely to be highest. In the unlikely event of a spill occurring, plankton 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. Any planktonic communities (including fish and coral eggs and larvae) impacted by entrained hydrocarbons are expected to recover quickly (weeks/months) due to fast population turnover (ITOPF 2011), and high rates of natural mortality. Given the fast population turnover of open water planktonic populations it is considered that any potential impacts will be low and temporary in nature.
Marine mammals	Eleven migratory marine mammal species were identified by the EPBC Protected Matters search within the EMBA (**Table 3-10**). 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 breeding and foraging BIAs for Australian snubfin dolphins, Indo-Pacific humpback dolphins, spotted bottlenose dolphins, and dugong. The EMBA also overlaps the migration BIA for pygmy blue whales. However, the BIAs are all beyond the EMBA for surface hydrocarbons and all but the BIA for Australian snubfin dolphins are outside the EMBA for moderate entrained hydrocarbons (refer to **Section 7.1.2.5**). Impacts to animals within the BIAs are therefore not expected. These species are expected to be present in the EMBA in low numbers and limited to isolated individuals or small pods. No other critical habitats or aggregation areas (feeding, breeding, resting) for marine mammals have been identified within the EMBA, therefore cetaceans and dugongs within the EMBA are expected to be transient and in the unlikely event of a spill occurring, they are not expected to remain in the vicinity of spilled hydrocarbons for extended periods. For environmental impacts through hydrocarbon exposure and toxicity to marine mammals, refer to **Table 7-7**.
Marine reptiles	Eight species of threatened marine reptile and one migratory species were identified as possibly being impacted by a spill. Short-nosed seasnake, leaf-scaled seasnake, flatback, hawksbill, leatherback, green, olive ridley and loggerhead turtles and salt-water crocodiles are widely dispersed at low densities across the region 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 hydrocarbon spill EMBA overlaps with flatback, green, loggerhead and olive ridley turtle foraging BIAs (refer to **Section 3.7.4**). Oil spill modelling predicted that the foraging BIAs may be partially exposed to high concentrations of sea surface hydrocarbons (50 g/m^3), high concentrations of dissolved hydrocarbons (400 ppb) and high concentrations of entrained hydrocarbons (100 ppb). The EMBA also overlaps with 'habitat critical' and internesting BIAs for green turtles, and internesting BIAs for flatback, hawksbill, loggerhead and olive ridley turtles. Only the internesting BIA for flatback

Receptor	Impacts of MDO/MGO
	turtles in the JBG is predicted to be potentially exposed to surface hydrocarbons above exposure values. It is noted that oil spill modelling predicted no shoreline contact and no floating oil at or above the lowest threshold (1 g/m^2) to reach state or territory waters, impacts to nesting beaches are therefore not expected. There is a risk of transient adults encountering surface and submerged MDO/MGO. A hydrocarbon spill within the Operational Area may result in impacts to individual marine turtles and a potential disruption to a portion of the foraging/internesting habitat; however this is not expected to result in a threat to the overall population viability due to the rapid dispersion of MDO/MGO. For environmental impacts through hydrocarbon exposure and increased toxicity to marine reptiles, refer to **Table 7-7**. The Recovery Plan for Marine Turtles in Australia: 2017-2027 (DoEE 2017) highlights acute chemical discharge as one of several threats to marine turtles.
Seabirds and migratory shorebirds	Twelve threatened bird species, as identified by the EPBC Protected Matters database search may be encountered during the Activity (refer to **Table 3-10**). Three of the threatened bird species may occur in the Operational Area, with the remaining species potentially present within the EMBA. The EMBA overlaps breeding BIAs for 10 bird species, and a resting BIA for one species (refer to **Section 3.7.6**). A breeding BIA for the lesser crested tern overlaps with the south-west portion of the Operational Area, while the remaining BIAs are located a minimum distance of 63 km away and are not predicted to be impacted by surface oil above exposure values. Oil spill modelling predicted no shoreline contact and no floating oil at or above the lowest threshold (1 g/m^2) to reach state or territory waters. Therefore, surface and submerged MDO/MGO is unlikely to impact nesting or egg laying individuals in colonies, however, it is possible that breeding individuals could come into contact with surface or submerged MDO/MGO while foraging (diving and skim feeding). Although breeding oceanic seabird species can travel long distances to forage in offshore waters, most breeding seabirds tend to forage in nearshore waters near their breeding colony, resulting in intensive feeding by higher seabird densities in these areas during the breeding season and making these areas particularly sensitive in the event of a spill. Given the rapid evaporation and dispersion of MDO/MGO, significant impacts at the population level are not anticipated and therefore the risk of surface and submerged MDO/MGO to seabirds is considered low. Potential impacts to seabirds/shorebirds from exposure/contact with MDO/MGO are further detailed in **Table 7-7.**
Fish, sharks and rays	The JBG supports a diverse assemblage of fish, particularly in shallower water near the mainland and islands. Thirteen threatened and/or migratory species of sharks and rays identified by the EPBC Protected Matters search include the great white shark, oceanic whitetip shark, northern river shark, speartooth shark, shortfin and longfin mako shark, whale shark, green, freshwater, dwarf and narrow sawfish, giant manta ray and reef manta rays which may be present in the affected area (refer to **Table 3-10**). Given the absence of critical habitat for most of these species, significant numbers are not expected to be impacted. The western portion of the EMBA overlaps with a whale shark foraging BIA (approximately 185 km from the Operational Area). This BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in Spring (September to November). Therefore, any whale sharks located in offshore waters within the JBG are most likely transiting the region. Oil spill modelling predicted that the BIA was only exposed to low concentrations of entrained hydrocarbons (10 ppb) (refer to **Section 7.1.2.5**). Other species of sharks and rays 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.

Receptor	Impacts of MDO/MGO
	Fish populations in the open water, offshore environment of the Operational Area and EMBA are highly mobile and have the ability to move away from a marine diesel spill. The spill affected area will likely be confined to the upper surface layers (0-10 m). It is therefore unlikely that fish populations would be exposed to hydrocarbon contamination. Fish populations are likely to be distributed over a wide geographical area so impacts on populations or species level are considered to be negligible. Combined with these factors and the rapid dispersion of marine diesel, it is considered that any potential impacts will be negligible. For further detailed environmental impacts through hydrocarbon exposure and toxicity effects, refer to **Table 7-7**.
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 submerged and dissolved hydrocarbons, 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	Tourism and recreational activities in the region occur predominantly in State/Territory waters adjacent to population centres, such as Broome and Darwin. Charter vessels may occasionally transit through the Operational Area and EMBA between Darwin and the northern Kimberley coastline, however interactions with the Petrel Sub-Basin SW 3D MSS are considered unlikely due to the remoteness and predominantly deep waters of the Operational Area, and the lack of overlap between the proposed survey period (December to March) and the peak tourism season (May to October). In the unlikely event of a marine diesel spill, there is the potential for specific sites close to the spill or areas affected by visible hydrocarbons to be temporarily closed to recreational activities, which may inconvenience tourism and charter boat operators that may have to conduct their activities elsewhere.
Shipping	Heavy vessel traffic directly north of the Operational Area is expected, due to vessels heading in and out of Darwin (refer to **Figure 3-25**). Traffic within the Operational Area itself is relatively low (in comparison to other locations along the NWS). In the event of a vessel collision and significant marine diesel spill, the AMSA Joint Rescue Coordination Centre may issue a warning to shipping traffic in the area to avoid the incident location. 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	The Operational Area overlaps with the North Australian Exercise Area (NAXA). Defence have advised Santos that they are planning Exercise KAKADU between 1 August to 30 September 2022, and request avoidance of the area. Given the proposed Petrel Sub-Basin SW MSS period (1 December to 31 March), there is no overlap between the MSS and Exercise KAKADU. In the unlikely event of a marine diesel spill, there is the potential for some interference with defence activities in the NAXA. This may include the immediate area of the incident and an area where volatile aromatic vapours evaporating from the sea surface may present a safety hazard.
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 are therefore unlikely to have an impact on shipwrecks.

Receptor	Impacts of MDO/MGO
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.
Existing oil and gas activity	The Bonaparte Basin is an established hydrocarbon province with a number of commercial operations including other Santos activities. Exclusion zones surrounding spills will reduce access potentially leading to delays to work schedules with subsequent financial implications.
KEFs	KEFs overlapping the EMBA are described in **Section 3.6.1** and are summarised below. Pinnacles of the Bonaparte Basin • Areas of hard substrate in an otherwise soft sediment environment • Rise steeply from depths of about 80 m to emergent within 30 m of the water's surface • Important for sessile species and allow light dependent organisms to thrive • Support communities of benthic invertebrates and aggregations of demersal fish species • Biodiversity hotspot for sponges Carbonate bank and terrace system of the Sahul Shelf • Unique seafloor feature supporting relatively high species diversity • Enhances biodiversity and local productivity relative to its surrounds • Areas of hard substrate in an otherwise soft sediment environment • Rise steeply from depths of about 80 m to emergent within 30 m of the water's surface • Important for sessile species and allow light dependent organisms to thrive • Biodiversity hotspot for sponges • Known foraging area for flatback, olive ridley and leatherback turtles. Carbonate bank and terrace system of Van Diemen Rise • Areas of hard substrate in an otherwise soft sediment environment; banks, ridges and terraces. • Enhances biodiversity and local productivity relative to its surrounds • Biodiversity hotspot for sponges • Known foraging area for olive ridley turtles, seasnakes and sharks. Ancient coastline at 125 m depth contour • Areas of hard substrate in an otherwise soft sediment environment

Receptor	Impacts of MDO/MGO
	• Contributes to higher diversity and enhanced species richness • Attracts opportunistic feeding by larger marine life including humpback whales, whale sharks and large pelagic fish. Continental slope demersal fish communities • High level of endemism and diversity of demersal fish • Attracts high order consumers including carnivorous fish, deepwater sharks, large squid and toothed whales. Ashmore Reef and Cartier Island and surrounding Commonwealth Waters • Biodiversity hotspot supporting a diverse array of pelagic and benthic marine species • Enhanced primarily productivity in an otherwise low-nutrient environment, attracting aggregations of marine life • Regionally important for feeding and breeding aggregations of birds and other marine life, including an unusually high diversity of seasnakes, a genetically distinct breeding population of green turtles and foraging grounds for green, loggerhead and hawksbill turtles. The carbonate bank and terrace system of the Sahul Shelf KEF is the only KEF predicted to be exposed to concentrations of surface and entrained hydrocarbons above the moderate exposure values. The other KEFs have a low probability of contact with entrained hydrocarbons above the low exposure value only. 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.
Marine Protected Areas	Marine Protected Areas are described in **Section 3.5.1** and potential impacts to protected areas are discussed in **Section 7.1.6**. Marine Protected Areas within the EMBA include: • JBG AMP; • Oceanic Shoals AMP; • Kimberley AMP; • Cartier Island AMP; and • Ashmore Reef AMP. The JBG AMP is the only AMP predicted to be exposed to concentrations of surface and entrained hydrocarbons above the moderate exposure values. The Kimberley AMP and Oceanic Shoals AMP are predicted to have a 16% and 1% chance respectively of being exposed to entrained hydrocarbons above the moderate exposure value. The other AMPs have a low probability of contact with entrained hydrocarbons above the low exposure value only. The EMBA partially overlaps with the Multiple Use Zone (IUCN VI) and Special Purpose Zone (IUCN VI) of the JBG Marine Park (JBGMP). The designated natural values of the JBGMP include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and

Receptor	Impacts of MDO/MGO
	foraging habitat for marine turtles and the Australian snubfin dolphin. Potential impacts to these values from a worst case marine diesel spill within the Operational Area are assessed in the sub-sections above. The EMBA partially overlaps with the Multiple Use Zone (IUCN VI) and Special Purpose Zone (IUCN VI) of the Oceanic Shoals Marine Park (OSMP). The designated natural values of the OSMP include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and foraging and internesting habitat for marine turtles. Potential impacts to these values from a worst case marine diesel spill within the Operational Area are assessed in the sub-sections above. Potential impacts to commercial fisheries occurring within the Multiple Use Zone of the OSMP are assessed below. The EMBA partially overlaps with the Multiple Use Zone (IUCN VI) of the Kimberley Marine Park. The designated natural values of the marine park include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and foraging and nesting habitat for dolphin species (including Australian snub-fin dolphin, Indo-Pacific humpback dolphin and spotted bottlenose dolphin). Potential impacts to these values from a worst case marine diesel spill within the Operational Area are assessed in the sub-sections above. The EMBA partially overlaps with the Sanctuary Zone (IUCN Ia) of the Cartier Island Marine Park. The designated natural values of the marine park include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and foraging and nesting habitat for marine turtle and seabird and migratory shorebird species. Potential impacts to these values from a worst case marine diesel spill within the Operational Area are assessed in the sub-sections above. The EMBA partially overlaps with the Sanctuary Zone (IUCN Ia) and Recreational Use Zone (IUCN IV) of the Ashmore Reef Marine Park. The designated natural values of the marine park include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and foraging and nesting habitat for marine turtles, dugongs and seabird and migratory shorebird species. Potential impacts to these values from a worst case marine diesel spill within the Operational Area are assessed in the sub-sections above.

7.1.4 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ Protect and maintain biological diversity and other natural, cultural and heritage values of the North-west Marine Parks Network and North Marine Parks Network (EPO-13).
+ No unplanned objects, emissions or discharges to sea or air (EPO-16).
+ No injury to marine fauna during the Activity (EPO-18);
+ No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (EPO-19);

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 maneuverability 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 (safety) 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	No additional costs.	**Adopted –** no additional costs. This is a maritime requirement.

CM Reference	Control measure (CM)	Environmental benefit	Potential cost/issues	Evaluation
		party vessels which may be approaching or enter the exclusion zone.		
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-28	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-32	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	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 Reference	Control measure (CM)	Environmental benefit	Potential cost/issues	Evaluation
	collision and rupture of an in-board fuel tank containing small volumes of the fuel.			
CM-33	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-34	Vessel spill response plans (SOPEP/SMPEP)	Vessel spill response plans (SOPEP/SMPEP) outline responses to be implemented in the event of 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.
Additional control measures				
CM-35	Maximum volume of fuel stored in a single tank of vessels used for the Activity will not exceed 1,062 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 1,062 m^3 and the tanks are larger in volume (therefore less tanks in the vessel).	**Adopted –** benefits of ensuring volume is less than 1,062 m^3 outweighs the potential to not be able to contract a vessel.

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.

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 7-9** 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 are the key considerations that were 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.

Table 7-9: 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	Reject

Strategy	Description	Evaluation	Adopt/ Reject
		(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. 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

Strategy	Description	Evaluation	Adopt/ Reject
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 and 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 an 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
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.	Modelling predicted no shoreline contact above the low exposure threshold from a spill at any of the three release locations. Therefore, shoreline protection and deflection is not a relevant strategy for the purposes of this EP.	Reject
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.	Modelling predicted no shoreline contact above the low exposure threshold from a spill at any of the three release locations. Therefore, shoreline clean-up is not a relevant strategy for the purposes of this EP.	Reject
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 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.	Adopt

Strategy	Description	Evaluation	Adopt/ Reject
		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 WA Oiled Wildlife Response Plan (WAOWRP) and NT 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' 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 and Northern Territory 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**; 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 contact at 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 7-10**, including a description of values and a consequence rating for 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 7-4** to **Table 7-6**), from the predicted concentrations/levels of MDO/MGO for each location presented in **Section 7.1.2**.

The following HEV areas were identified for detailed assessment in **Table 7-10**:

+ JBG AMP
+ JBG West Coast
+ JBG East Coast
+ Kimberley Coast PMZ
+ Kimberley AMP

Other protected areas identified within the EMBA are not predicted to be contacted by hydrocarbons exceeding thresholds that may result in ecological impacts or impacts to socio-economic or heritage receptors include:

+ Vernon Islands CR
+ Beagle Gulf-Darwin Coast
+ JBG South Coast
+ Gale Bank
+ Penguin Shoal
+ Fantome Shoal
+ Eugene McDermott Shoal
+ Barracouta Shoals
+ Vulcan Shoals
+ Woodbine Bank
+ Cartier Island AMP
+ Ashmore Reef AMP
+ Heywood Shoals
+ Echuca Shoals
+ Browse Island
+ Van Cloon/Deep Shoals

The values and sensitivities of these protected areas are described in **Section 3.5**. While these areas fall within the EMBA for spill response planning (based on the low exposure values for total submerged 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.

Table 7-10: **Consequence summary for High Environmental Value areas in the EMBA**

Receptor Name	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking
JBG AMP	4	The EMBA partially overlaps with the Multiple Use Zone (IUCN VI) and Special Purpose Zone (IUCN VI) of the JBG Marine Park. The designated natural values of the JBGMP include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), and foraging habitat for marine turtles and the Australian snubfin dolphin. Potential impacts to these receptors are described in **Table 7-7** and **Table 7-8**. Modelling results predict a maximum probability of contact above the moderate exposure value (which may result in ecological impacts) of 10% for surface hydrocarbons, 53% for total submerged hydrocarbons, and 1% for dissolved hydrocarbons. Submerged and dissolved hydrocarbons will be limited to the top 10 m of the water column. Impacts to individual marine fauna may occur and a potential disruption to a portion of the foraging/internesting habitat for turtles and foraging habitat for snubfin dolphins. This is not expected to result in a threat to the overall population viability due to the rapid dispersion of MDO/MGO.	Threatened / Migratory Fauna Physical Habitat Protected Areas Socio-economic and Heritage Receptors	III (Moderate) III (Moderate) III (Moderate) III (Moderate)	IIII (Moderate)
JBG East	5	Coastal habitats in the JBG include beaches, mudflats, saltmarsh, rocky coastlines and mangroves. Potential impacts to these receptors are described in **Table 7-7** and **Table 7-8**. The JBG is not considered to be a significant mangrove area, although mangroves occur throughout the Gulf and there are locally important groups, mainly on the southern coast of the Gulf (LDM 1994). The inner Joseph Bonaparte Gulf is not expected to support significant seagrass areas due to unsuitable environmental conditions, which include highly turbid water conditions and the mobile nature of the sediments (LDM 1994). Modelling results predict a maximum probability of contact above the moderate exposure value for total submerged hydrocarbons (entrained) of 2% for JBG East and 5% for JBG West. Submerged hydrocarbons will be limited to the top 10 m of the water column and therefore only have the potential to contact nearshore benthic habitats, noting that no shoreline contact above the low exposure threshold was predicted from the modelling at any of the three locations. No contact is predicted above moderate exposure values for surface or dissolved hydrocarbons.	Physical Habitat Threatened / Migratory Fauna Socio-economic and Heritage Receptors	II (Minor) II (Minor) II (Minor)	II (Minor)
JBG West	4				

Receptor Name	HEV Score	Potential Impacts to Values and Sensitivities	Consequence Category	Consequence Ranking	Overall consequence ranking
Kimberley AMP	3	The Kimberley AMP is approximately 100 km north of Broome. It covers 74,469 km^2, with depths from less than 15 m to 800 m. The eastern boundary of the Kimberley AMP is located approximately 105 km west of the Operational Area. The Kimberley AMP is a hotspot for marine mammals such as dolphins, whales and dugong. The humpback whale breeds and calves in the Kimberley AMP annually after undertaking an extensive migration from Antarctica. Three dolphin species use the Kimberley AMP to feed and travel to coastal waters to breed. Modelling results predict a maximum probability of contact above the moderate exposure value (which may result in ecological impacts) of 16% for total submerged hydrocarbons. No contact is predicted above moderate exposure values for surface or dissolved hydrocarbons.	Threatened / Migratory Fauna Physical Habitat Protected Areas Socio-economic and Heritage Receptors	II (Minor) II (Minor) II (Minor) II (Minor)	II (Minor)
Kimberley Coast PMZ	3	Coastlines in the PMZ area of the Kimberley include rocky shore, sandy beaches and tidal wetland (including saltmarsh and mangroves). Fringing coral occurs in areas off the coastline. Turtles, dugong, dolphins and sharks are common in the nearshore waters of the region. Modelling results predict a maximum probability of contact above the moderate exposure value for total submerged hydrocarbons (entrained) of 6% for the Kimberley coast PMZ. Submerged hydrocarbons will be limited to the top 10 m of the water column and therefore only have the potential to contact nearshore benthic habitats, noting that no shoreline contact above the low exposure threshold was predicted from the modelling at any of the three locations. No contact is predicted above moderate exposure values for surface or dissolved hydrocarbons.	Physical Habitat Threatened / Migratory Fauna Socio-economic and Heritage Receptors	II (Minor) II (Minor) II (Minor)	II (Minor)

7.1.7 Impact, Consequence and Likelihood Ranking

<table>
<tr><td>Receptors</td><td>Marine fauna – plankton, fish, sharks and rays, marine mammals, marine reptiles, seabirds and shorebirds;
Physical environment/habitats;
Marine Protected Areas; and
Socio-economic and heritage receptors</td></tr>
<tr><td>Consequence</td><td>III - 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 (1,062 m^3). Given the nature of the MDO/MGO and the distance from shorelines, dilution and dispersion from natural weathering processes such as ocean currents will occur.
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. The potential for impacts to marine fauna is summarised in Table 7-7 and Table 7-8.
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 fishes and elasmobranchs, marine mammals, marine reptiles and seabirds and shorebirds at the sea surface, as discussed in Table 7-8. 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 7-7 and Table 7-8.
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 7-10. This is due to the potential for:
- Surface oil and entrained oil impacts on the AMP values within the JBG AMP.
It is noted that potential impacts identified are based on stochastic modelling of 300 spill trajectories from three release locations. For any single spill trajectory, impacts would not occur at all locations.</td></tr>
<tr><td>Likelihood</td><td>a - Remote</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.
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 remote.</td></tr>
<tr><td>Residual Risk</td><td>The residual risk associated with this hazard is Very Low.</td></tr>
</table>

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 (Remote) 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 7.1.5** (Response Strategy Selection), 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 **Appendix B of the OPEP**. 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.

7.1.9 Acceptability Evaluation

<table>
<tr><td colspan="2">Is the risk ranked between Very Low to Medium?</td><td colspan="2">Yes – Maximum hydrocarbon spill – MDO/MGO residual risk is ranked Very Low.</td></tr>
<tr><td colspan="2">Is further information required in the consequence assessment?</td><td colspan="2">Yes – Hydrocarbon spill modelling results were used to determine consequence and risk.</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?</td><td colspan="2">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.</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with the Santos Environmental Management Policy?</td><td colspan="2">Yes – Aligns with the Environmental Management Policy.</td></tr>
<tr><td colspan="2">Are performance outcomes and standards consistent with stakeholder expectations?</td><td colspan="2">Yes – No concerns raised.</td></tr>
<tr><td colspan="2">Are control measures and performance standards such that the impact or risk is considered to be ALARP?</td><td colspan="2">Yes (see ALARP evaluation above).</td></tr>
<tr><td colspan="4">Defined Acceptable Levels</td></tr>
<tr><td rowspan="2">Does the predicted risk level meet defined acceptable levels of risk (refer to Section 5.6)?</td><td>Defined Acceptable Level</td><td>Comparison with Predicted Levels of Risk</td><td>EPO</td></tr>
<tr><td>No unplanned discharge of hydrocarbons to sea.

No long-term environmental impact in the event of an unplanned hydrocarbon release to sea.

The risk of an impact from an unplanned hydrocarbon spill must be ranked Very Low to Medium according to the Santos Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004).</td><td>The residual risk of an unplanned hydrocarbon spill is considered to be Very Low and acceptable This is due to the proposed control measures and resultant low likelihood of a vessel collision and significant hydrocarbon spill. Additionally, through the application of mitigation measures detailed in spill response plans (SOPEP and OPEP).</td><td>EPO-13
EPO-16
EPO-18
EPO-19</td></tr>
</table>

7.2 Minor Hydrocarbon Release

7.2.1 Description of Event

Minor Hydrocarbon Release	
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	MGO/MDO fuel at the sea surface will 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 an accidental release ~37.5 m^3 of MDO/MGO 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 is required.

7.2.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ No unplanned objects, emissions or discharges to sea or air (EPO-16).
+ No injury to marine fauna during the Activity (EPO-18).
+ No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (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**.

CM reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-20	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-21	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-28	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-33	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-34	Vessel spill response plans (SOPEP/SMPEP).			
CM-36	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-37	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 reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-38	Bulk refuelling transfer procedures.	Prevents probability of unplanned hydrocarbon spills or leaks occurring during bunkering leading to negative impacts to the marine environment.	Additional personnel costs of ensuring procedures in place and followed.	**Adopted -** benefits of ensuring procedures are followed outweighs the minimal 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-39	Undertake bunkering / bunkering drill prior to the Activity.	Ensures the controls can be implemented and there is familiarity with the process.	Associated cost with the time spent testing bunkering during mobilisation.	**Adopted –** Benefit of conducting bunkering / bunkering drill prior to arrival in the Operational Area outweighs the cost in lost time.

7.2.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Marine fauna – plankton, fish, sharks and rays, marine mammals, marine reptiles
Consequence	I – Negligible
In the event of a minor hydrocarbon spill, the quantities would be limited to ~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. 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 3-11**). 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. Toxic impacts are not expected to the benthic community due to the water depths of the Operational Area (minimum depth of 40 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 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 2011) 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 seasnakes 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	b – 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 Very 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

<table>
<tr><td colspan="2">Is the risk ranked between Very Low to Medium?</td><td colspan="2">Yes – Residual risk is ranked Very Low.</td></tr>
<tr><td colspan="2">Is further information required in the consequence assessment?</td><td colspan="2">No – Potential impacts and risks are well understood through the information available.</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?</td><td colspan="2">Yes – Management consistent with International Convention of the Safety of Life at Sea (SOLAS) 1974, Navigation Act 2012, MARPOL Annex I - Prevention of Pollution from Ships, and relevant recovery plans (Table 3-11).</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with the Santos Environmental Management Policy?</td><td colspan="2">Yes – Aligns with the Environmental Management Policy.</td></tr>
<tr><td colspan="2">Are performance outcomes and standards consistent with stakeholder expectations?</td><td colspan="2">Yes – No concerns raised.</td></tr>
<tr><td colspan="2">Are control measures and performance standards such that the impact or risk is considered to be ALARP?</td><td colspan="2">Yes (see ALARP evaluation above).</td></tr>
<tr><td colspan="4">Defined Acceptable Levels</td></tr>
<tr><td rowspan="2">Does the predicted risk level meet defined acceptable levels of risk (refer to Section 5.6)?</td><td>Defined Acceptable Level</td><td>Comparison with Predicted Levels of Risk</td><td>EPO</td></tr>
<tr><td>No unplanned discharge of hydrocarbons to sea.
No long-term environmental impact in the event of an unplanned hydrocarbon release to sea.
The risk of an impact from an unplanned hydrocarbon spill must be ranked Very Low to Medium according to the Santos Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004).</td><td>The residual risk of an unplanned minor hydrocarbon spill is considered to be Very Low and acceptable This is due to the proposed control measures and resultant low likelihood of a significant hydrocarbon spill to sea. Additionally, through the application of mitigation measures detailed in spill response plans (SOPEP and OPEP).</td><td>EPO-16
EPO-18
EPO-19</td></tr>
</table>

7.3 Spill Response Operations

7.3.1 Description of Event

Spill Response Operations	
Event	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 6.7 of the OPEP**. Spill response will be under the direction of the relevant Control Agency, as defined within the **Section 4.2 of the OPEP**. The response strategies and supporting activities deemed appropriate for the worst-case oil spill scenarios identified for the Activity are detailed in **Sections 9 to 14 of the OPEP** and comprise: + Source control; + Operational monitoring; + Mechanical dispersion; + 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.
Extent	Extent of the hydrocarbon release
Duration	As required.

Santos

7.3.2 Details of the Environmental Impacts and Risks for the Activities

Light emissions	
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 not expected as no shoreline oiling is predicted by modelling of the worst case credible spill scenario.	
Potential receptors:	Fauna (including Threatened/Migratory/Local fauna) Protected Areas Socio-economic receptors
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 6.5** for further detail on the impacts of light to fish, birds and marine turtles. Spill response activities that require lighting may take place in protected areas in open ocean through response strategy implementation. Environmental values and sensitivities potentially impacted by light from response strategy implementation, including BIAs for turtles and birds have been identified in **Section 6.5**. However, given the scale of the response any impacts are expected to be short term, geographically confined and minor. Additionally, light impacts would be considered in the operational NEBA process.	
Noise emissions	
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.	
Potential receptors:	Fauna (including Threatened/Migratory/Local fauna) Protected Areas Socio-economic receptors
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 6.3.3** for further detail on the environmental impact of noise attributed to vessel operations. Cetaceans have been identified as the key receptor that may be impacted by vessel noise associated with response strategy implementation. However, individuals are expected to be present in the EMBA in low numbers and limited to isolated individuals or small pods and BIAs for cetaceans are not expected to be impacted by spill response activities.	
Atmospheric emissions	
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

Santos

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 to be significant.	
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; • 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 6.6.** 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. Sewage, putrescible and municipal waste could 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 any anchoring and operations 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 in nearshore environments is not expected but if required may disturb benthic habitats including corals, seagrass and macroalgae. Impacts to habitats from vessels include damage through the deployment of anchor/chain, and grounding. Vessel use in coastal waters also increases the chance of contact or physical disturbance with marine megafauna such as turtles and dugongs. 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. 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	
Spill response activities may involve the use of vessels, equipment and vehicles in areas used by the general public or industry.	
Potential receptors:	Socio-economic receptors
The use of vessels in the nearshore and offshore environment 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.	

7.3.3 Environmental Performance Outcomes and Control Measures

For EPOs, EPSs and Measurement Criteria relating to spill response in the event of a spill during this Activity, refer to 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 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)

Control measure	Environmental benefit	Evaluation
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)
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 nearshore operations	Reduces seabed disturbance	**Adopt** - Considered a standard control
Conduct nearshore habitat/bathymetry assessment	Reduces nearshore habitat disturbance	**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 and NT Oiled Wildlife Response Plans	Oiled wildlife hazing, capture, handling and rehabilitation meet minimum standards as outlined within the WA and NT Oiled Wildlife Response Plans	**Adopt** - Considered a standard control to be adopted by the relevant Controlling Agency
Use existing moorings or anchor locations where possible or available	Reduces seabed disturbance from anchoring operations	**Adopt** - Considered a standard control
Disruption to other users of marine and coastal areas		
Stakeholder consultation	Early awareness of spill response activities which reduces potential disruption	**Adopt** - Considered a standard control

7.3.4 Impact and Consequence Ranking

Light emissions	
Potential receptors	Fauna (including Threatened/Migratory/Local fauna): seabirds and shorebirds, turtles Protected Areas Socio-economic receptors
Consequence	Fauna (including Threatened/Migratory/Local fauna): I (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: I (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: I (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 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***. These species are likely to be values of the protected areas in which they occur 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 emissions	
Potential receptors	Fauna (including Threatened/Migratory/Local fauna): marine mammals Protected Areas Socio-economic receptors
Consequence	Fauna (including Threatened/Migratory/Local fauna): I (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: I (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: I (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 migrating cetacean species. A temporary behavioural disturbance is expected only with a consequence of ***Negligible***.	

Atmospheric emissions	
Potential receptors	Physical Environment/Habitat: air quality Fauna (including Threatened/Migratory/Local fauna): seabirds and shorebirds Protected Areas
Consequence	Physical Environment/Habitat: I (Negligible) – No or negligible reduction in habitat area/function. Fauna (including Threatened/Migratory/Local fauna): I (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: I (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	Physical Environment/Habitat: I (Negligible) – No or negligible reduction in habitat area/function. Fauna (including Threatened/Migratory/Local fauna): I (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: I (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: I (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***.	
Physical presence and disturbance	

Potential receptors	Fauna (including Threatened/Migratory/Local fauna): marine mammals, turtles Protected Areas Physical Environment/Habitat: offshore and shallow habitats (corals, mangroves, seagrass, macroalgae) Socio-economic receptors
Consequence	Fauna (including Threatened/Migratory/Local fauna): II (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: I (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. Physical Environment/Habitat: I (Negligible) – No or negligible reduction in habitat area/function. Socio-economic receptors: I (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 use of vessels will be limited to offshore locations, and has the potential to disturb benthic habitats including sensitive habitats in coastal waters such as corals, seagrass, macroalgae and mangroves. A review of shallow water habitats, and bathymetry, utilising existing moorings and the establishment of demarcated areas anchoring will reduce the level of impact to ***Negligible***. 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 WAOWRP and the NTOWRP. 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 considered ***Negligible***. The disturbance to marine 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), but is expected to be minimal. This impact is considered ***Negligible***.	
Disruption to other users of marine and coastal areas	
Potential receptors	Socio-economic receptors: fisheries, fisheries and aquaculture, tourism
Consequence	II (Minor) – Detectable but insignificant short-term loss of value of the local industry.
The use of vessels in the nearshore and offshore environment 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 could have a 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	b – 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 Very 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.

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 and NT Oiled Wildlife Response Plans.

Santos considers the actions prescribed in the Recovery Plan for Marine Turtles in Australia (DoEE 2017) and Approved Conservation Advice for other threatened fauna (**Table 3-11**) 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 risk ranked between Very Low to Medium?		Yes – Residual risk is ranked Very Low.	
Is further information required in 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 industry standards and regulatory requirements. Oil spill response activities will be undertaken in a manner consistent with the applicable objectives and actions of Conservation Advice, Recovery Plans or Guidelines; and AMP management 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. 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 and NT Oiled Wildlife Response Plans.	
Are control measures and performance standards such that the impact or risk is considered to be ALARP?		Yes (see ALARP evaluation above).	
Defined Acceptable Levels			
Does the predicted risk level meet defined acceptable levels of risk (refer to **Section 5.6**)?	Defined Acceptable Level	Comparison with Predicted Levels of Risk	EPO
	The net environmental benefit of a spill response strategy must be greater than no response. The environmental risk of spill response strategies must be ranked Very Low to Medium according to the Santos Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004).	The residual risk of spill response is considered to be Very Low and acceptable. This is due to the nature of the oil spill (i.e. marine diesel); and the maintenance of a competent and prepared incident management team, selection of response. Strategies based on Net Environmental Benefit Analysis (NEBA) and implementation of the OPEP.	Refer to the OPEP.

7.4 Hazardous and Non-Hazardous Unplanned Discharges - Liquid

7.4.1 Description of Event

Hazardous and Non-Hazardous Unplanned Discharges - Liquid	
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 up to 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 released from an on-deck hydraulic hose (loss of ~200 L), however the worst case overall is up to 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 include fish, sharks and rays, marine mammals, marine reptiles, seabirds and migratory shorebirds.

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 toxicity effects to marine fauna and fish in the immediate vicinity of the spill release location, through direct contact or accidental ingestion. However, given the open water, high dispersion location of the Operational Area, the extent and duration of potential exposures, impacts to marine fauna (e.g. pelagic/benthic fish, epifauna, marine mammals, marine reptiles and seabirds) are expected to be highly localised (within the vicinity of the point of release) and short term. Chronic impacts are considered unlikely due to the expected low concentrations and short exposure times.

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.

7.4.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ No unplanned objects, emissions or discharges to sea or air (EPO-16).
+ No injury to marine fauna during the Activity (EPO-18).
+ No long-term environmental impact in the event of an unplanned hydrocarbon release to sea (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**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-20	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-21	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-34	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-36	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-40	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-41	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 and Consequence Ranking

Description	
Receptors	Marine fauna: fish, sharks and rays, marine mammals, marine reptiles, seabirds and migratory shorebirds
Consequence	I – Negligible
In the event of a hazardous/ non-hazardous liquid spill, the worst-case quantity would be limited to up 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 (up to 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 3-11**). 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 (up to 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	b – 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 Very 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 Very Low to Medium?		Yes – Maximum hazardous/non-hazardous liquid release residual risk is ranked Very Low.	
Is further information required in 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 *MARPOL Annex III - Prevention of Pollution by Harmful Substances, International Maritime Dangerous Goods Code,* and relevant Recovery Plans and Approved Conservation Advice (**Table 3-11**).	
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).	
Defined Acceptable Levels			
Does the predicted risk level meet defined acceptable levels of risk (refer to **Section 5.6**)?	Defined Acceptable Level	Comparison with Predicted Levels of Risk	EPO
	No unplanned discharge of hazardous or non-hazardous liquid to sea. The risk of an unplanned discharge must be ranked Very Low to Medium according to the Santos Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004).	The residual risk of an unplanned discharge is considered to be Very Low and acceptable. This is due to application of maritime regulatory requirements and best practices.	EPO-16 EPO-18 EPO-19

7.5 Hazardous and Non-Hazardous Unplanned Discharges – Solid

7.5.1 Description of Event

Hazardous and Non-Hazardous Unplanned Discharges - Solid	
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 (up to approximately 9.5 km in 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 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 as described in **Section 2**) or until the solid waste degrades or is retrieved.

7.5.2 Nature and Scale of Environmental Impacts

Potential receptors include benthic habitats, fish, sharks and rays, marine mammals, marine reptiles, seabirds and migratory shorebirds, and socio-economic receptors.

The seismic survey vessel and support vessel(s) will generate a variety of solid waste including non-hazardous wastes (e.g. paper, plastics, waste metal and glass) and/or hazardous wastes (e.g. batteries and oil filters). Of relevance to this Activity is the legislation for the prevention of garbage disposal from vessels, which Santos implements through adherence to MARPOL. Solid wastes will not be discharged to sea but rather will be stored on board the vessels prior to transfer to a support vessel for onshore recycling or disposal.

If solid wastes on board vessels are not managed or disposed of appropriately, small quantities may be released with the potential to impact the environment. All domestic waste discharge will be managed in accordance with the requirements of MARPOL 73/78 and the AMSA Marine Orders made under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*.

Loss of solid wastes to the marine environment have the potential to:

+ Temporarily create a localised change in water/sediment quality resulting in localised, minor and temporary ecological impacts; and
+ Cause injury, ingestion or entanglement by marine fauna.

Non-hazardous solids such as plastics have the potential to smother benthic environments and harm marine fauna through entanglement or ingestion. Marine turtles, seabirds and migratory shorebirds 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 (DoEE 2017), Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) and Approved Conservation Advice for *Rhincodon typus* (whale shark) (refer to **Table 3-11**). The Recovery Plans and Approved Conservation Advices have specified a number of recovery actions to help combat this threat.

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 and rays, marine mammals, marine reptiles, seabirds and migratory shorebirds.

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 infrequent localised rocky outcrops, gravel deposits and sandy banks. The muddy substrates that cover the majority of the Operational Area support relatively little seabed structure or sessile epibenthos. Seabed habitat is expected to be sparsely covered by sessile filter-feeding organisms (e.g. gorgonians, sponges, ascidians and bryozoans) and mobile invertebrates (e.g. echinoderms, prawns and detritus-feeding crabs). Such habitats are well represented throughout the region.

A portion of the carbonate bank and terrace system of the Sahul Shelf KEF and pinnacles of the Bonaparte Basin KEF partially overlap with the Operational Area. The KEFs provide areas of hard substrate that are important for sessile species benthic invertebrates including hard and soft corals, sponges, whips, fans, bryozoans and aggregations of demersal fish species such as snappers, emperors and groupers (Brewer et al. 2007; Nichol et al. 2013).

In the unlikely event that an object is dropped, damage to substrates and associated fauna is expected to be restricted to the size of the dropped object, and 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. Impacts to benthic habitats such as shelf and slope habitats and the KEFs are not expected. Given the water depths of the Operational Area, benthic impacts from the loss of a streamer are not considered credible.

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 potentially sinking and dragging along 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.

Impacts to socio-economic 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). Buoyant objects may cause interference with commercial fisheries and 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. Should disruption occur, it is only expected to affect individual users and cause temporary disruption through avoidance of a highly localised area. The potential for such interactions will be limited to a short period of time while the equipment is retrieved (if possible). Given the nature and size of the equipment to be used during the survey, lost equipment is not expected to result in a navigational hazard.

7.5.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ No unplanned objects, emissions or discharges to sea or air (EPO-16);
+ No injury to marine fauna during the Activity (EPO-18); and
+ No unplanned seabed disturbance (EPO-20).

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**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-23	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-40	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-41	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-42	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-43	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.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
Additional control measures				
CM-44	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-45	Streamers have locating devices fitted.	Enables location and retrieval of streamers if they are lost.	None identified.	**Adopted** – benefits outweigh operational constraints.

7.5.4 Impact, Consequence and Likelihood Ranking

<table>
<tr><th colspan="2">Description</th></tr>
<tr><td>Receptors</td><td>Physical Environment - benthic habitats
Marine Fauna – cetaceans, marine turtles, fish, sharks and rays, seabirds
Socio-economic receptors – other marine users (fisheries, shipping, oil and gas operators)</td></tr>
<tr><td>Consequence</td><td>I – Negligible</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td colspan="2">Marine Fauna – marine mammals, marine turtles, fish, sharks and rays, seabirds and migratory shorebirds
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 3-11). 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.</td></tr>
<tr><td colspan="2">Socio-economic receptors – 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.</td></tr>
<tr><td>Likelihood</td><td>b – Unlikely</td></tr>
<tr><td colspan="2">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 unlikely (assumes potential for a single loss of solid waste incident during the Activity).</td></tr>
<tr><td>Residual Risk</td><td>The risk associated with this hazard is Very Low.</td></tr>
</table>

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

<table>
<tr><td colspan="2">Is the risk ranked between Very Low to Medium?</td><td colspan="2">Yes – Residual risk is ranked Very Low.</td></tr>
<tr><td colspan="2">Is further information required in the consequence assessment?</td><td colspan="2">No – Potential impacts and risks are well understood through the information available.</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?</td><td colspan="2">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 3-11) as having the potential to be impacted by marine debris (solid hazardous/ non-hazardous releases).</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with the Santos Environmental Management Policy?</td><td colspan="2">Yes – Aligns with the Environmental Management Policy.</td></tr>
<tr><td colspan="2">Are performance outcomes and standards consistent with stakeholder expectations?</td><td colspan="2">Yes – No concerns raised.</td></tr>
<tr><td colspan="2">Are control measures and performance standards such that the impact or risk is considered to be ALARP?</td><td colspan="2">Yes (see ALARP evaluation above).</td></tr>
<tr><td colspan="4">Defined Acceptable Levels</td></tr>
<tr><td rowspan="2">Does the predicted risk level meet defined acceptable levels of risk (refer to Section 5.6)?</td><td>Defined Acceptable Level</td><td>Comparison with Predicted Levels of Risk</td><td>EPO</td></tr>
<tr><td>No unplanned discharge of hazardous or non-hazardous solid object to sea.
The risk of an unplanned discharge must be ranked Very Low to Medium according to the Santos Environmental Offshore Division Hazard Identification and Assessment Guideline (EA-91-IG-00004).</td><td>The residual risk of an unplanned discharge is considered to be Very Low and acceptable. This is due to application of maritime regulatory requirements and best practices.</td><td>EPO-16
EPO-18
EPO-20</td></tr>
</table>

7.6 Marine Fauna Collisions

7.6.1 Description of Event

Marine Fauna Collisions	
Aspect	There is the potential for vessels and/or equipment involved in the Activity to collide with marine fauna including cetaceans, fish, sharks and rays, marine reptiles and seabirds and migratory shorebirds. The main collision risk associated with the Activity is through vessel collision or equipment collision (i.e. streamers and seismic source) 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 as described in **Section 2**.

7.6.2 Nature and Scale of Environmental Impacts

Potential receptors include marine mammals, marine reptiles, fish, sharks, rays, seabirds and migratory shorebirds

Vessel movements can result in collisions between the vessel (hull, propellers and streamer array) and marine fauna. Vessel collisions have the potential to result in superficial injury, serious injury that may affect life functions (e.g. movement and reproduction) or cause mortality to marine fauna. The risk of a vessel collision or entanglement with marine fauna is limited to the footprint of the vessels, which is temporary in nature at any one position, as the vessels transits within the Operational Area for the acquisition period. The factors that contribute to the frequency and severity of impacts due to collisions vary greatly due to vessel type, vessel operation (specific activity, speed), physical environment (e.g. water depth), and the type of fauna potentially present and their behaviours. Research shows that faster vessels have a greater risk of collision with marine fauna than slower-moving vessels. To date, there have been no reported cases of marine fauna becoming entangled in seismic equipment in Australian waters.

Cetaceans are naturally inquisitive marine mammals that are often attracted to offshore vessels, and dolphins commonly 'bow ride' with offshore vessels. The reaction of whales to the approach of a vessel is quite variable. Some species remain motionless when close to a vessel while others are known to be curious and often approach ships that have stopped or are slow moving, although they generally do not approach, and sometimes avoid, faster moving ships (Richardson et al. 1995). In Australia, the majority of vessel strikes to known cetacean species involved humpback, southern right whale and sperm whales, in descending order (Peel et al. 2016). Van Warebeek et al. (2007) report just five blue whale ship strikes in the Southern Hemisphere. No vessel strikes were reported in the Northern coast of Australia (Peel et al. 2016).

Several species of cetaceans are known to occur in the NWMR and NMR and have wide distributions that are associated with feeding and migration patterns linked to reproductive cycles. However, there are no known important cetacean habitats within or nearby the Operational Area. The closest marine mammal BIA is the breeding and foraging BIAs for the Australian snubfin dolphin (located approximately 23 km south-east of the Operational Area). Due to the absence of important habitat, the predominantly offshore waters of the Operational Area, the occurrence of marine mammals within the Operational Area is expected to be infrequent and limited to transitory individuals.

Marine turtles are at potential risk from vessel strike and entanglement with the in-water seismic equipment. Hazel and Gyuris (2006) reviewed vessel strike data from 1999-2002 on the Queensland east coast and found that during that period at least 65 turtles were killed annually as a result of collisions with vessels. Green turtles, followed by loggerhead turtles comprised the majority of vessel related records, and 72% of cases were adult or sub-adult turtles (Hazel and Gyuris 2006). In Australian waters, all species of marine turtle have been involved in vessel strikes (DoEE 2016). Marine turtles appear to be more vulnerable to boat strike in areas of high urban population where incidents of pleasure crafts are higher.

The effect of vessel speed and turtle flee response can be significant. A study by Hazel et al. (2007) found that 60% of green turtles fled from vessels travelling at 2.2 knots (4 km/h) while only 4% fled from vessels travelling at 10.2 knots (19km/h). When fleeing 75% of turtles moved away from the vessel's track, 8% swam along the vessel track and 18% crossed in front of the vessel. The study concluded that most turtles would be unlikely to avoid vessels travelling at speeds greater than around 2.2 knots (Hazel et al. 2007; DoEE 2017).

There is no published literature on marine turtle entanglement with seismic equipment during seismic surveys, however Nelms et al. (2016) state that they received anecdotal reports of turtle entrapments in tail buoys and airgun strings during several offshore seismic surveys off the west coast of Africa, and media reports of eight Olive Ridley turtles becoming entangled in ocean bottom cable. Additionally, there is evidence of marine turtles becoming entangled in discarded seismic cable (Duncan et al. 2017).

The NWMR and NMR are considered to be significant for supporting large feeding and nesting turtle populations. The Operational Area overlaps with BIAs for foraging marine turtles (loggerhead, flatback, green and olive ridley). A portion of the carbonate bank and terrace system of the Sahul Shelf KEF and pinnacles of the Bonaparte Basin KEF partially overlaps with the Operational Area and has been identified as foraging areas for loggerhead, olive ridley and flatback turtles (DEWHA 2008b). Bycatch records from the NPF within the southern portion of the Operational Area and EMBA identified that turtle catches varied with water depth: the highest catch rates were from trawls in water depths between 20 and 30 m deep, relatively few turtles (10%) were captured in water deeper than 40 m (Poiner and Harris 1996). It is unlikely that the marine environment within the Operational Area is a predominant foraging area for turtles. The majority of the Operational Area is located in water depths greater than 60 m, typically outside of the preferred depth range for foraging marine turtles. The occurrence of marine turtles within the Operational Area is expected to be low.

Whale sharks are at risk from vessel strikes when feeding at the surface or in shallow waters (where there is limited option to dive). Whale sharks may traverse the offshore waters of the Operational Area during their migrations to and from Ningaloo Reef. A foraging BIA for the whale shark overlaps with the western portion of the EMBA, approximately 185 km from the Operational Area. The foraging route follows the continental shelf within the 200 m isobath and extends from Ningaloo to waters in the north Kimberley region. 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). The foraging BIA that overlaps the EMBA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November). It is expected that whale shark presence in the Operational Area would not comprise of significant numbers, given main aggregations are recorded in coastal waters (MPRA 2005; Sleeman et al. 2010) and their presence would be transitory and of a short duration.

Vessels will be moving at slow speeds (4-5 knots) 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. Additionally, while the seismic source is in operation it is unlikely that marine fauna would become entangled in the array or collide with the seismic equipment, as the sound generated during operations would act as a deterrent. During line turns, when typically the seismic source is not in full operation, the source is activated at low power in accordance with industry standards as a precautionary measure to reduce the likelihood of entanglement or contact during line turns. Close-range encounters with marine fauna are expected to be infrequent and limited to isolated individuals in the vicinity of the operating vessels and survey area.

7.6.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ No injury to marine fauna during the Activity (EPO-18).

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**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-11	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-46	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. 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.
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-13	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 Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-14	Implementation of some control options consistent with EPBC Policy Statement 2.1 Part B: Use of two 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.
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.	**Not Adopted** – based on cost outweighing benefits.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
			Cost of specialist aircraft with good downward visibility, or cost of an additional spotter vessel additional MFOs required on aboard aircraft/vessels. Additional risks to environment through use of vessels/airplanes, increased safety risks to personnel on board additional vessels.	

7.6.4 Impact, Consequence and Likelihood Ranking

Description	
Receptors	Marine Fauna – marine mammals, marine reptiles, fish, sharks and rays
Consequence	I - 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 3-11**). 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	b – 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). 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 unlikely.	
Residual risk	The residual risk associated with this hazard is Very 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 7.6.3**. 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.

7.6.6 Acceptability Evaluation

Is the risk ranked between Very Low to Medium?	Yes – Residual risk is ranked Very Low.
Is further information required in 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 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 (**Table 3-11**).
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).

Defined Acceptable Levels			
Does the predicted risk level meet defined acceptable levels of risk (refer to **Section 5.6**)?	Defined Acceptable Level	Comparison with Predicted Levels of Risk	EPO
	No collision that results in injury marine fauna. The risk of a collision with marine fauna must be ranked Very Low to Medium according to the Santos Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004).	The residual risk of colliding with marine fauna is considered to be Very Low and acceptable. This is due to the low vessel speeds, compliance with Part 8 of the EPBC Regulations and presence of marine fauna observers.	EPO-18

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 as described in **Section 2**) to long-term (in the event of successful translocation).

7.7.2 Nature and Scale of Environmental Impacts

Potential receptors include marine ecosystem as a whole and commercial/recreational users of the marine environment.

IMS are non-indigenous 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). Shallow coastal marine environments in particular, are thought to be amongst the ecosystems most susceptible to the establishment of IMS, which largely reflects the accidental transport of IMS by international shipping to marinas and ports (Commonwealth of Australia 2009; Wells et al. 2009).

Some IMS pose a significant risk to environmental values, biodiversity, ecosystem health, human health, fisheries, aquaculture, shipping, ports and tourism (Wells et al. 2009). IMS 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;
+ Changing the nature of the environment, resulting in an alteration to the structure (species biodiversity and abundance) and the functioning of ecological communities);
+ 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 which can be spread by human mediated or natural means and are likely to survive and establish in the region. 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 invasive marine species being introduced. Hence ports are often areas of higher IMS risk (Neil et al. 2005).

Once established, it is often difficult to eradicate IMS populations, and management options tend to be limited to ongoing control or impact minimisation. Eradication is dependent on environmental conditions and species. For this reason, Commonwealth and State regulatory agencies have implemented increased management requirements in recent years.

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 is linked to the length of time that the vessel has already been operating in Australian waters. If the vessels have been operating outside of Australian waters, the biofouling risk is a combination of the following factors:

+ Location of previous operations;
+ Length of time spent at these location/s; and
+ Completion of hull inspections, cleaning and application of new anti-foulant coating prior to returning to Australian waters.

7.7.3 Environmental Performance Outcomes and Control Measures

Environmental Performance Outcomes relating to this hazard include:

+ No introduction of marine pest species (EPO-21).

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**.

CM Reference	Control measure	Environmental benefit	Potential cost/issues	Evaluation
CM-47	Aquatic Biosecurity Solution 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 Aquatic Biosecurity Solution 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-48	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-49	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-50	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 and Consequence Ranking

Description	
Receptors	Marine Fauna (including Threatened/Migratory/Local fauna) Physical Environment/Habitat Socio-economic receptors
Consequence	III - 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	a – Remote
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 – 107 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 remote.	
Residual risk	The residual risk associated with this hazard is Very Low

7.7.5 ALARP Evaluation

Santos will forward the most current Western Australian Prevention List for Introduced Marine Pests to all vessel operators prior to the survey to ensure they are aware of potential invasive marine pest species and the reporting requirements.

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 Aquatic Biosecurity Solution vessel check tool) to minimise the risk of introduction of a marine pest species.

Completion of the Aquatic Biosecurity Solution 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 Aquatic Biosecurity Solution 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

<table>
<tr><td colspan="2">Is the risk ranked between Very Low to Medium?</td><td colspan="2">Yes – Residual risk is ranked Very Low.</td></tr>
<tr><td colspan="2">Is further information required in the consequence assessment?</td><td colspan="2">No – Potential impacts and risks are well understood through the information available.</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with industry standards, legal and regulatory requirements, including protected matters?</td><td colspan="2">Yes – Management will meet Commonwealth Biosecurity Act 2015, Offshore Installations Biosecurity Guide (DAWR, 2019), National Biofouling Guidance for the Petroleum Industry (Australian Government, 2009) and Australian Ballast Water Management Requirements 2017; and Western Australian Fish Resources Management Act 1994 and DPIRD’s Aquatic Biosecurity Policy (2017).</td></tr>
<tr><td colspan="2">Are control measures and performance standards consistent with the Santos Environmental Management Policy?</td><td colspan="2">Yes – Aligns with the Environmental Management Policy.</td></tr>
<tr><td colspan="2">Are performance outcomes and standards consistent with stakeholder expectations?</td><td colspan="2">Yes – No concerns raised.</td></tr>
<tr><td colspan="2">Are control measures and performance standards such that the impact or risk is considered to be ALARP?</td><td colspan="2">Yes (see ALARP evaluation above).</td></tr>
<tr><td colspan="4">Defined Acceptable Level</td></tr>
<tr><td rowspan="2">Does the predicted risk level meet defined acceptable levels of risk (refer to Section 5.6)?</td><td>Defined Acceptable Level</td><td>Comparison with Predicted Levels of Risk</td><td>EPO</td></tr>
<tr><td>No introduction of an invasive marine species.
The risk of introducing invasive marine species must be ranked Very Low to Medium according to the Santos Offshore Division Environmental Hazard Identification and Assessment Guideline (EA-91-IG-00004).</td><td>The residual risk of introducing invasive marine species is considered to be Very Low and acceptable. This is due to the proposed control measures which comply with Commonwealth and State legislation and are consistent with regulatory and industry guidance.</td><td>EPO-21</td></tr>
</table>

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

The 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 1-2**) 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 Subsurface and Technical Upstream Northern Australia, Timor Leste & PNG 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 Subsurface and Technical Upstream Northern Australia, Timor Leste & PNG	+ 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.

Role	Responsibilities
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.
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 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.

Role	Responsibilities
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	Survey information provided to regulatory authorities and marine users directly affected by planned activities prior to commencement of the survey.
EPO-2	No unplanned interactions with commercial fishers.
EPO-3	Commercial fishing licence holders are no worse off as a result of the seismic survey.
EPO-4	No unplanned interactions with other marine users.
EPO-5	Undertake seismic acquisition in a manner that prevents serious or irreversible impacts to plankton communities or fauna dependent on plankton as a food source within the Operational Area.
EPO-6	No serious or irreversible impacts to listed marine fish (including sharks) due to noise associated with the operation of seismic source, consistent with the MNES Significant Impact Guideline 1.1.
EPO-7	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 source.
EPO-8	No injury to cetaceans due to noise associated with the operation of seismic sources.
EPO-9	No injury to turtles due to noise associated with the operation of seismic sources.
EPO-10	Undertake seismic acquisition in a manner consistent with the Recovery Plan for Marine Turtles in Australia 2017-2027.
EPO-11	No serious or irreversible impact to the sustainability of indicator commercial fish stocks for the following commercial fisheries due to noise associated with the operation of the seismic source: + Commonwealth Northern Prawn Fishery (NPF); + WA Northern Demersal Scalefish Managed Fishery (NDSMF); + WA Mackerel Managed Fishery (MMF) + NT Demersal Fishery (DF); + NT Spanish Mackerel Fishery (SMF); and + NT Offshore Net and Line Fishery (ONLF).
EPO-12	Far-field source levels for the selected seismic source for the Activity are consistent with levels assessed in this EP.
EPO-13	Protect and maintain biological diversity and other natural, cultural and heritage values of the North-west Marine Parks Network and North Marine Parks Network.
EPO-14	Potential cumulative and additive impacts resulting from the Petrel Sub-Basin 3D MSS and other seismic survey operations are identified and reduced as far as reasonably practicable.
EPO-15	Discharges to sea meet legislated permissible discharge requirements.
EPO-16	No unplanned objects, emissions or discharges to sea or air.

Reference	Environmental Performance Outcomes
EPO-17	Emissions to air meet legislated requirements.
EPO-18	No injury to marine fauna during the Activity.
EPO-19	No long-term environmental impact in the event of an unplanned hydrocarbon release to sea.
EPO-20	No unplanned seabed disturbance.
EPO-21	No introduction of marine pest species.

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 demonstrated 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.

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 and following vessel departure (within one week) to the following, so the maritime industry is aware of seismic survey activities: + Australian Maritime Safety Authority (AMSA) Joint Rescue Coordination Centre (JRCC) (minimum two days prior); + Australian Hydrographic Office (AHO) (where practicable minimum four weeks prior); and + the Kimberley Ports Authority (minimum one week prior).	CM-1-EPS-1	Notice to stakeholder	EPO-1 EPO-2 EPO-5
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 EPO-2 EPO-4
		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 phase.	CM-2-EPS-3	Consultation Coordinator contact details provided to relevant persons in all correspondence	
CM-3	Exclusion (safety) zone established to reduce potential for collision or interference with other marine user activities	A minimum 3 nautical mile exclusion zone is defined around the seismic survey vessel and streamers.	CM-3-EPS-1	Stakeholder consultation Vessel communication records	EPO-1 EPO-2 EPO-4

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
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-2 EPO-4 EPO-16 EPO-19
		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-5	Support vessel is present and operational 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 (AIS).	CM-5-EPS-1	Daily vessel report	EPO-2 EPO-4 EPO-16 EPO-19
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-2 EPO-4 EPO-16 EPO-18 EPO-19
CM-7	Vessels fitted with AIS systems and radars, and AIS (virtual or installed) to mark the location of seismic streamer tail buoys.	Support vessels and the seismic survey vessel will be equipped with an automatic identification system (AIS) and radar, and virtual or installed AIS shall be used to mark the location of seismic streamer tail buoys.	CM-7-EPS-1	Written confirmation from vessel contractor that the correct equipment is on-board.	EPO-2 EPO-4 EPO-16 EPO-19

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-8	Concurrent operations planning with relevant commercial fishers	Santos will develop and implement a protocol for communications between survey vessels and fishing vessels.	CM-8-EPS-1	Development of a communication protocol. Documented correspondence with commercial fishing licence holders.	EPO-3
		If requested by a commercial fishing licence holder Santos will provide operational survey plans, commencement and cessation notifications, and daily operational reports. 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	Documented correspondence with commercial fishing licence holders. Completed daily reports, if requested by commercial fishing licence holders	EPO-2 EPO-3
		The Petrel Sub-Basin SW MSS will be acquired between 1 December and 31 March to reduce the interaction with NPF activities.	CM-8-EPS-3	Vessel contractor procedures	
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 the survey 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-3

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		All evidence-based payment claims made by a commercial fishing licence holder that the survey 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 the survey 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-4	Payment invoice	
CM-10	Notices to Department of Defence (DoD)	A notification will be provided to DoD five weeks prior to seismic survey commencement concerning timing of acquisition of the Petrel Sub-Basin SW 3D MSS.	CM-10 EPS-1	Documented correspondence with DoD.	EPO-4
		No seismic acquisition during scheduled military exercises with NAXA (1 Aug – 30 Sept).	CM-10 EPS-1	Vessel contractor procedures align with DoD request.	EPO-4
CM-11	EPBC Regulations (Part 8) for interacting with cetaceans	Vessels 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 the risk of collision with marine fauna including:	CM-11-EPS-1	Vessel 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	EPO-8 EPO-18

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		+ Travel at less than 6 knots within the cautionary zone of a cetacean or turtle (150 m radius for dolphins, 300 m for whales and turtles). + Do not approach closer than the caution zones for dolphins, whales and turtles. + If cetacean or turtle shows signs of disturbance move away at a constant speed less than 6 knots.		Recordable Incident Report and Environmental Performance Report. Vessel Statement of conformance	
		Any vessel strikes with cetaceans will be reported in the National Ship Strike Database.	CM-11-EPS-2	Documented correspondence	
		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-11-EPS-3	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.	
CM-12	Implementation of EPBC Policy Statement 2.1 (Part A):	Implementation of Part A of the EPBC Policy Statement 2.1 with the below cautionary zones observed. Compliance with the following policy statement sections:	CM-12-EPS-1	Completed marine fauna sighting datasheet	EPO-5 EPO-6 EPO-7 EPO-8

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
	+ pre start-up visual observation + Soft start procedures + Start-up delay procedure + Operations procedure + Shut-down procedure + Night-time and low visibility procedures	+ 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 + A4: Compliance and sighting report provided to DoE The following precaution zones will be implemented for cetaceans: + 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: 500 m horizontal radius from the acoustic source.		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 sightings report within 2 months of survey (refer **Section 8.14**). Induction records confirm that vessel crew and survey personnel have been briefed on the implementation requirements of Part A of the EPBC Policy Statement 2.1.	EPO-9 EPO-10 EPO-18
CM-13	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-13-EPS-1	Binoculars and Marine Fauna Sighting Datasheets present	EPO-6 EPO-8 EPO-9 EPO-10 EPO-18
		All vessels note any marine fauna observations and at the time of the sighting communicates findings with the seismic survey vessel.	CM-13-EPS-2	Marine Fauna Sighting Database	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-14	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-14-EPS-1	Vessel POB lists. MFO training and competency records. MFO Report.	EPO-6 EPO-8 EPO-9 EPO-10 EPO-18
		At least one MFO will have >12 months experience on a seismic survey vessel as an MFO in Australian waters.	CM-14-EPS-2	Vessel POB lists. MFO training and competency records.	
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 using the JASCO AASM model to confirm that the far-field horizontal 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 source modelling report.	EPO-12
CM-16	Shutdown procedures for turtles	A 250 m shut-down zone from the operating source will be applied to turtles. The seismic source will be shut-down if a turtle is observed within the 250 m shut-down zone during start-up or full power operation of the seismic source. Power-up of the seismic source will only commence after the turtle(s) are observed to move outside the 250 m shut-down zone, or when	CM-16-EPS-1	Completed marine fauna sighting datasheet Vessel logs with records of all shut down procedures. MFO records/reports (daily, weekly) show that marine fauna interaction procedures are followed during survey	EPO-9

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		30 minutes has lapsed since the last turtle sighting within the 250 m shut-down zone.			
CM-17	No operation of the seismic source within the internesting BIA for flatback turtles during the nesting season.	Santos will not acquire any seismic surveys within the internesting BIA for flatback turtles during the nesting season (peak June to September).	CM-17 EPS-1	Consultation records	EPO-9
CM-18	Management of concurrent seismic surveys within the commercial fisheries.	If concurrent seismic surveys with Petrel are expected within the same commercial fisheries, Santos will: + Consult with the seismic survey operator on ways to minimise interference with relevant commercial fishers. + Provide the survey operator proposed survey plans, 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-18-EPS-1	Consultation records	EPO-2 EPO-3 EPO-14
CM-19	Seismic source separation distance during concurrent surveys: minimum 40 km while operating.	During operation of the seismic sources, a minimum separation distance of 40 km shall be maintained between the Petrel seismic source and a third-party seismic source.	CM-19-EPS-1	Daily operational reports	EPO-6 EPO-8 EPO-9 EPO-14 EPO-18

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-20	General chemical management procedures	Safety data sheet (SDS7F[2]) available for all chemicals to aid in the process of hazard identification and chemical management.	CM-20-EPS-1	Completed inspection checklist	EPO-15 EPO-16
		Chemicals managed in accordance with SDS in relation to safe handling and storage, spill-response and emergency procedures, and disposal considerations.	CM-20-EPS-2		
CM-21	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-21-EPS-1	Completed inspection checklist	EPO-15 EPO-16

[2] Safety Data Sheet (SDS) or Material Safety Data Sheet (MSDS)

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-22	Sewage treatment system	Pursuant to MARPOL Annex IV, vessel has a current International Sewage Pollution Prevention (ISPP) Certificate or equivalent which confirms that required measures to reduce impacts from sewage disposal are in place.	CM-22-EPS-1	Current ISPP certificate or equivalent	EPO-15 EPO-16
		Sewage discharged in accordance with MARPOL Annex IV.	CM-22-EPS-2	Completed inspection checklist	
		Preventive maintenance on sewage treatment equipment is completed as scheduled.	CM-22-EPS-3	Maintenance records	
CM-23	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-23-EPS-1	Completed inspection checklist	EPO-15 EPO-16
		Food waste is disposed in accordance with MARPOL Annex V.	CM-23-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-23-EPS-3	Up-to-date Garbage Record Book	
CM-24	Oily water treatment system	Oily mixtures only discharged to sea in accordance with MARPOL Annex I.	CM-24-EPS-1	Completed inspection checklist Oil record book.	EPO-15 EPO-16
		Preventative maintenance on oil filtering equipment completed as scheduled.	CM-24-EPS-2	Maintenance records or evidence of maintenance in operational reports	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		Pursuant to MARPOL 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-24-EPS-3	Current IOPP certificate or equivalent	
CM-25	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-25-EPS-1	Safety data sheet (SDS) and product supplier supplementary data as required	EPO-15 EPO-16
CM-26	Clean up of oil/ lubricant spills to deck in accordance with vessel Shipboard Oil Pollution Emergency Plan (SOPEP)	Reported spills to deck are cleaned up as per the vessel SOPEP.	CM-26-EPS-1	Incident report details spill clean up	EPO-15 EPO-16
CM-27	Waste incineration managed in accordance MARPOL and Marine Orders as appropriate	Waste incineration managed in accordance with MARPOL Annex VI.	CM-27-EPS-1	Completed waste record book or recording system	EPO-16 EPO-17
CM-28	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-28-EPS-1	Fuel bunkering records	EPO-17
CM-29	Air pollution prevention certification	Pursuant to MARPOL Annex VI, vessel will maintain a current International Air Pollution Prevention (IAPP) Certificate or equivalent which	CM-29-EPS-1	Current IAPP certificate or equivalent	EPO-16 EPO-17

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		confirms that measures to prevent ozone-depleting substance (ODS) emissions, and reduce NOx, SOx and incineration emissions during the Activity are in place.			
CM-30	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-30-EPS-1	Completed ODS record book or recording system	EPO-16 EPO-17
CM-31	All vessel engines to be maintained in accordance with manufacturers specifications	Documented maintenance program is in place for equipment on vessels, that provides a status on the maintenance of equipment.	CM-31-EPS-1	Vessel maintenance records show that there are no outstanding maintenance activities for emission generating equipment.	EPO-16 EPO-17
CM-32	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	IFO and HFO will not be used as the fuel source during the survey.	CM-32-EPS-1	Vessel operational logs	EPO-16 EPO-19
		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-32-EPS-2	Completed risk assessment.	
		IFO and/or HFO stored on a vessel must not be stored in tanks that are against the external hull of the vessel.	CM-32-EPS-3	Vessel operational logs	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
	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.				
CM-33	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-33-EPS-1	Completed incident documentation	EPO-19
CM-34	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-34-EPS-1	Approved SMPEP or SOPEP	EPO-16 EPO-19
		SMPEP/SOPEP spill response exercises conducted not less often than every three months to ensure personnel are prepared.	CM-34-EPS-2	Spill exercise records or evidence of a spill exercise in an operational report	
CM-35	Maximum volume of fuel stored in a single tank of vessels used for the Activity will not exceed 1,062 m^3	The maximum volume of MGO/MDO stored in a single tank shall not exceed 1,062 m^3.	CM-35-EPS-1	Written directive to vessel contractor	EPO-19
CM-36	Maritime dangerous goods code	Dangerous goods managed in accordance with International Maritime Dangerous Goods Code (IMDG Code) to reduce the risk of an	CM-36-EPS-1	Completed Multimodal Dangerous Goods Form	EPO-15 EPO-16
				Completed inspection checklist	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		environmental incident, such as an accidental release to sea or unintended chemical reaction.			
CM-37	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-37-EPS-1	Weekly environmental inspection checklist	EPO-16
CM-38	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.	CM-38-EPS-1	Completed procedural documents, for example work permits, job safety analysis forms, checklists, etc. Spill details contained in incident documentation.	EPO-16

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		+ 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-39	Undertake bunkering / bunkering drill prior to the Activity.	Bunkering drill undertaken by seismic survey vessel prior to arrival in the Operational Area, unless bunkering completed within the previous three months in Australian waters.	CM-39-EPS-1	Vessel logs record bunkering undertaken.	EPO-16
CM-40	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-40-EPS-1	Completed inspection checklist	EPO-16 EPO-20
		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-40-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-40-EPS-3	Vessel PMS schedule and maintenance records	

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
		Lifting equipment maintained and certified.	CM-40-EPS-4	Lifting equipment certification valid and current	
CM-41	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-41-EPS-1	Vessel equipment maintenance records show that there are no outstanding maintenance activities for equipment.	EPO-16 EPO-20
CM-42	Streamers are fitted with floatation devices	Solid-filled seismic streamer contains buoyancy devices and is fitted with marker buoys.	CM-42-EPS-1	End of survey report provides diagrams and report of streamers	EPO-16 EPO-20
CM-43	Streamer deployment / retrieval procedure	Seismic streamers undergo regular inspection, at least every 7 days weather permitting, and planned maintenance system checks on streamer towing systems for wear and damaged components. These components are replaced on an 'as required' basis.	CM-43-EPS-1	Seismic streamers maintenance log	EPO-16 EPO-20
		A secondary retaining/ attachment device is utilised.	CM-43-EPS-2	End of survey report provides diagrams and report of streamers	
		Vessel crew involved in streamer deployment/retrieval are trained in the requirements of the procedures for streamer deployment and retrieval.	CM-43-EPS-3	Training records	
CM-44	Streamer towing depth	Streamers are towed at least 10 m above the seabed to avoid seabed disturbance.	CM-44-EPS-1	Streamer deployment procedure includes streamers must be towed at a minimum of 10m above the seabed.	EPO-20
CM-45	Streamers have locating devices fitted	Deployed streamers will be fitted with locating devices and tracked on the seismic survey vessel.	CM-45-EPS-1	Vessel streamer specifications	EPO-20

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
				Streamer location tracking on boarding vessel.	
CM-46	Use of turtle guards / a 'turtle friendly' tail buoy	Tail buoys on the streamers will be fitted with turtle guards or be of another design that to minimise the risk of entrapment of marine fauna.	CM-46-EPS-1	Vessel streamer specifications	EPO-9 EPO-18
CM-47	Aquatic Biosecurity Solution vessel check tool (applied to vessels), and immersible equipment clean.	Vessels to be risk assessed using the Aquatic Biosecurity Solution vessel check tool demonstrating vessel is at 'low risk' of introducing invasive marine species.	CM-47-EPS-1	Completed Aquatic Biosecurity Solution vessel check report demonstrating vessel are low risk.	EPO-21
		Immersible equipment to be cleaned to 'low risk' of introducing invasive marine species if being deployed to sea during the Activity.	CM-47-EPS-2	Verification that immersible equipment was cleaned to low risk (e.g. photos, inspection reports)	
		Vessel operators will be provided with the most current Western Australian Prevention List for Introduced Marine Pests to ensure they are aware of potential invasive marine pest species and the reporting requirements.	CM-47-EPS-3	Verification that current Western Australian Prevention List has been provided to vessel operators.	
CM-48	Anti-foulant system	Anti-foulant systems are maintained in compliance with International Convention on the Control of Harmful Anti-Fouling Systems on Ships.	CM-48-EPS-1	Current International Anti-Fouling System Certificate.	EPO-21
CM-49	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-49-EPS-1	Written evidence that the seismic survey vessel meets the requirements set out in the Determination.	EPO-21

CM Reference	Control measure	Environmental Performance Standards	EPS Reference	Measurement criteria	EPO Reference
CM-50	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; + Duties of officers and crew; + Coordination with local authorities; and + Record keeping.	CM-50-EPS-1	Administrator-approved ballast water management plan. Completed ballast water record book or log	EPO-21
CM-51	Recreational fishing restrictions	Seismic survey and support vessels within the Operational Area are prohibited from fishing.	CM-51-EPS-1	No recorded breaches Environment induction	EPO-11
CM-52	Activity assurance reviews	If a survey has not been conducted within 6 months of the EP acceptance, 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 acceptable and ALARP for the duration of this EP.	CM-52-EPS-1	Completed assurance review	All

Santos

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 six 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 eight months of the survey stage completion. The eight 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 six 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 six months following completion of the survey for fishers to lodge claims is appropriate. In addition, beyond six 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, Richardson et al. (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 4**.

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 8.10**), such as new management plans or conservation advice. If new information is identified, this is treated as "Change that has an impact on Environment Plan" as show 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.

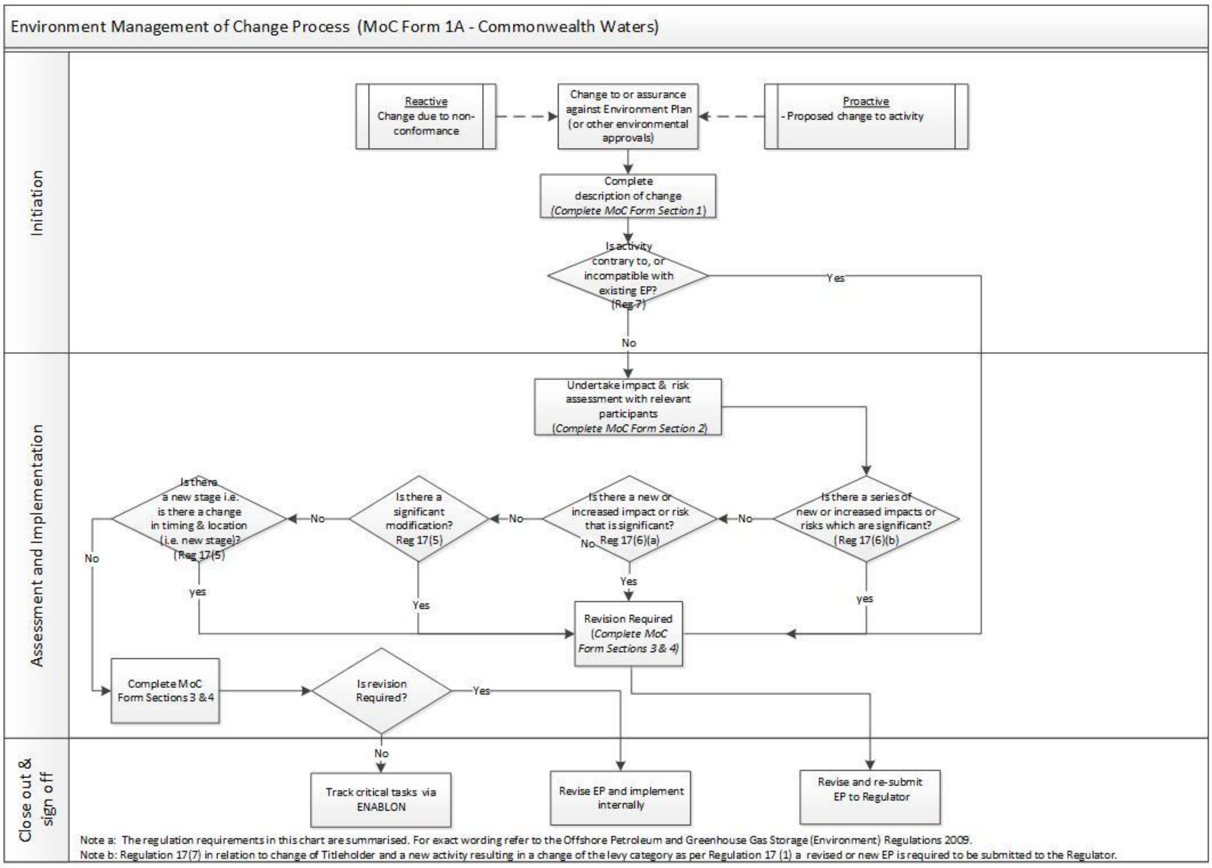


Figure 8-1: Environment Management of Change Process

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 Petrel Sub-Basin SW 3D Marine Seismic Survey Oil Pollution Emergency Plan (SO-91-RI-20090.01) 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 E**)).

Reportable 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

In accordance with Regulation 14(2) of the OPGGS (E) Regulations, an environmental performance report will be submitted to NOPSEMA at least annually. The reporting period will commence from the day of environment plan acceptance. A final environmental performance report will be submitted within 3 months of the end of the activity providing this reporting timeframe is not more than 1 year from the previous environmental performance report. Reports will meet the requirements of Regulation 26(C). These 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.

Table 8-4: **Regulator Activity Notification and Reporting Requirements**

Regulation	Requirement	Required Information	Timing	Type	Recipient
Before the Activity					
Regulation 29 and 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
N/A	Department of Defence (DoD)		5 weeks prior to Activity commencement.	Written	DoD
Department of Agriculture, Compliance Division	Voluntary biosecurity risk assessment under the Biosecurity Act 2015	In the event a vessel contractor is unable to conduct an independent biosecurity risk assessment, then the department will work with installation representatives to assess the biosecurity risk of the installation and associated support conveyances (vessels and aircraft. To have risk status assessed, offshore installation projects must apply to the department at least one month prior to project commencement.	At least one month before the survey as practicable.	Written	DoA
During the Activity					
Regulation 16(c), 26 and 26A – Reportable Incident	NOPSEMA must be notified of any reportable incidents. For the purposes of Regulation 16(c), a reportable incident is defined as:	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	As soon as practicable, and in any case not later than 2 hours after the first occurrence of a reportable incident, or if the incident was not detected at the time of the first occurrence, at the	Oral	NOPSEMA

Regulation	Requirement	Required Information	Timing	Type	Recipient
	+ 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. Any ship strike incident will also be reported to the National Ship Strike database.	+ The corrective action that has been taken, or is proposed to be taken, to sop, control or remedy the reportable incident.	time of becoming aware of the reportable incident.		
		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
		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:	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

Regulation	Requirement	Required Information	Timing	Type	Recipient
		https://data.marinemammals.gov.au/report/shipstrike			
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 + contact details for the response coordinator. Notification made to the Marine Compliance Duty Officer on 0419 293 465.	Within 24 hours	Oral	Director of National Parks
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;	A written report must contain: + Incident details (date and time); + Location; + Type of incident; + Incident description; + Vessels involved; + Persons involved; and + 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

Regulation	Requirement	Required Information	Timing	Type	Recipient
	+ 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.				
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 incidents of entanglement.	Within 48 hours.	Written	DBCA
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 14(2) and 26C Environmental Performance. Refer to Section 8.14.	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.	In accordance with Regulation 14(2), a detailed environmental performance report will be submitted at least annually.	Written	NOPSEMA

Regulation	Requirement	Required Information	Timing	Type	Recipient
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) and 26C – Environmental Performance. Refer to Section 8.14.	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.	Final environmental performance report submitted within 3 months of the end of the activity providing this reporting time frame is not more than 1 year from the previous environmental performance report.	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

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 two-year EP, it is recognised that the following parameters 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; and
+ 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, if a survey has not been conducted within six months of the EP acceptance, 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 8.16.2**, 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 4**;
+ 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 4**); 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.

9 References

[ABARES] Australian Bureau of Agricultural and Resource Economics and Sciences 2018. Fishery Status Reports 2018. Available at: http://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/fsr2018.pdf.

[AFMA] Australian Fisheries Management Authority 2018a. Fisheries Management: Western Tuna and Billfish Fishery. Available at: https://www.afma.gov.au/fisheries/western-tuna-and-billfish-fishery.

[AFMA] Australian Fisheries Management Authority 2018b. Fisheries Management: Southern Bluefin Tuna Fishery. Available at: https://www.afma.gov.au/fisheries/southern-bluefin-tuna-fishery.

[AFMA] Australian Fisheries Management Authority 2018c. Fisheries Management: Western Skipjack Fishery. Available at: https://www.afma.gov.au/fisheries/skipjack-tuna-fishery.

[AFMA] Australian Fisheries Management Authority 2018d. Fisheries Management: Northern Prawn Fishery. Available at: https://www.afma.gov.au/fisheries/northern-prawn-fishery.

[AFMA] Australian Fisheries Management Authority, 2018d. Fisheries Management: Northern Prawn Fishery. Available at: https://www.afma.gov.au/fisheries/northern-prawn-fishery.

[AFMA] Australian Fisheries Management Authority, 2021a. Northern Prawn Fishery. Available at https://www.afma.gov.au/fisheries/northern-prawn-fishery.

[AFMA] Australian Fisheries Management Authority, 2021b. Northern Prawn Fishery Directions and Closures 2021. Canberra, Australia.

[AMSA] Australian Maritime Safety Authority, 2015. *Technical Guidelines for the preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities.* Available at: https://www.amsa.gov.au/sites/default/files/2015-04-np-gui012-contingency-planning.pdf.

[BoM] Bureau of Meteorology 2019a. Climatology of Tropical Cyclones in Western Australia. Available at: http://www.bom.gov.au/cyclone/climatology/. Viewed on 8 October 2019.

[BoM] Bureau of Meteorology, 2019b. Climate Statistics for Australian Locations – Dum In Mirrie Airstrip. Available at: http://www.bom.gov.au/climate/averages/tables/cw_014253.shtml. Viewed on 8 October 2019.

[BoM] Bureau of Meteorology, 2019c. Climate Statistics for Australian Locations – Channel point. Available at: http://www.bom.gov.au/climate/averages/tables/cw_014277.shtml. Viewed on 8 October 2019.

[BoM] Bureau of Meteorology, 2019d. Climate Statistics for Australian Locations – Port Keats Airport. Available at: http://www.bom.gov.au/climate/averages/tables/cw_014948.shtml. Viewed on 8 October 2019.

[BoM] Bureau of Meteorology, 2019e. Climate Statistics for Australian Locations – Truscott. Available at: http://www.bom.gov.au/climate/averages/tables/cw_001020.shtml. Viewed on 8 October 2019.

[BoM] Bureau of Meteorology, 2019f. Tide Predictions for Australia, South Pacific and Antarctica – Rocky Island. Available at: http://www.bom.gov.au/australia/tides/. Viewed on 8 October 2019.

[CALM] Department of Conservation and Land Management, 2005. Indicative Management Plan for the proposed Dampier Archipelago Marine Park and Cape Preston marine management area, Department of Conservation and Land Management, Perth, Australia. 145 pp.

[CSIRO] Commonwealth Scientific and Industrial Research Organisation, 2005. Collation and Analysis of Oceanographic Datasets for National Marine Bioregionalisation. The Northern Large Marine Domain. Available at: https://www.environment.gov.au/system/files/resources/51abf1da-40b7-4513-8fad-b4537e1fac62/files/nmb-northern-domain.pdf.

[DAFF] Department of Agriculture, Fisheries and Forestry, 2011. Fishery status reports 2011. Research by the Australian Bureau of Agricultural and Resource Economics and Sciences, published 2012.

[DAWE] Department of Agriculture, Water and the Environment, 2021. Continental shelf and demersal fish communities. Commonwealth of Australia 2021. Available at: https://www.environment.gov.au/sprat.

[DAWR] Department of Agriculture and Water Resources, 2017. Australian Ballast Water Management Requirements. Version 7. Available at: http://www.agriculture.gov.au/SiteCollectionDocuments/biosecurity/avm/vessels/ballast/australian-ballast-water-management-requirements.pdf.

[DEWHA] Department of the Environment, Water, Heritage and the Arts, 2008a. The North Marine Region Bioregional Plan Bioregional Profile. Commonwealth of Australia.

[DEWHA] Department of the Environment, Water, Heritage and the Arts 2008b. The North-west Marine Region Bioregional Plan Bioregional Profile. Commonwealth of Australia.

[DFO] Department of Fisheries and Oceans, 2004. Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals. Canadian Science Advisory Secretariat (CSAS), Habitat Status Report 2004/002, 15 pp.

[DNREAS] Department of Natural Resources, Environment, the Arts and Sport, 2009. Sites of conservation significance: the Tiwi Islands. Northern Territory Government. Available at: https://web.archive.org/web/20090922200131/http://nt.gov.au/nreta/environment/conservation/pdf/09_tiwi.pdf.

[DoD] Department of Defence, 2019. Unexploded Ordnance (UXO) Mapping Application. Available at: http://www.defence.gov.au/UXO/Where/.

[DoE] Department of the Environment, 2010. Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Seasnake). Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1115-conservation-advice.pdf.

[DoE] Department of the Environment, 2013. Approved Conservation Advice for *Rostratula Australia* (Australian painted snipe). Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=77037.

[DoE] Department of the Environment, 2014a. Approved Conservation Advice for *Glyphis garricki* (northern river shark). Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/82454-conservation-advice.pdf.

[DoE] Department of the Environment, 2014b. Approved Conservation Advice for *Pristis pristis* (largetooth sawfish). Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/60756-conservation-advice.pdf.

[DoE] Department of the Environment, 2014c. Approved Conservation Advice for *Glyphis glyphis* (speartooth shark). Available at: http://environment.gov.au/biodiversity/threatened/species/pubs/82453-conservation-advice.pdf.

[DOE] Department of the Environment, 2015a. *Balaenoptra edeni* in Species Profile and Threats Database. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=35.

[DoE] Department of the Environment, 2015a. Conservation Advice: *Megaptera novaeangliae* humpback whale. Threatened Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/38-conservation-advice-10102015.pdf.

[DoE] Department of the Environment, 2015b. Conservation Management Plan for the Blue Whale—A Recovery Plan under the Environment Protection and Biodiversity Conservation Act 1999. Available at: https://www.environment.gov.au/system/files/resources/9c058c02-afd1-4e5d-abff-11cac2ebc486/files/blue-whale-conservation-management-plan.pdf

[DOE] Department of the Environment, 2015b. *Dermochelys coriacea* (Leatherback Turtle). Species Profile and Threats Database. Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1768.

[DoE] Department of the Environment, 2015c. Conservation Advice *Balaenoptera borealis* sei whale. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/34-conservation-advice-01102015.pdf.

[DoE] Department of the Environment, 2015d. Conservation Advice *Balaenoptera physalus* fin whale. Threatened Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/37-conservation-advice-01102015.pdf

[DoE] Department of the Environment, 2015e.Conservation Advice *Rhincodon typus* (whale shark). Threatened Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/66680-conservation-advice-01102015.pdf.

[DoE] Department of the Environment, 2015f. Sawfish and River Sharks Multispecies Recovery Plan. Canberra, ACT: Commonwealth of Australia. Available at: http://www.environment.gov.au/biodiversity/threatened/publications/recovery/sawfish-river-sharks-multispecies-recovery-plan.

[DoE] Department of the Environment, 2015g. Conservation Advice: *Numenius madagascariensis* eastern curlew. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/847-conservation-advice.pdf.

[DoE] Department of the Environment, 2015h. Conservation Advice *Calidris ferruginea* curlew sandpiper. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/856-conservation-advice.pdf.

[DoE] Department of the Environment, 2015i. Conservation Advice: for *Anous tenuirostris melanops* (Australian lesser noddy). Threatened Scientific Committee. Available at:

http://www.environment.gov.au/biodiversity/threatened/species/pubs/38-conservation-advice-10102015.pdf.

[DoE] Department of the Environment, 2015j. Conservation Advice: for *Erythrotriorchis radiates* (red goshawk). Threatened Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/942-conservation-advice-31102015.pdf.

[DoE] Department of the Environment, 2015k. Wildlife Conservation Plan for Migratory Shorebirds. Available at: http://www.environment.gov.au/system/files/resources/9995c620-45c9-4574-af8e-a7cfb9571deb/files/widlife-conservation-plan-migratory-shorebirds.pdf.

[DoE] Department of the Environment, 2016a. Conservation Advice *Limosa lapponica baueri* (bar-tailed godwit northern Siberian). Threatened Species Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/86380-conservation-advice-05052016.pdf.

[DoE] Department of the Environment, 2016b. Conservation Advice *Limosa lapponica menzbierri* (bar-tailed godwit western Alaskan). Threatened Species Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/86432-conservation-advice-05052016.pdf.

[DoE] Department of the Environment, 2016c. Conservation Advice *Calidris canutus* Red knot. Threatened Species Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/855-conservation-advice-05052016.pdf.

[DoE] Department of the Environment, 2016d. Conservation Advice *Calidris tenuirostris* (Great Knot). Threatened Species Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/855-conservation-advice-05052016.pdf.

[DoE] Department of the Environment, 2016e. Conservation Advice *Charadrius mongolus (*lesser sand plover) Threatened Species Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/879-conservation-advice-05052016.pdf.

[DoE] Department of the Environment, 2016f. Conservation Advice *Charadrius leschenaultia (*greater sand plover) Threatened Species Scientific Committee. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/877-conservation-advice-05052016.pdf.

[DoEE] Department of the Environment and Energy 2019a. SPRAT Profile http://www.environment.gov.au/cgi-bin/sprat/public/sprat.

[DoEE] Department of the Environment and Energy, 2016. National strategy for mitigating vessel strike of marine fauna. Commonwealth of Australia 2016.

[DoEE] Department of the Environment and Energy, 2017. Recovery Plan for Marine Turtles in Australia. Available at: http://www.environment.gov.au/system/files/resources/46eedcfc-204b-43de-99c5-4d6f6e72704f/files/recovery-plan-marine-turtles-2017.pdf.

[DoEE] Department of the Environment and Energy, 2019b. Pinnacles of the Bonaparte Basin. Species Profile and Threats Database. Available at: https://environment.gov.au/sprat-public/action/kef/view/62.

[DoEE] Department of the Environment and Energy, n.d. Marine Bioregional Plans. Commonwealth of Australia. Canberra. Available at: https://www.environment.gov.au/marine/marine-bioregional-plans.

[DoEE] Department of the Environment and Energy. n.d.g. Australian National Heritage List. Available at: https://www.environment.gov.au/heritage/places/national-heritage-list.

[DoF] Department of Fisheries (WA), 2013. Guidance Statement for Oil and Gas Industry Consultation with the Department of Fisheries. Fisheries Occasional Publication No. 113, 2013.

[DoF] Department of Fisheries, 2015a. Assessment of the status of red emperor (Lutjanus sebae) and goldband snapper (*Pristipomoides multidens*) in the Northern Demersal Scalefish Fishery. Government of Western Australia. September 2015.

[DoF] Department of Fisheries, 2015b. Harvest Strategy Policy and Operational Guidelines for the Aquatic Resources of Western Australia. Fisheries Management Paper No. 271. Government of Western Australia, June 2015.

[DNP] Director of National Parks, 2018a. North-west Marine Parks Network Management Plan 2018. Commonwealth of Australia, 2018.

[DNP] Director of National Parks, 2018b. North Marine Parks Network Management Plan 2018. Commonwealth of Australia, 2018.

[DPAW] Department of Parks and Wildlife, 2014. WA Oiled Wildlife Response Plan Available at: https://www.dpaw.wa.gov.au/images/documents/conservation-management/marine/wildlife/West_Australian_Oiled_Wildlife_Response_Plan_V1.1.pdf.

[DPaW] Department of Parks and Wildlife, 2016a. Proposed North Kimberley Marine Park indicative joint management plan 2016. Department of Parks and Wildlife, Perth.

[DPaW] Department of Parks and Wildlife, 2016b. North Kimberley Marine Park joint management plan 2916 Uunguu, Balanggarra, Miriuwug and Wilinggin management areas. Plan No. 89, Department of Parks and Wildlife, Perth.

[DPIR] Department of Primary Industry and Resources, 2016. NT Fisheries. Status of Key Northern Territory Fish Stocks Report 2016. Fishery Report No. 119. Available at: https://dpir.nt.gov.au/__data/assets/pdf_file/0007/546640/FR119.pdf.

[DPIR] Department of Primary Industry and Resources, 2018. NT Fisheries. Management Arrangements for the Northern Territory Offshore Net and Line Fishery. Available at: Available at: https://dpir.nt.gov.au/__data/assets/pdf_file/0017/620432/mgt-arranagements-offshore-net-line-fishery.pdf.

[DPIR] Department of Primary Industry and Resources, 2019a. NT Fisheries. Demersal Fishery and Licences. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/demersal-fishery-and-licences.

[DPIR] Department of Primary Industry and Resources, 2019b. NT Fisheries. Spanish Mackerel Fishery and Licences. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/spanish-mackerel-fishery-and-licences.

[DPIR] Department of Primary Industry and Resources, 2019c. NT Fisheries. Offshore Net and Line Fishery. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/offshore-net-and-line-fishery.

[DPIR] Department of Primary Industry and Resources, 2019d. NT Fisheries. Pearl Oyster Fishery. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/pearl-oyster-industry.

[DPIR] Department of Primary Industry and Resources, 2019e. NT Fisheries. Aquarium Fishery and Licences. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/aquarium-fishery-and-licences.

[DPIR] Department of Primary Industry and Resources, 2019f. Status of key Northern Territory fish stocks report 2017. Fishery report no. 121. Available at: https://dpir.nt.gov.au/__data/assets/pdf_file/0005/744278/FR121.pdf. Accessed on 15 April 2020.

[DPIRD] Department of Primary Industries and Regional Development, 2019. Finfish Spawning Table for some Key Species – Updated 5 June 2019. Perth, Western Australia

[DPIRD] Department of Primary Industries and Regional Development, 2017. North coast demersal scalefish resource harvest strategy 2017-2021, Version 1.0. Fisheries Management Paper No. 285. Perth, Western Australia.

[DPIRD] Department of Primary Industries and regional Development, 2018. Commercial Fishing Guide. Available at https://www.fish.wa.gov.au/Fishing-and-Aquaculture/Commercial-Fishing/Pages/Commercial-Fishing-Guide.aspx. Accessed 10 October 2019.

[DPIRD] Department of Primary Industries and Regional Development. 2017. Aquatic Biosecurity Policy. Available at https://www.fish.wa.gov.au/Documents/biosecurity/aquatic_biosecurity_policy.pdf.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2010. Approved Conservation Advice for *Aipysurus foliosquama* (Leaf-scaled seasnake). Commonwealth of Australia, Canberra. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1118-conservation-advice.pdf.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012a. Marine bioregional plan for the North-west Marine Region. Department of Sustainability Environment, Water, Population and Communities. Commonwealth of Australia. Canberra.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities 2012b. Marine Bioregional Plan for the North Marine Region. Department of Sustainability Environment, Water, Population and Communities. Commonwealth of Australia. Canberra.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities 2012c Species group report card – Marine Reptiles. Supporting the marine bioregional plan for the North Marine Region

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities 2012d. Species group report card – cetaceans. Supporting the marine bioregional plan for the North Marine Region

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012e Species group report card – seabirds. Commonwealth of Australia, 2012.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012f. Species group report card – seabirds and migratory shorebirds. Commonwealth of Australia, 2012.

[ERM] Environmental Resources Management, 2011. GDF SUEZ – Marine Baseline Survey and Ecological Assessment. Report prepared for GDF SUEZ LNG, Perth, Western Australia.

[ERM] Environmental Resources Management, 2012. Marine Environmental Baseline Study: Field Survey Report. 0119757, Rev 1, July 2012, Final. Report prepared for PTTEP AA.

[ERM] Environmental Resources Management, 2017. Bethany 3D Survey Environment Plan - Seismic Airguns and Fish Mortality Literature Review. Final Report to Santos, Reference No. 0436696. 1 December 2017. 39 pp.

[FRDC] Fisheries Research & Development Corporation, 2019. Status of Australian Fish Stocks Reports.

[FRDC] Fisheries Research & Development. 2021, Grey Mackerel *Scomberomorus semifasciatus.* Available at: https://fish.gov.au/report/397-Grey-Mackerel-2020.

[FRDC] Fisheries Research and Development Council, 2018. Seafood Assessment Report, Northern Territory Demersal Fishery. Available at: http://whichfish.com.au/wp-content/uploads/sites/4/2018/02/FRDC-SRA-NT-DF-Feb-2018.pdf.

[HESS] High Energy Seismic Survey, 1999. High energy seismic survey review process and interim operational guidelines for marine surveys offshore Southern California. Prepared for The California State Lands Commission and The United States Minerals Management Service Pacific Outer Continental Shelf Region. Camarillo, California: High Energy Seismic Survey Team.

[ITOPF] International Tanker Owners Pollution Federation, 2011. Effects of Oil Pollution on the Marine Environment. Technical Information Paper. Technical paper No. 13. The International Tank Owners Pollution Federation Limited.

[MPRA] Marine Parks and Reserves Authority, 2005. Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area 2005 – 2015. Marine Parks and Reserves Authority, Perth, Western Australia.

[NLPG] Commonwealth of Australia, 2020. National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds. Commonwealth of Australia 2020

[NMFS] National Marine Fisheries Service, 2001 - Fisheries Statistics and Economics Division, Silver Spring, MD.

[NMFS] National Marine Fisheries Service, 2014. Marine Mammals: Interim Sound Threshold Guidance (webpage). National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

[NMFS] National Marine Fisheries Service, 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55. 189 pp.

[NMFS] National Marine Fisheries Service, 2018. 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 pp.

[NMFS] National Marine Fisheries Service, 2019. Endangered Species Conservation Section 7 Consultation Tools for Marine Mammals on the West Coast: Marine Mammal Acoustic Thresholds. Available online: https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west Accessed 31st July 2020.

[NMSC] The Australian National Marine Safety Committee, 2010. Marine Incidents during 2009. Preliminary Data Analysis. A WWW database accessed during July 2012 at http://www.nmsc.gov.au

[NNTT] National Native Title Tribunal, 2019, Representative Aboriginal/Torres Strait Island Body Areas. Available at: http://www.nntt.gov.au/Maps/RATSIB_map.pdf.

[NOAA] National Oceanic and Atmospheric Administration (US), 2019. ESA Section 7 Consultation Tools for Marine Mammals on the West Coast (webpage), 27 Sep 2019. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west. Accessed 10 March 2020.

[NOAA] National Oceanic and Atmospheric Administration, 2010. Oil and Sea Turtles: Biology Planning and Response, US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Response and Restoration, pp. 116.

[NOPSEMA] The National Offshore Petroleum Safety and Environmental Management Authority, 2014. Consultation requirements under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. N-04750-IP1411. Rev 2. December 2014. Available at: https://www.nopsema.gov.au/assets/Information-papers/A347285.pdf

[NOPSEMA] The National Offshore Petroleum Safety and Environmental Management Authority, 2019. Bulletin #1 Oil Spill Modelling, April 2019. Available at https://www.nopsema.gov.au/assets/Bulletins/A652993.pdf

[NSF] National Science Foundation (U.S.), U.S. Geological Survey, and [NOAA] National Oceanic and Atmospheric Administration (U.S.), 2011. Final Programmatic Environmental Impact Statement/Overseas. Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey. National Science Foundation, Arlington, VA.

[NTG] Northern Territory Government, 2014. Fishery Status Reports 2012. Northern Territory Government Department of Primary Industry and Fisheries. Fishery Report No. 113.

[NTSC] Northern Territory Seafood Council, 2017. Aquarium fishery. Available at https://www.ntsc.com.au/content/about-our-fisheries/aquarium.

[WA EPA] Environmental Protection Authority, 2010. Environmental Assessments Guidelines for protecting marine turtles from light impacts. Western Australia.

[WAFIC] Western Australian Fishing Industry Council. 2019. Beche-De-Mer Fishery. North coast bioregion. Available at: https://www.wafic.org.au/fishery/beche-de-mer-fishery/.

Abdul Wahab, M.A., Radford, B., Cappo, M., Colquhoun, J., Stowar, M., Depczynski, M., Miller, K. and Heyward, A., 2018. Biodiversity and spatial patterns of benthic habitat and associated demersal fish communities at two tropical submerged reef ecosystems. Coral Reefs. 37. 327-343. https://doi.org/10.1007/s00338-017-1655-9

Aerts, L., Blees, M., Blackwell, S., Greene, C., Kim, K., Hannay, D.E. and Austin, M., 2008. Marine mammal monitoring and mitigation during BP Liberty OBC seismic survey in Foggy Island Bay, Beaufort Sea, July-August 2008: 90-day report. Document Number LGL Report P1011-1. Report by LGL Alaska Research Associates Inc., LGL Ltd., Greeneridge Sciences Inc. and JASCO Applied Sciences for BP Exploration Alaska. 199 pp. http://www.nmfs.noaa.gov/pr/pdfs/permits/bp_liberty_monitoring.pdf.

Allen, G.R. and Talbot, J.H., 1985. Review of the snappers of the genus *Lutjanus* (Pisces Lutjanidae) from the Indo-Pacific with the description of a new species. Indo-Pac. Fish. (11):87.

Allen, G.R., 2000. Personal communication – referenced in the Species Profile and Threats Database for the Pristis pristis — Freshwater Sawfish.

Amoser, S. and Ladich, F., 2003. Diversity in noise-induced temporary hearing loss in otophysine fishes. Journal of the Acoustical Society of America 113: 2170–2179.

Anderson, T.J., Nichol, S., Radke, L., Heap, A.D., Battershill, C., Hughes, M., Siwabessy, P.J., Barrie, V., Alvarez de Glasby, B., Tran, M., Daniell, J., Shipboard Party, 2011. Seabed environments of the eastern Joseph Bonaparte Gulf, northern Australia: GA0325/Sol5117-post survey report, record 2011/08, Geoscience Australia, Canberra.

Andriguetto-Filho, J.M., Ostrensky, A., Pie, M.R., Silva, U.A., Boeger, W.A., 2005. Evaluating the impact of seismic prospecting on artisanal shrimp fisheries. Continental Shelf Research 25(14): 1720-1727.

AS/NZS ISO 31000 Risk Management – Guidelines. 2018.

Austin, D. and Pollom, R., 2019. The IUCN Red List of Threatened Species 2019. http://www.iucnredlist.org/ viewed 5/04/2019.

Austin, M. and Bailey, L., 2013. Sound Source Verification: TGS Chukchi Sea Seismic Survey Program 2013. Document Number 00706, Version 1.0. Technical report by JASCO Applied Sciences for TGS-NOPEC Geophysical Company.

Austin, M. and Li, Z., 2016. Marine Mammal Monitoring and Mitigation During Exploratory Drilling by Shell in the Alaskan Chukchi Sea, July–October 2015: Draft 90-day report. In: Ireland, D.S. and L.N. Bisson (eds.). Underwater Sound Measurements. LGL Rep. P1363D. Report from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. For Shell Gulf of Mexico Inc., National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 188 pp + appendices pp.

Austin, M. and Warner, G., 2012. Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey. Version 2.0. Technical report for Fairweather LLC and Apache Corporation by JASCO Applied Sciences Ltd.

Austin, M., 2014. Underwater noise emissions from drillships in the Arctic. Underwater Acoustics 2014. Rhodes, Greece.

Austin, M., McCrodan, A., O'Neill, C., Li, Z. and MacGillivray, A.O., 2013. Marine mammal monitoring and mitigation during exploratory drilling by Shell in the Alaskan Chukchi and Beaufort Seas, July–November 2012: 90-Day Report. In: Funk, D.W., C.M. Reiser, and W.R. Koski (eds.). Underwater Sound Measurements. LGL Rep. P1272D–1. Report from LGL Alaska Research Associates Inc. and JASCO Applied Sciences, for Shell Offshore Inc., National Marine Fisheries Service (US), and U.S. Fish and Wildlife Service. 266 pp plus appendices.

Austin, M.A., Yurk, H. and Mills, R., 2015. Acoustic Measurements and Animal Exclusion Zone Distance Verification for Furie's 2015 Kitchen Light Pile Driving Operations in Cook Inlet. Version 2.0. Technical report for Jacobs LLC and Furie Alaska by JASCO Applied Sciences.

Australian Government, 2009. National Biofouling Guidance for the Petroleum Industry. Marine Pests, Commonwealth of Australia.

Australian Museum, 2014. Manta Ray, Manta birostris (Walbaum, 1792) http://australianmuseum.net.au/Manta-Ray-Manta-birostris

Baker, C., Potter, A., Tran, M. and Heap, A.D., 2008. Geomorphology and sedimentology of the North-west Marine Region of Australia., record 2008/07, Geoscience Australia, Canberra.

Begg, G.A., Chen, C.C.-M., O'Neill, M.F. and Rose, D.B., 2006. Stock assessment of the Torres Strait Spanish mackerel fishery. CRC Reef Research Centre Technical Report No. 66. CRC Reef Research Centre, Townsville, Queensland.

Berry, O., England, P., Marriott, R.J., Burridge, C.P. and Newman S.J., 2012. Understanding age-specific dispersal in fishes through hydrodynamic modelling, genetic simulations and microsatellite DNA analysis. Molecular Ecology, 21, 2145–2159, doi:10.1111/j.1365-294X.2012.05520.x.

Bertrand, A. and Josse, E., 2000. Tuna target-strength related to fish length and swimbladder volume. ICES Journal of Marine Science 57: 1143-1146.

Best, P.B., Butterworth, D.S. and Rickett, L.H., 1984. An Assessment Cruise for the South African Inshore Atock of Bryde's Whales (*Balaenoptera edeni*). Report of the International Whaling Commission. vol. 34, pp. 403-423.

BirdLife International, 2019a. Species factsheet: *Calonectris leucomelas*. Downloaded from http://www.birdlife.org on 02/04/2019.

BirdLife International, 2019b. Species factsheet: *Fregata ariel.* Downloaded from http://www.birdlife.org on 02/04/2019.

Blaber, S.J.M., Dichmont, C.M., Buckworth, R.C., Badrudin, Sumiono, B., Nurhakim, S., Iskandar, B., Fegan, B., Ramm, D.C., Salini, J.P., 2005. Shared stocks of snappers (Lutjanidae) in Australia and Indonesia: integrating biology, population dynamics and socio-economics to examine management scenarios. Reviews in Fish Biology and Fisheries, 15: 111-27.

Bolle, L.J., de Jong, C.A.F, Bierman, S.M., van Beek, P.J.G., van Keeken, O.A., Wessels, P.W., van Damme, C.J.G., Winter, H.V., de Hann, D., Dekeling, R.P.A., 2012. Common Sole Larvae Survive High Levels of Pile-Driving Sound in Controlled Exposure Experiments. PLoS ONE 7(3): e33052. doi:10.1371/journal.pone.0033052.

Braun, C.B. and Grande, T., 2008. Evolution of peripheral mechanisms for the enhancement of sound reception. In: Webb JF, Popper AN, Fay RR (eds.) Fish bioacoustics. Springer, New York, NY, pp 99-144.

Bray, D.J. and Thompson, V.J., 2019. Fishes of Australia. http://fishesofaustralia.net.au/home/species/ viewed 5/04/2019.

Brewer, D. Lyne, V. Skewes, T. and Rothlisberg, P. 2007. Trophic Systems of the Northwest Marine Region. Report to the Department of the Environment and Water Resources, CSIRO Marine and Atmospheric Research, Cleveland.

Bruce, B., Bradford, R., Foster, S., Lee, K., Lansdell, M., Cooper, S. and Przeslawski, R., 2018. Quantifying fish behaviour and commercial catch rates in relation to a marine seismic survey. Marine Environmental Research 140: 18-30.

Budelmann, B.U., 1992a. Hearing in Nonarthropod Invertebrates. (Chapter 10) In Webster, D.B., A.N. Popper, and R.R. Fay (eds.). The Evolutionary Biology of Hearing. Springer, New York. pp 141-155. https://doi.org/10.1007/978-1-4612-2784-7_10.

Budelmann, B.U., 1992b. Hearing in crustacea. In Webster, D.B., R.A. Fay, and A.N. Popper (eds.). The Evolutionary Biology of Hearing. Springer-Verlag, New York. pp 131-139.

Burbidge, A., Woinarski, J. and Harrison, P., 2014. The Action Plan for Australian Mammals 2012. CSIRO Publishing, Victoria.

Butler, I., Roelofs, A. and Kanga, M., 2018. Banana Prawns. *Penaeus indicus & Penaeus meguiensis*. Fisheries Research & Development Corporation. Available at: https://fish.gov.au/report/272-BANANA-PRAWNS-2020

Butler, I., Roelofs, A. and Kanga, M., 2020. Status of Australian Fish Stocks. Fisheries Research & Development Corporation. Available at: https://www.fish.gov.au/

Caiger, P.E., Montgomery, J.C. and Radford, C.A., 2012. Chronic low-intensity noise exposure affects the hearing thresholds of juvenile snapper. Marine Ecology Progress Series 466: 225–232.

Cailliet, G.M., Cavanagh, R.D., Kulka, D.W., Stevens, J.D., Soldo, A., Clo, S., Macias, D., Baum, J., Kohin, S., Duarte, A., Holtzhausen, J.A., Acuña, E., Amorim, A., Domingo, A., 2009. *Isurus oxyrinchus*. The IUCN Red List of Threatened Species 2009.

Cameron, D. and Begg, G., 2002. Fisheries biology and interaction in the northern Australian small mackerel fishery. Final report to the Fisheries Research and Development Corporation, projects 92/144 and 92/144.02. Department of Primary Industries, Brisbane, Queensland.

Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M. and Bruce, B., 2017. A critical review of the potential impacts of marine seismic surveys on fish and invertebrates. Marine Pollution Bulletin 114: 9-24.

Casper, B.M., Halvorsen, M.B. and Popper, A.N., 2012. Are sharks even bothered by a noisy environment? Advances in Experimental Medicine and Biology 739: 93–97.

Castro, J.I., Woodley, C.M. and Brudek, R.L., 1999. A preliminary evaluation of the status of shark species. FAO Fisheries Technical Paper 380. FAO, Rome.

Celi, M., Filiciotto, F., Parrinello, D., Buscaino, G., Damiano, M.A., Cuttitta, A., D'Angelo, S., Mazzola, S., Vazzana, M., 2013. Physiological and agonistic behavioural response of Procambarus clarkii to an acoustic stimulus. Journal. Experimental Biology 216: 709–718.

Chatto, R., 2001. The distribution and status of colonial breeding seabirds in the Northern Territory, technical report 70, Parks and Wildlife Commission of the Northern Territory, Palmerston.

Chatto, R., 2003. The Distribution and Status Of Shorebirds Around The Coast and Coastal Wetlands Of The Northern Territory - Parks and Wildlife Commission of the Northern Territory

Chilvers, B. L. Delean, S. Gales, NJ. Holley, DK. Lawler, IR. Marsh, H. and Preen, A.R., 2004. Diving behaviour of dugongs, *Dugong dugong*. Journal of Experimental Marine Biology and Ecology 204: 203-224 Elsevier

Christian J.R., Mathieu A., Thomson D.H., White D. and Buchanan R.A., 2003. Effect of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report 144, pp 1-92. Environmental Studies Research Funds.

Clark, C.W., Ellison, W.T., Southall, B.L., Hatch, L., Van Parijs, S.M., Frankel, A., Ponirakis, D., 2009. Acoustic masking in marine ecosystems: Intuitions, analysis, and implication. Marine Ecology Progress Series 395: 201-222. http://www.int-res.com/abstracts/meps/v395/p201-222/.

Clarke, R.H., 2010. The status of seabirds and shorebirds at Ashmore Reef, Cartier Island and Browse Island: monitoring program for the Montara well release – pre-impact assessment and first post-impact field survey. Prepared on behalf of PTTEP Australasia and the Department of the Environment, Water, Heritage and the Arts, Australia (now the Department of Sustainability, Environment, Water, Population and Communities).

Cohen, M.J., 1955. The function of receptors in the statocyst of the lobster Homarus americanus. Journal of Physiology 130(1): 9-34. https://doi.org/10.1113/jphysiol.1955.sp005389.

Cohen, M.J., Katsuki, Y. and Bullock, T.H., 1953. Oscillographic analysis of equilibrium receptors in Crustacea. Experientia 9(11): 434-435. https://doi.org/10.1007/BF02175537.

Colman, J.G., 1997. A review of the biology and ecology of the whale shark. Journal of Fish Biology. 51:1219-1234

Commonwealth of Australia, 2009. National biofouling management guidelines for the petroleum production and exploration industry. Available at: https://www.marinepests.gov.au/sites/default/files/Documents/petroleum-exploration-biofouling-guidelines.pdf

Commonwealth of Australia, 2012. *Sternula albifrons* (Little Tern) Available at: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=82849

Commonwealth of Australia, 2013. Recovery plan for the white shark (*Carcharodon carcharias*) Available at: http://www.environment.gov.au/biodiversity/threatened/recovery-plans/recovery-plan-white-shark-carcharodon-carcharias

Commonwealth of Australia, 2017. EPBC Act Policy Statement 3.21—Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species, Commonwealth of Australia 2017.

Commonwealth of Australia, 2019. National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds. Available at: https://www.environment.gov.au/biodiversity/publications/national-light-pollution-guidelines-wildlife

Compagno, L.J.V., 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. FAO Fisheries Synopsis No. 125, Volume 4, Part 1.

Corwin, J.T., 1981. Postembryonic production and aging in inner ear hair cells in sharks.4. 541-553. DOI: 10.1002/cne.902010406

Corwin, J.T., 1983. Postembryonic growth of the macula neglecta auditory detector in the ray *Raja clavata*: continual increases in hair cell number, neural convergence, and physiological sensitivity. J comp Neurol. 217:345-356.

Dale, J.J., Gray, M.D., Popper, A.N., Rogers, P.H. and Block, B.A., 2015. Hearing thresholds of swimming Pacific tuna *Thunnus orientalis*. Journal of Comparative Physiology A; DOI: 10.1007/s00359-015-0991-x.

Davis, T.L.O. and West, G.J., 1993. Maturation, reproduction seasonality, fecundity and spawning in *Lutjanus vittus* (Quoy and Gaimard) from the north West shelf of Australia. Fishery Bulletin, US. 91:244-236

Day R.D., McCauley R.D., Fitzgibbon Q.P., Hartman K. and Semmens J.M., 2016b. Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop Pecten fumatus. Fisheries and Aquaculture Centre, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, TAS 7001, Australia; and Centre for Marine Science and Technology, Curtin University, Perth, WA 6845, Australia.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P. and Semmens, J.M., 2016a. Seismic Air Gun Exposure during Early-Stage Embryonic Development Does Not Negatively Affect Spiny Lobster *Jasus Edwardsii* Larvae (Decapoda:Palinuridae)'. Scientific Reports 6 (7 March 2016): 22723. doi:10.1038/srep22723.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartmann, K. and Semmens, J.M., 2017. Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop Pecten fumatus. Proceedings of the National Academy of Science of the United States of America, October 2017, 114 (40) E8537-E8546; DOI: 10.1073/pnas.1700564114.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartmann, K. and Semmens, J.M., 2019. Seismic air guns damage rock lobster mechanosensory organs and impair righting reflex. *Proc. R. Soc. B.***286**2019142420191424

Dement'ev, G.P. and Gladkov, N.A. (eds.), 1951. Birds of the Soviet Union, Volume 3. Jerusalem: Israel Program for Scientific Translations.

Department of Fisheries, 2004. Final Application to the Australian Government Department of Environment and Heritage on the Pilbara Trap Managed Fishery

Department of Fisheries, 2017. Aquatic Biosecurity Policy. https://www.fish.wa.gov.au/Documents/biosecurity/aquatic_biosecurity_policy.pdf

Dichmont, C., Jarrett, A., Hill, F. and Brown, M., 2012. Harvest strategy for the Northern Prawn Fishery under input controls, Australian Fisheries Management Authority, Canberra

Donovan, A. Brewer, D. van der Velde, T and Skewes, T., 2008. Scientific descriptions of four selected key ecological features (key ecological features) in the North-west Bioregion: final report, report to the Australian Government Department of Environment, Water Heritage and the Arts, CSIRO Marine and Atmospheric Research, Cleveland.

Double, M.C. Andrews-Goff, V., Jenner, K.C.S., Jenner, M.N., Laverick, S.M., Branch, T.A., Gales, N.J., 2014. Migratory Movements of Pygmy Blue Whales (*Balaenoptera musculus brevicauda*) Between Australia and Indonesia as Revealed by Satellite Telemetry.

Duncan, E.M., Botterell, Z.L.R., Broderick, A.C., Galloway, T.S., Lindeque, P.K., Nuno, A., Godley, B.J., 2017. A global review of marine turtle entanglement in anthropogenic debris: a baseline for further action. Endangered Species Research 34: 431-448.

Engås, A. and Løkkeborg, S., 2002. Effects of seismic shooting and vessel-generated noise on fish behaviour and catch rates. Bioacoustics 12: 313–316.

Engås, A., Løkkeborg, S., Ona, E. and Soldal, A.V., 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fisheries and Aquatic Sciences 53: 2238–2249.

Engineering-Environmental Management Inc., 2008. United States Coast Guard and Maritime Administration draft environmental impact statement for Port Dolphin LLC Deepwater Port licence application. Prepared by Engineering-Environmental Management, Inc, Kansas, USA for USCG Deepwater Ports Standards Division, Washington.

Erbe, C. and Farmer, D.M., 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. Deep-Sea Research Part II 45(7): 1373-1388.

Erbe, C., 2008. Critical ratios of beluga whales (*Delphinapterus leucas*) and masked signal duration. Journal of the Acoustical Society of America 124(4): 2216-2223.

Erbe, C., Reichmuth, C., Cunningham, K., Lucke, K. and Dooling, R., 2016. Communication masking in marine mammals: A review and research strategy. Marine Pollution Bulletin 103(1): 15-38.

Farcas, A., Thompson, P.M., and Merchant, N.D., 2016.Underwater noise modelling for environmental impact assessment. Environmental Impact Assessment Review. 57. 114-122

Field, I.C., Charters, R., Buckworth, R.C., Meekan, M.G. and Bradshaw, C.J.A., 2008. Distribution and abundance of Glyphis and sawfishes in northern Australia and their potential interactions with commercial fisheries. Report to Australian Government, Department of the Environment, Water, Heritage and the Arts. Charles Darwin University: Darwin, Australia.

Fields, D. M., Handegard, N. O., Dalen, J., Eichner, C., Malde, K., Karlsen, Ø., Skiftesvik, A. B., Durif, C. M. F., and Browman, H. I., 2019. Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod *Calanus finmarchicus*. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsz126.

Finneran, J., Henderson, E., Houser, D., Jenkins, K., Kotecki, S. and Mulsow, J., 2017. Criteria and thresholds for U.S. navy acoustic and explosive effects analysis (phase III). Department of Navy, San Diego, California, USA. 183 pp.

Finneran, J.J., 2015. Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. Journal of the Acoustical Society of America 138, 1702-1726. DOI: 10.1121/1.4927418.

Finneran, J.J., 2016. Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise. Technical Report. Space and Naval Warfare Systems Center Pacific, San Diego, USA.

Fletcher, W.J. and Santoro, K. (eds), 2014. Status Reports of the Fisheries and Aquatic Resources of Western Australia 2013/14.

Fletcher, W.J. and Santoro, K., 2015. Status Reports of the Fisheries and Aquatic Resources of Western Australia 2014/15: The State of the Fisheries. Department of Fisheries, Western Australia.

Fletcher, W.J., Mumme, M.D. and Webster, F.J. (eds), 2017. Status Reports of the Fisheries and Aquatic Resources of Western Australia 2015/16: The State of the Fisheries. Department of Fisheries, Western Australia.

Froese, R. and Pauly, D. (eds.), 2019. FishBase. Available at: .http://www.fishbase.org/.

Fry, G., Milton, D.A., Van Der Velde, T., Stobutzki, I., Andamari, R., Badrudin and Sumiono, B., 2009. Reproductive dynamics and nursery habitat preferences of two commercially important Indo-Pacific red snappers *Lutjanus erythropterus* and *L. malabaricus*. Fisheries Science. 75. 145-158

Fukunaga A, Kosaki RK, Wagner D, Kane C (2016) Structure of

Funk, D., Hannay, D.E., Ireland, D., Rodrigues, R. and Koski, W. (eds.), 2008. Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day report. LGL Report P969-1. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for Shell Offshore Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service. 218 pp.

Gagnon, M.M. and Rawson, C., 2011. Montara well release monitoring study S4A: Assessment of effects on Timor Sea fish. Report prepared by Curtin University for PTTEP Australasia, West Perth, Western Australia.

Garnett, S.T. and Crowley, G.M., 2000, The action plan for Australian birds 2000, Department of the Environment and Heritage, Canberra, ACT.

Gaughan, D.J. and Santoro, K. (eds), 2018. Status Reports of the Fisheries and Aquatic Resources of Western Australia 2016/17: The State of the Fisheries. Department of Primary Industries and Regional Development, Western Australia.

Gaughan, D.J. and Santoro, K. (eds), 2020. Status Reports of the Fisheries and Aquatic Resources of Western Australia 2018/19: The State of the Fisheries. Department of Primary Industries and Regional Development, Western Australia.

Gedamke, J., McCauley, R.D., 2010. Initial quantification of low-frequency masking potential of a seismic survey, SC/60/E12. Paper presented at the International Whaling.

Geoscience Australia, 2021. Ashmore and Cartier Islands. Australian Government, 2021. Available at: https://www.ga.gov.au/scientific-topics/national-location-information/dimensions/remote-offshore-territories/ashmore-and-cartier-islands.

Gilmour, J., Smith, L., Cook, K. and Pincock, S., 2013. Discovering Scott Reef: 20 years of Exploration and Research, Australian Institute of Marine Science, Townsville.

Gomez, C., Lawson, J.W., Wright, A.J., Buren, A.D., Tollit, D. and Lesage, V., 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. Canadian Journal of Zoology 94: 801–819.

Götz, T., Hastie, G., Hatch, L.T., Raustein, O., Southall, B., Tasker, M. and Thomsen, F., 2009. Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Biodiversity Series, Vol 441

Grimes, C.B., 1987. Reproductive biology of the Lutjanidae: a review, p. 239-294. In J.J. Polovina and S. Ralston (eds.) Tropical snappers and groupers: biology and fisheries management. Westview press, Boulder, Colorado.

Grubert, M. A., Saunders, T. M., Martin, J. M., Lee, H. S. and Walters, C. J., 2013. Stock Assessments of Selected Northern Territory Fishes. Fishery Report No. 110. Northern Territory Government, Australia.

Guinea, M., 2013. Monitoring Program for the Montara Well Release Timor Sea Monitoring Study S6 Seasnakes / Turtles. Available at: http://www.environment.gov.au/system/files/pages/bcefac9b-ebc5-4013-9c88-a356280c202c/files/surveys-sea-snakes-turtles.pdf.

Guinea, M.L., 1995. Report to Australian Nature Conservation Agency: The Sea Turtles and Seasnakes of Ashmore Reef National Nature Reserve, Northern Territory University, Darwin, Australia.

Hannay, D.E. and Racca, R.G., 2005. Acoustic Model Validation. Document Number 0000-S-90-04-T-7006-00-E, Revision 02. Technical report by JASCO Research Ltd. for Sakhalin Energy Investment Company Ltd. 34 pp.

Harasti, D., Lee, K.A., Gallen, C., Hughes, J.M. and Stewart, J., 2015. Movements, home range and site fidelity of snapper (*Chrysophrys auratus*) within a temperate marine protected area. PLoS ONE 10(11): e0142454.

Hart, A., Travaille, K.L., Jones, R., Brand-Gardner, S., Webster, F., Irving, A. and Harry, A.V., 2016. Western Australian Marine Stewardship Council Report Series No. 5: Western Australian Silver-lipped Pearl Oyster (*Pinctada maxima*) Industry. Department of Fisheries, Western Australia. 316 pp.

Hastings, M.C. and Miksis-Olds, J., 2012. Shipboard assessment of hearing sensitivity of tropical fishes immediately after exposure to seismic air gun emissions at Scott Reef. Advances in Experimental Medicine and Biology 730: 239-243.

Hastings, M.C., 2008. Coming to terms with the effects of ocean noise on marine animals. Acoustics Today 4(2): 22-33.

Hatch, L.T., Clark, C.W., Van Parijs, S.M., Frankel, A.S. and Ponirakis, D.W., 2012. Quantifying loss of acoustic communication space for right whales in and around a U.S. National Marine Sanctuary. Conservation Biology 26(5): 983-994.

Hawkins, A.D. and Popper, A.N., 2016. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science 74(3): 635-651.

Hazel, J., Gyuris, E., 2006. Vessel-related mortality of sea turtles in Queensland, Australia. Wildlife Research 33(2):149–154.

Hazel, J., Lawler, I.R. and Hamann, M., 2009. Diving at the shallow end: Green turtle behaviour in near-shore foraging habitat. Journal of Experimental Marine Biology and Ecology, vol. 371, pp. 84-92.

Hazel, J., Lawler, I.R., Marsh, H. and Robson, S., 2007. Vessel speed increases collision risk for the green turtle Chelonia mydas. Endangered Species Research, vol. 3 pp. 105-113.

Heatwole, H. and Cogger, H.G., 1993. 'Family Hydrophiidae', in Fauna of Australia Volume 2A: Amphibia and Reptilia, eds CG Glasby, GJB Ross and PL Beesley, AGPS Canberra, pp. 439.

Hedley, S.L., Bannister, J.L. and Dunlop, R.A., 2011. Abundance estimates of Breeding Stock 'D' humpback whales from aerial and land-based surveys off Shark Bay, Western Australia, 2008. J. Cetacean Res. Manage (special issue 3): 209–21

Heyward, A., Colquhoun, J., Cripps, E., McCorry, D., Stowar, M., Radford, B., Miller, K., Miller, I. and Battershill, C., 2018. No evidence of damage to the soft tissue or skeletal integrity of mesophotic corals exposed to a 3D marine seismic survey. Marine Pollution Bulletin 129: 8-13.

Heyward, A., Colquhoun, J., Cripps, E., McCorry, D., M., Radford, B., Miller, K., Miller, I., and Battershill, C., 2018. No evidence of damage to the soft tissue o skeletal integrity of mesophotic corals exposed to a 3D marine seismic survey. Mar Pollut Bull. 129(1):8-13.

Heyward, A., Jones, R., Meeuwig, J., Burns, K., Radford, B., Colquhoun, J., Cappo, M., Case, M., O'Leary, R., Fisher, R., Meekan, M. and Stowar, M., 2011. Montara: 2011 Offshore Banks Assessment Survey. Monitoring Study S5. Final Report prepared by the Australian Institute of Marine Science for PTTEP Australasia (Ashmore Cartier).

Higgins, P.J. and Davies, S.J.JF. (eds.), 1996. Handbook of Australian, New Zealand and Antarctic Birds. Volume Three - Snipe to Pigeons, Melbourne, Victoria, Oxford University Press.

Higgs, D. M., Lu, Z. and Mann, D. A. 2006. Hearing and mechanoreception. pp. 391-429 in Evans, D. H. and Claiborne, J. B. (eds.), The physiology of fishes. Taylor & Francis Group, Florida, USA.

Hildebrand, J.A., 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series 395: 5-20.

Houde, E.D. and Zastrow, C.E., 1993. Ecosystem- and taxon-specific dynamic and energetics properties of larval fish assemblages. Bulletin of Marine Science 53 (2): 290-335.

Houser, D.S., Yost, W., Burkard, R., Finneran, J.J., Reichmuth, J.J. and Mulsow, J., 2017. A review of the history, development and application of auditory weighting functions in humans and marine mammals. The Journal of the Acoustical Society of America 141: 1371-1413.

International Federation of the Red Cross, 1974. International Convention for the Safety of Life at Sea. https://www.ifrc.org/docs/idrl/I456EN.pdf

Ireland, D.S., Rodrigues, R., Funk, D., Koski, W. and Hannay, D.E., 2009. Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–October 2008: 90-Day Report. Document Number LGL Report P1049-1. 277 pp.

Islands. PLoS One 11:e015786

Jarrett, A., Dennis, D.M., Buckworth, R.C., Bustamante, R., Haywood, M.D.E., Fry, G.C., Tonks, M., Venables, W., Barwick, M., NPF Industry Inc. and CSIRO, 2015. Synthesis of Existing Information, Analysis and Prioritisation of Future Monitoring Activities to Confirm Sustainability of the Red-legged Banana Prawn Sub-fishery in the Joseph Bonaparte Gulf. FRDC Project: 2013/047. 68 pp.

Jenkins, G.P., Milward, N.E. and Hartwick, R.F., 1985. Occurrence of larvae of Spanish mackerels, genus Scomberomorus (Teleostei: Scombridae), in shelf waters of the Great Barrier Reef. Australian Journal of Marine and Freshwater Research 36, 635-640

Jenner, K.C.S., Jenner, M.N, and McCabe, K.A., 2001. Geographical and temporal movements of humpback whales in Western Australian waters. APPEA Journal, 2001: 749-765.

Jensen, F.H., Bejder, L., Wahlberg, M., Aguilar Soto, N., Johnson, M., Madsen, P.T., 2009. Vessel noise effects on delphinid communication. Mar Ecol Prog Ser 395:161-175.

Johnstone, R.E. and Storr, G.M., 1998. Handbook of Western Australian Birds, Non-passerines (Emu to Dollarbird), Vol. 1, Perth, Western Australia: West Australian Museum.

Jones, D.S. and Morgan, G.J., 1994. A field guide to crustaceans of Western Australia. Western Australian Museum.

Kahng, S.E., Garcia-Sais, .JR., Spalding, H.L., Brokovich, E., Wagner, D., Weil, E., Hinderstein, L., Toonen, R.J., 2010. Community ecology of mesophotic coral reef ecosystems. Coral Reefs 29:255–275

Kahng, S.E., Copus, J.M., Wagner, D., 2014.Recent advances in the ecology of mesophotic coral ecosystems (MCEs). Current Opinion in Environment Sustainability. 7. 72-81.

Kathiresan, K. and Bingham, B.L., 2001. Biology of Mangroves and mangrove Ecosystems. Advances in Marine Biology. 40: 81-251.

Kato, H., 2002. Bryde's Whales Balaenoptera edeni and B. brydei. In: Perrin W.F., B. Wrsig and H.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. Pp. 171-177. Academic Press.

Kennish, M.J., 1997. Practical handbook of Estuarine and Marine Pollution. Boca Raton, FL: CRC Press.

Kent, C.S., McCauley, R.D., Duncan, A., Erbe, C., Gavrilov, A., Lucke, K. and Parnum, I., 2016. Underwater sound and vibration from offshore petroleum activities and their potential effects on marine fauna: An Australian Perspective. Centre for Marine Science and Technology (CMST). Curtin University.

Klimley, A.P. and Myrberg Jr, A.A., 1979. Acoustic stimuli underlying withdrawal from a sound source by adult lemon sharks, *Negaprion brevirostris* (Poey). Bulletin of Marine Science, 29: 447–458.

Koessler, M.W. and McPherson, C.R., 2021. Petrel Sub-Basin SW 3D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures. Document 02115, Version 1.0. Technical report by JASCO Applied Sciences for Santos WA Energy Limited.

Kritzer, J.P., 2004. Sex-specific growth and mortality, spawning season, and female maturation of the stripey bass (*Lutjanus carponotatus*) on the Great Barrier Reef.

Ladich, F., Fay, R.R., 2013. Effects of Noise on Sound Detection and Acoustic Communication in Fishes. In: H Brumm (ed.), Animal Communication and Noise, Animal Signals and Communication 2, Springer-Verlag Berlin, Heidelberg. DOI: 10.1007/978-3-642-41494-7_4.

Laird, A., 2017. Northern Prawn Fishery Data Summary 2016. NPF Industry Pty Ltd, Australia. 66 pp.

Laird, A., 2018. Northern Prawn Fishery Data Summary 2017. NPF Industry Pty Ltd, Australia. Available at: https://www.afma.gov.au/sites/default/files/uploads/2018/04/NPFData-Summary-2017-FINAL.pdf.

Lane, B.A., 1987. Shorebirds in Australia. Sydney, NSW: Reed.

Langstreth, J., Williams, A., Stewart, J., Marton, N., Lewis, P. and Saunders, T., 2018. Spanish Mackerel (2018). Accessed online on 20 March 2019 at <https://www.fish.gov.au/report/253-Spanish-Mackerel-2018>.

Larcombe, J. and Bath, A., 2017. Chapter 5: Northern Prawn Fishery. Fishery status reports 2017. Commonwealth of Australia.

Larcombe, J., Marton, N. and Curtotti, R., 2018. Northern Prawn Fishery, in H Patterson, J Larcombe, S Nicol and R Curtotti (eds), Fishery status reports 2018, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Last, P.R. and Stevens, J.D., 2009. Sharks and Rays of Australia. Second Edition. CSIRO Publishing, Collingwood.

Leatherwood, S. and Reeves, R.R., 1983. The Sierra Club Handbook of Whales and Dolphins. Sierra Club Books, San Francisco. 302 pp.

Lenhardt, M.L., 1994. Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (*Caretta caretta*). In Proceedings of the fourteenth annual symposium on sea turtle biology and conservation (K.A. Bjorndal, A.B. Bolten, D.A. Johnson & P.J. Eliazar, eds.) NOAA Technical Memorandum, NMFS-SEFC-351, National Technical Information Service, Springfield, Virginia, 238-241.

Lesser, M.P., Slattery, M., Leichter, J.J., 2009. Ecology of mesophotic coral reefs. Journal of Experimental Marine Biology and Ecology. 375:1-8

Lewis, P. and Bray, N., 2020. Statewide Large Pelagic Finfish Resource Status Report 2018. In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2018/19: The State of the Fisheries (eds). D.J. Gaughan and K. Santoro. Department of Primary Industries and Regional Development, Western Australia. pp. 244-249.

Lewis, P. and Jones, R., 2018. Statewide Large Pelagic Finfish Resource Status Report 2017 In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2016/17: The State of the Fisheries eds. D.J. Gaughan and K. Santoro. Department of Primary Industries and Regional Development, Western Australia.

LGL, 2012. Environmental Assessment of Marine Geophysical Surveys by the R/V Marcus G. Langseth in the Northeastern Pacific Ocean, June–July 2012. LGL Ltd., environmental research associates. 225 pp.

Liberman, M.C., 2015. Noise-induced hearing loss: permanent vs. temporary threshold shifts and the effects of hair-cell versus neuronal degeneration. pp. 1-7 in Popper, A.N. and Hawkins, A.D. (eds.) The effects of noise on aquatic life II. Springer, New York, USA.

Limpus, C.J., 2007. A biological review of Australian Marine Turtles: The flatback turtle *Narator depressus* (Garman). Queensland Environmental Protection Agency. 20:513-523

Limpus, C.J., 2008. A Biological Review of Australian Marine Turtle Species. 1. Loggerhead turtle, *Caretta caretta* (Linneaus), The State of Queensland, Environmental Protection Agency, Australia.

Limpus, C.J., 2009. A Biological Review of Australian Marine Turtle Species. The State of Queensland, Environmental Protection Agency, Australia.

Lindfield, S.J. Harvey, E.S., Halford, A.R. and Mcllwain, J.L., 2016, Mesophotic depths as refuge areas for fishery-targeted species on coral reefs. Coral Reefs. 35:125-137.

Lindquist, D.C., Shaw, R.F., Hernandez Jr, F.J., 2005. Distribution patterns of larval and juvenile fishes at offshore petroleum platforms in the north-central Gulf of Mexico. Estuarine, Coastal and Shelf Science. 62(4):655-665.

Lombarte, A. and Popper, A.N., 1994. Quantitative analyses of postembryonic hair cell addition in the otolithic endorgans of the inner ear of the European hake, *merluccius merluccius* (gadiformes, teleostei). Journal of Comparative Eurology. 345(3):419-428.

Lombarte, A., Lleonart, J. 1993. Otolith size changes related with body growth, habitat depth and temperature. Environ Biol Fish 37, 297–306. doi:10.1007/BF00004637.

Loneragan, N., Die, D., Kenyon, R., Taylor, B., Vance, D., Manson, F., Pendrey, B. and Venables, B., 2002. The growth, mortality, movements and nursery habitats of red-legged banana prawns (*Penaeus indicus*) in the Joseph Bonaparte Gulf. CSIRO Marine Research. Project FRDC 97/105. 142 pp.

Santos

MacGillivray, A.O., 2018a. An Airgun Array Source Model Accounting for High-frequency Sound Emissions During Firing and Solutions to the IAMW Source Test Cases. IEEE Journal of Oceanic Engineering. https://ieeexplore.ieee.org/document/8423063/.

MacGillivray, A.O., 2018b. Underwater noise from pile driving of conductor casing at a deep-water oil platform. Journal of the Acoustical Society of America 143(1): 450-459. https://doi.org/10.1121/1.5021554.

Mackie M.C., Lewis P.D., Kennedy J., Saville K., Crowe F., Newman, S.J. and Smith, K.A., 2010. Western Australian Mackerel Fishery. Ecologically Sustainable Development Series No. 7. Western Australian Department of Fisheries, Perth, Western Australia.

Mackintosh, N.A., 1965. The stocks of whales. Fishing News (Books) Ltd, London.

Malme, C.I., Miles, P.R., Clark, C.W., Tyack, P. and Bird, J.E., 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Bolt Beranek and Newman Report No. 5366 submitted to the Minerals Management Service, U.S. Department of the Interior, Washington, DC. NTIS PB86-218377.

Marchant, S. and Higgins, P.J. (eds.), 1993. Handbook of Australian, New Zealand and Antarctic Birds. Volume 2 - Raptors to Lapwings. Melbourne, Victoria: Oxford University Press.

Marchant, S. and Higgins, P.J., 1990. Handbook of Australian, New Zealand and Antarctic birds, Vol. 1, Part A: Ratites to Petrelexs. Oxford University Press, Melbourne.

Marchesan, M., Spotto, M., Verginella, L. and Ferrero, E.A., 2006. Behavioural Effects of Artificial Light on Fish Species of Commercial Interest. Fisheries Research, vol. 73, pp. 171-185.

Marine order 94. Marine pollution prevention- packaged harmful substances. 2014.

Marine order 95. Marine pollution prevention – garbage. 2018.

Marine order 96. Marine pollution prevention- sewage. 2018.

Marine Pest Sectoral Committee, 2018. National biofouling management guidelines for the petroleum production and exploration industry. Available at: https://www.marinepests.gov.au/sites/default/files/Documents/petroleum-exploration-biofouling-guidelines.pdf

Marquenie, J. Donners, M. Poot, H. Steckel, W. de Wit, B. and Nam, A., 2008. Adapting the Spectral Composition of Artificial Lighting to Safeguard the Environment, Petroleum and Chemical Industry Conference Europe – Electrical and Instrumentation Applications, 5th PCIC Europe, pp. 1 - 6.

Marquez, R., 1990. FAO Species Catalogue; Sea Turtles of the World. An annotated and illustrated catalogue of the sea turtle species known to date. FAO Fisheries Synopsis. 125 (11): pp 81. Rome: Food and Agriculture Organisation of United Nations.

Marriot, R., Jackson, G., Lenaton, R., Telfer, C., Stephenson E., Bruce, C., Adams, D. and Noriss, J., 2012. Biology and Stock Status of Inshore Demersal Scalefish Indicator Species in the Gascoyne Coast Bioregion. Fisheries Research Report No. 228. Department of Fisheries.

Marriott R.J., Mapstone, B.D., Begg, G.A., 2007. Age-specific demographic parameters, and their implications for management of the red bass, *Lutjanus bohar* (Forsskal 1775): A large, long-lived reef fish. Fisheries Research. 83(2-3): 204-214.

Marriott, R.J., O'Neill, M.F., Newman, S.J., Skepper, C.L., 2014. Abundance indices for log-lived tropical snappers: estimating standardized catch rates from spatially and temporally coarse logbook data. ICEA Journal of Marine Science, 71(3):616-627.

Marshall, A., Bennett, M.B., Kodja, G., Hinojosa-Alvarez, S., Galvan-Magana, F., Harding, M., Stevens, G. and Kashiwagi, T., 2018a. *Mobula birostris* (amended version of 2011 assessment). The IUCN Red List of Threatened Species 2018: e.T198921A126669349. http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T198921A126669349.en. Downloaded on 21 June 2019.

Marshall, A., Kashiwagi, T., Bennett, M.B., Deakos, M., Stevens, G., McGregor, F., Clark, T., Ishihara, H. and Sato, K., 2018b. *Mobula alfredi* (amended version of 2011 assessment). The IUCN Red List of Threatened Species 2018: e.T195459A126665723. http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T195459A126665723.en. Downloaded on 21 June 2019.

Martin, B., Broker, K., Matthews, M-N.R., MacDonnell, J. and Bailey, L., 2015. Comparison of measured and modeled air-gun array sound levels in Baffin Bay, West Greenland. Ocean Noise 2015, 11-15 May, Barcelona, Spain.

Martin, B., MacDonnell, J.T. and Bröker, K., 2017a. Cumulative sound exposure levels—Insights from seismic survey measurements. Journal of the Acoustical Society of America 141(5): 3603-3603.

Martin, J., Keag, M., Newman, S. and Wakefield, C., 2014. Goldband Snapper *Pristipomoides multidens*. Accessed online on 27 February 2019 at <https://www.fish.gov.au/2014-Reports/Goldband_Snapper>.

Martin, S.B. and Popper, A.N., 2016. Short- and long-term monitoring of underwater sound levels in the Hudson River (New York, USA). Journal of the Acoustical Society of America 139(4): 1886-1897. http://dx.doi.org/10.1121/1.4944876.

Martin, S.B., Matthews, M-N.R., MacDonnell, J.T. and Bröker, K., 2017b. Characteristics of seismic survey pulses and the ambient soundscape in Baffin Bay and Melville Bay, West Greenland. Journal of the Acoustical Society of America 142(6): 3331-3346. https://doi.org/10.1121/1.5014049.

Matishov, G.G., 1992. The reaction of bottom-fish larvae to airgun pulses in the context of the vulnerable Barent Sea ecosystem. Fisheries and Offshore Petroleum Exploitation, 2nd International Conference. Bergen, Norway, 6-8 April, 1992

Matthews, M-N.R. and MacGillivray, A.O., 2013. Comparing modeled and measured sound levels from a seismic survey in the Canadian Beaufort Sea. Proceedings of Meetings on Acoustics 19(1): 1-8. https://doi.org/10.1121/1.4800553.

Maxwell, A.J., Vincent, L.W, and Woods, E.P., 2004. The Audacious discovery, Timor Sea and the role of pre-stack depth migration seismic processing. In: Ellis GK, Baillie PW and Munsoon TJ (eds.), Timor Sea Petroleum Geoscience, Proceedings of the Timor Sea Symposium, Darwin, Northern Territory, 19 - 20 June 2003, Northern Territory Geological Survey, Special Publication 1, 53-65.

McCauley, R.D. and Kent, C.S., 2012. A lack of correlation between air gun signal pressure waveforms and fish hearing damage. In: Popper, A.N. and A.D. Hawkins (eds.), The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biology, Volume 730. Springer Science+Business Media, New York, pp 245-250.

McCauley, R.D., 1994. Seismic surveys. In: Environmental Implications of Offshore Oil and Gas Development in Australia—The Findings of an Independent Scientific Review, Swan, J.M. Neff, J.M. and Young, P.C. (eds.), Australian Petroleum Exploration Association, Sydney, pp. 19–122.

McCauley, R.D., 2011. Woodside Kimberley Sea Noise Logger Program, Sept 2006 to June-2009: Whales, Fish and Man-made noise. Report produced for Woodside Energy Ltd, pp. 86.

McCauley, R.D., Day, R.D., Swadling, K.M., Fitzgibbon, Q.P., Watson, R.A. and Semmens, J.M., 2017. Widely used marine seismic survey air gun operations negatively impact zooplankton. Nature Ecology & Evolution 1: 1-8. http://dx.doi.org/10.1038/s41559-017-0195.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J., McCabe, K., 2000a. Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid. Report Number R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Marine Science and Technology, Western Australia. 198 pp.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J., McCable, K., 2000b. Marine seismic surveys: A study of environmental implications. Australian Petroleum Production Exploration Association (APPEA) Journal 40(1): 692-708.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K., 2003. Marine seismic surveys: analysis and propagation of air-gun signals; and effects of exposure on humpback whales, sea turtles, fishes and squid. In: Anon eds.), Environmental implications of offshore oil and gas development in Australia: further research, Australian Petroleum Production Exploration Association, Canberra.

McCauley, R.D., Jenner, M-N., Jenner, C., McCabe, K.A. and Murdoch, J., 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working vessel and experimental exposures. APPEA Journal. Vol. 38(1), pp. 692-707.

McCrodan, A., McPherson, C. and Hannay, D.E., 2011. Sound Source Characterization (SSC) Measurements for Apache's 2011 Cook Inlet 2D Technology Test. Version 3.0. Technical report for Fairweather LLC and Apache Corporation by JASCO Applied Sciences. 51 pp.

McPherson, C., MacGillivray, A. and Hagar, E., 2018a. Validation of airgun array modelled source signatures. 176th Meeting Acoustical Society of America, 5–9 November 2018. Accepted Abstract, Victoria, BC, Canada.

Mcpherson, C., Martin, B., MacDonnel, J. and Whitt, C. 2016. Examining the value of the acoustic variability index in the charactisation of Australian marine soundscapes. JASCO Applied Sciences.

McPherson, C.R. and Warner, G., 2012. Sound Sources Characterization for the 2012 Simpson Lagoon OBC Seismic Survey 90-Day Report. Document Number 00443, Version 2.0. Technical report by JASCO Applied Sciences for BP Exploration (Alaska) Inc. http://www.nmfs.noaa.gov/pr/pdfs/permits/bp_openwater_90dayreport_appendices.pdf.

McPherson, C.R., Lucke, K., Gaudet, B., Martin, B.S. and Whitt, C.J., 2018b. Pelican 3-D Seismic Survey Sound Source Characterisation. Report Number 001583. Version 1.0. Technical report by JASCO Applied Sciences for RPS Energy Services Pty Ltd.

McPherson, G.R., 1993. Reproductive biology of the narrow barred Spanish Mackerel (*Scomberomorus commerson*) in Queensland waters. Asian Fish. Sci. 6, 169–182.

Meekan, M.G., Bradshaw, C.J.A., Press, M., McLean, C., Richards, A., Quasnichka, S. and Taylor, J.G., 2006. Population size and structure of whale sharks *Rhincodon typus* at Ningaloo Reef, Western Australia. Marine Ecology Progress Series. 319:275-85.

Meekan, M.G., Wilson, S.G., Halford , A. and Retzel, A., 2001. A comparison of catches of fishes and invertebrates by two light trap designs, in tropical NW Australia. Marine Biology, 139: 373–381.

Milicich, M J., 1992. Light traps: a novel technique for monitoring larval supply and replenishment of coral reef fish populations. Ph.D. thesis, Griffith University, Brisbane.

Miller, I. and Cripps, E., 2013. Three dimensional marine seismic survey has no measurable effect on species richness or abundance of a coral reef associated fish community. Marine Pollution Bulletin 77(1-2): 63-70.

Miller, K., 2017. Seabed Biodiversity of the Kimberley., 2017 WAMSI Research Conference, 27-29 November 2017, State Library of Western Australia.

Milton, D.A., 2005. Birds of Ashmore Reef National Nature Reserve: an assessment of its importance for seabirds and waders. The Beagle: Records of the Museums and Art Galleries of the Northern Territory. 1:133-141.

Moein, S.E., Musick, J.A., Keinath, J.A., 1995. Evaluation of seismic sources for repelling sea turtles from hopper dredges. In: Hales LZ (ed) Sea turtle research program: summary report. Prepared for US Army Engineer Division, South Atlantic, Atlanta, GA, and US Naval Submarine Base, Kings Bay, GA. Technical Report CERC-95, 90, pp. 75–78.

Mollet, H.F., Cliff, G., Pratt Jr, H.L. and Stevens, J.D., 2000. Reproductive biology of the female shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, with comments on the embryonic development of lamnoids. Fishery Bulletin. 98:298-318.

Moran, M., Burton, C. and Jenke, J., 2004. Long-term movement patterns of continental shelf and inner gulf snapper (*Pagrus auratus, Sparidae*) from tagging in the Shark Bay region of Western Australia. Marine and Freshwater Research 54 (8): 913–922.

Morley, E.L., Jones, G. and Radford, A.N., 2014. The importance of invertebrates when considering the impacts of anthropogenic noise. Proceedings of the Royal Society of London B: Biological Sciences 281(1776).
http://rspb.royalsocietypublishing.org/content/royprsb/281/1776/20132683.full.pdf.

Myrberg Jr, A.A., 2001. The acoustical biology of elasmobranchs. Environmental Biology of Fishes, 60: 31-45.

Navigation Act, 2012. Australian Government. Available at:
https://www.legislation.gov.au/Details/C2019C00268

Nedwell, J.R., Edwards, B., Turnpenny, A.W.H., Gordon, J., 2004. Fish and marine mammal audiograms: A summary of available information. Subacoustech Report ref: 534R0214.

Neil, K.M., Hilliard, R.W., Clark, P., Russell, B., Clark, R. and Polglaze, J., 2005. Situation and Gaps Analysis of Introduced Marine Species, Vectors, Nodes and Management Arrangements for the Northern Planning Area, Report published by the National Oceans Office (Marine Division, Department of Environment and Heritage), Canberra

Nelms, S., Piniak, W.E.D., Weir, C.R., and Godley, B.J., 2016. Seismic surveys and marine turtles: an understanding global threat. Biological Conservation 193: 49-65.

NERP MBH National Environmental Research Program Marine Biodiversity Hub, 2014. Exploring the Oceanic Shoals Commonwealth Marine Reserve, NERP MBH, Hobart.

Newman S.J., Smith K.A., Skepper C.L. and Stephenson P.C., 2008. Northern Demersal Scalefish Managed Fishery. Department of Fisheries, Western Australia. ESD Report Series No. 6, June 2008.

Newman, S., Wakefield, C., Skepper, C., Boddington D. and Smith, E., 2019. North Coast Demersal Resource Status Report 2018. In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2017/18: The State of the Fisheries eds. D.J. Gaughan and K. Santoro. Department of Primary Industries and Regional Development, Western Australia. pp. 125-133.

Newman, S., Wakefield, C., Skepper, C., Boddington, D. and Blay, N., 2020. North Coast Demersal Resource Status Report 2019. In: Status Reports of the Fisheries and Aquatic Resources of Western Australia 2018/19: The State of the Fisheries (eds). D.J. Gaughan and K. Santoro. Department of Primary Industries and Regional Development, Western Australia. pp. 159-168.

Newman, S.J., Steckis, R.A., Edmonds, J.S. and Lloyd, J., 2000. Stock structure of the goldband snapper *Pristipomoides multidens* (Pisces: Lutjanidae) from the waters of northern and western Australia by stable isotope ratio analysis of sagittal otolith carbonate. Marine Ecology Progress Series 198: 239-247.

Newman, S.J., Wakefield, C., Skepper, C., Boddington, D., Jones, R. and Smith, E., 2018. North Coast Demersal Resource Status Report 2017, in Gaughan, D.J. and Santoro, K. (Ed.) Status Reports of the Fisheries and Aquatic Resources of Western Australia 2016/2017: The State of Fisheries. Department of Primary Industries and Regional Development, Western Australia.

Newman, S.J., Young, G. C., Travers, M. J., Pember, M. B., Skepper, C. L., Williamson, P. C., and Potter, I. C., 2003. Characterisation of the inshore fish assemblages of the Pilbara and Kimberley coasts. Final Report to the Fisheries Research and Development Corporation for Project 2000/132. Fisheries Research and Development Corporation, Canberra, ACT.

Nichol, S.L., Howard, F.J.F., Kool, J., Stowar, M., Bouchet, P., Radke, L., Siwabessy, J., Przeslawski, R., Picard, K., Alvarez de Glasby, B., Colquhoun, J., Letessier, T. and Heyward, A., 2013. Oceanic Shoals Commonwealth Marine Reserve (Timor Sea) Biodiversity Survey: GA0339/SOL5650 – Post Survey Report. Record 2013/38. Geoscience Australia: Canberra.

Nohaïc, M.L., Ross, C.L., Cornwall, C.E., Comeau, S., Lowe, R., McCulloch, M.T. and Schoepf, V., 2017. Marine heatwave causes unprecedented regional mass bleaching of thermally resistant corals in north western Australia. Scientific Reports. 7, 14999.

Nowacek D.P, Johnson M.P, Tyack P.L. 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli Proceedings of the Royal Society B: Biological Sciences, 271, pp. 227-231, 10.1098/rspb.2003.2570.

NT Government 2020c. Bait Net Fishery. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/bait-net-fishery-and-licences

NT Government, 2018. Snapper Crimson. Available at: https://nt.gov.au/marine/recreational-fishing/types-of-fish/fish-species/crimson-snapper

NT Government, 2020a. Barramundi fishery and licences. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/barramundi-fishery-and-licences. Accessed on 19 May 2020.

NT Government, 2020b. Coastal Line Fishery. Available at: https://nt.gov.au/marine/commercial-fishing/fishery-licenses/coastal-line-fishery-and-licences. Accessed on 19 May 2020.

NT Government, 2020d Grey Mackerel. Available at: https://www.fish.gov.au/report/397-Grey-Mackerel-2020

O'Hara, J. and Wilcox, R., 1990. Avoidance responses of loggerhead turtles, Caretta caretta, to low frequency sound. Copeia, 1990 (2): 564-567.

Odell, D.K. and MacMurray, C., 1986. Behavioural response to oil. In: Vargo S, Lutz PL, Odell DK, Van Vleet T, Bossart G (eds) Final Report. Study of the effect of oil on marine turtles. Minerals Management Service Contract Number 14–12–0001–30063, Florida Inst. of Oceanography, St. Petersburg, FL.

O'Neill, C., Leary, D. and McCrodan, A., 2010. Sound Source Verification. (Chapter 3) In Blees, M.K., K.G. Hartin, D.S. Ireland, and D.E. Hannay (eds.). Marine mammal monitoring and mitigation during open water seismic exploration by Statoil USA E&P Inc. in the Chukchi Sea, August-October 2010: 90-day report. LGL Report P1119. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. for Statoil USA E&P Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service. pp 1-34.

Ovenden, J.R., Salini, J., O'Connor, S. and Street, A.R., 2004. Pronounced genetic population structure in a potentially vagile fish species (*Pristipomoides multidens*, Teleostei; Perciformes; Lutjanidae) from the East Indies triangle. Molecular Ecology 13: 1991–1999.

Parry, G.D. and Gason, A. 2006. The effect of seismic surveys on catch rates of rock lobsters in western Victoria, Australia. Fisheries Research 79(3):272-284.

Parry, G.D., Heislers, S., Werner, G.F., Asplin, M.D., Gason, A., 2002. Assessment of Environmental Effects of Seismic Testing on Scallop Fisheries in Bass Strait. Marine and Freshwater Resources Institute Report No. 50. Marine and Freshwater Resources Institute, Queenscliff, Victoria.

Parsa, M., Larcombe, J., Butler, I. and Curtotti, R., 2020. Northern Prawn Fishery. In: Fishery status reports 2020. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra. CC BY 4.0. pp. 65-86.

Parsons, D.M., Morrison, M.A., McKenzie, J.R., Hartill, B.W., Bian, R. and Francis, R.C., 2011. A fisheries perspective of behavioural variability: differences in movement behaviour and extraction rate of an exploited sparid, snapper (*Pagrus auratus*). Canadian Journal of Fisheries and Aquatic Sciences 68(4): 632–42

Patterson, H., Larcombe, J., Woodhams, J. and Curtotti, R., 2020. Fishery status reports 2020, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra. CC BY 4.0.

Paulay, G., Kirkendale, L., Lambert, G. and Meyer, C. 2002. Anthropogenic Biotic Interchange in a Coral Reef Ecosystem: A Case Study from Guam. Pacific Science. 56. 10.1353/psc.2002.0036.

Payne, J.F., Andrews, C., Fancey, L., White, D. and Christian, J., 2008. Potential Effects of Seismic Energy on Fish and Shellfish: An Update since 2003. Report Number 2008/060. Canadian Science Advisory Secretariat. 22 pp.

Payne, J.F., Andrews, C.A., Fancey, L.L., Cook, A.L., Christian, J.R., 2007. Pilot study on the effects of seismic air gun noise on lobster (*Homarus americanus*). Citeseer.

Pearson, W.H., Skalski, J.R., Sulkin, S.D., and Malme, C.I., 1994. Effects of seismic releases on the survival of development of zoeal larvae of dungeness crab (Cancer magister). Marine Environmental Research 38: 93-113.

Peel, D., Smith., J.N. and Childerhouse, S., 2016. Historical data on Australian whale vessel strikes. Presented to the IWC Scientific Committee. SC/66b/HIM/05.

Peña, H., Handegard, N.O., and Ona, E., 2013. Feeding herring schools do not react to seismic air gun surveys. ICES Journal of Marine Science 70: 1174–1180.

Pendoley, K.L., Schofield, G., Whittock, P.A., Lerodiaconou, D. and Hays, G.C., 2014. Protected species use of a coastal marine migratory corridor connecting marine protected areas. Marine Biology. 161:1455-1466.

Peverell, S., Gribble, N. and Larson, H., 2004. 'Sawfish'. In: National Oceans Office, Description of Key Species Groups in the Northern Planning Area. [Online]. Hobart, Tasmania: Commonwealth of Australia. http://www.environment.gov.au/coasts/mbp/publications/north/pubs/n-key-species.pdf.

Pillans, R.D., Stevens, J.D., Peverell, S. and Edgar, S., 2008. Spatial distribution and habitat utilisation of the speartooth shark Glyphis sp. A in relation to fishing in Northern Australia. CSIRO Marine and Atmospheric Research.

Plagányi, É., Hutton, T., Kenyon, R., Moeseneder, C., Deng, R., Miller, M., Pascoe, S. & Upston, J., 2017. Environmental drivers of variability in Joseph Bonaparte Gulf red-legged banana prawn (*Penaeus indicus*) fishery, preliminary progress report for the Northern Prawn Fishery Resource Assessment Group, March 2017, AFMA Canberra.

Poiner, I.R. and Harris, A.N.M., 1996. The Incidental Capture, Direct Mortality and Delayed Mortality of Sea Turtles in Australia's Northern Prawn Fishery. Mar.Biol.125, 813–825.

Popper, A. and Hawkins, A., 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of Fish Biology. Volume 94, Issue 5. May 2019. Pg. 692-713.

Popper, A.N. and Clarke, N.L., 1976. The auditory system of the goldfish (*Carassius auratus*): effects of intense acoustic stimulation. Comparative Biochemistry Physiology Part A: Physiology 53:11–18.

Popper, A.N. and Fay, R.R., 2011. Rethinking sound detection by fishes. Hearing Research 273, 25-36.

Popper, A.N. and Hawkins, A.D., 2018. The importance of particle motion to fishes and invertebrates. J. Acoust. Soc. Am. 143 (1): 470-488.

Popper, A.N. and Hoxter, B., 1984. Growth of a fish ear: I. Quantitative analysis of sensory hair cell and ganglion cell proliferation. Hear Res 15:133-142.

Popper, A.N., 2018. Potential for Impact of Cumulative Sound Exposure on fishes during a seismic survey. Produced for Santos Ltd. Bethany 3D Seismic Survey Environment Plan Summary.

Popper, A.N., Halvorsen, M.B., Kane, E., Miller, D.L., Smith, M.E., Song, J., Stein, P. and Wysocki, l.E., 2007. The effects of high-intensity, low-frequency active sonar on rainbow trout. Journal of the Acoustical Society of America 122:623–635.

Popper, A.N., Hawkins, A., Fay, R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W., Gentry, R., Halvorsen, M., Løkkeborg, S., Rogers, P., Southall, B., Zeddies, D. and Tavolga, W., 2014., ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Part of the series SpringerBriefs in Oceanography pp 15-16.

Popper, A.N., Hawkins, A.D., Sand, O. and Sisneros, J.A., 2019. Examining the haring abilities of fishes. The Journal of the Acoustical Society of America. 146, 948.

Popper, A.N., Smith, M.E., Cott, P.A., Hanna, B.W., MacGillivray, A.O., Austin, M.E and Mann, D.A., 2005. Effects of exposure to seismic airgun use on hearing of three fish species. Journal of the Acoustical Society of America 117: 3958.

Protection of the sea (Prevention of Pollution from ships) Act 1983 Available at: https://www.legislation.gov.au/Details/C2017C00162

Przeslawski, R., Alvarez, B., Battershill, C. and Smith, T., 2014. Sponge biodiversity and ecology of the Van Diemen Rise and eastern Joseph Bonaparte Gulf, northern Australia. Hydrobiologia. 730:1-16

Przeslawski, R., Bruce, B., Carroll, A., Anderson, J., Bradford, R., Durrant, A., Edmunds, M., Foster, S., Huang, Z., Hurt, L., Lansdell, M., Lee, K., Lees, C., Nichols, P. and Williams, S., 2016b. Marine Seismic Survey Impacts on Fish and Invertebrates: Final Report for the Gippsland Marine Environmental Monitoring Project. Record 2016/35. Geoscience Australia, Canberra. 63 pp.

Przeslawski, R., Daniell, J., Anderson, T., Barrie, J.V., Heap, A., Hughes, M., Li, J., Potter, A., Radke, R., Siwabessy, J., Tran, M., Whiteway, T., Nichol, S., 2011. Seabed Habitats and Hazards of the Joseph Bonaparte Gulf and Timor Sea, Northern Australia. Geoscience Australia, Record 2011/40.

Przeslawski, R., Huang, Z., Anderson, J., Carroll, A., Edmonds, M., Hurt, L., Williams, S., 2018 Multiple field-based methods to assess the potential impacts of seismic surveys on scallops. Mar. Poll. Bull., 129, pp. 750-761.

Przeslawski, R., Hurt, L., Forrest, A., Carrol, A. and Geoscience Australia, 2016a. Potential short-term impacts of marine seismic surveys on scallops in the Gippsland Basin. Canberra. April. CC BY 3.0.

PTTEP, 2013. Montara Environmental Monitoring Program – Report of Research Edition 2. http://www.au.pttep.com/wp-content/uploads/2013/10/2013-Report-of-Research-Book-vii.pdf

Racca, R.G., Austin, M., Rutenko, A. and Bröker, K., 2015. Monitoring the gray whale sound exposure mitigation zone and estimating acoustic transmission during a 4-D seismic survey, Sakhalin Island, Russia. Endangered Species Research 29(2): 131-146. https://doi.org/10.3354/esr00703.

Racca, R.G., Bröker, K. and Gailey, G., 2012b. Model based sound level estimation and in-field adjustment for real-time mitigation of behavioural impacts from a seismic survey and post-event evaluation of sound exposure for individual whales. Acoustics 2012 Fremantle: Acoustics, Development and the Environment, Fremantle, Australia. http://www.acoustics.asn.au/conference_proceedings/AAS2012/papers/p92.pdf.

Racca, R.G., Rutenko, A., Bröker, K. and Austin, M., 2012a. A line in the water - design and enactment of a closed loop, model based sound level boundary estimation strategy for mitigation of behavioural impacts from a seismic survey. 11th European Conference on Underwater Acoustics 2012. Volume 34(3), Edinburgh, United Kingdom.

Reynolds, S.D., Norman, B.M., Beger, M., Franklin, C.E., Dwyer, R.G., 2017. Movement, distribution and marine reserves use by an endangered migratory giant. Biodiversity Research 23: 1268-1279.

Richardson, A.J., Matear, R.J, and Lenton, A., 2017. Potential impacts on zooplankton of seismic surveys. CSIRO, Australia. 34 pp.

Richardson, J., Greene, C., Malme, C. and Thomson, D., 1995. Marine Mammals and Sound. Academic Press, Waltham.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B. and Winker, H., 2019. Isurus paucus. The IUCN Red List of Threatened Species 2019: e.T60225A3095898. http://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T60225A3095898.en.

Rio Tinto, 2009. Cape Lambert Port B Development. Proponent Responses to Issues Raised in Submissions to the Public Environmental Review and Draft Public Environment Report.

Roberts, L. and Elliott, M., 2017. Good or bad vibrations? Impacts of anthropogenic vibration on the marine epibenthos. Science of the Total Environment 595: 255-268. https://doi.org/10.1016/j.scitotenv.2017.03.117.

Roberts, L., Cheesman, S., Breithaupt, T. and Elliott, M., 2015. Sensitivity of the mussel *Mytilus edulis* to substrate-borne vibration in relation to anthropogenically generated noise. Marine Ecology Progress Series 538: 185-195. http://www.int-res.com/abstracts/meps/v538/p185-195/.

Roberts, L., Cheesman, S., Elliott, M. and Breithaupt, T., 2016. Sensitivity of *Pagurus bernhardus* (L.) to substrate-borne vibration and anthropogenic noise. Journal of Experimental Marine Biology and Ecology 474: 185-194. http://www.sciencedirect.com/science/article/pii/S0022098115300277.

RPS, 2011. Bonaparte LNG Preliminary Metocean Study. Report prepared for GDF SUEX Bonaparte LNG, Perth, Western Australia.

RPS, 2019. Ancient coastline KEF fish and pearl oyster habitat survey report. Study commissioned by Santos WA.

RPS, 2021. Polarcus Petrel Sub-Basin SW 3D MSS. Oil Spill Modelling. Technical report by RPS for Santos WA Energy Limited.

RPS. 2010. Marine Mammals Technical Report. Wheatstone Project Technical Appendix O12. Report prepared for Chevron Australia Pty Ltd, May 2010.

Sætre, R. and Ona, E., 1996. Seismiske Undersøkelser og Skader på Fiskeegg og -Larver; en Vurdering av Mulige Effekter på Bestandsnivå. (Seismic Investigations and Injuries in Fish Eggs and Larvae; an Assessment of Potential Effects on Stock Level); Fisken og Havet, No 8-1996;

Salini, J.P., Ovenden, J.R., Street, R., Pendrey, R., Haryanti, Ngurah, 2006. Genetic population structure of red snappers (*Lutjanus malabaricus* Bloch & Schneider, 1801 and *Lutjanus erythropterus* Bloch, 1790) in central and eastern Indonesia and northern Australia. Journal of Fish Biology, 68(B): 217-234.

Salmon, M., Wyneken, J., Fritz, E. and Lucas, M., 1992. Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues. Behaviour. 122 (1) 56-77.

Santos, 2020. Keraudren Extension 3D Marine Seismic Survey Environment Plan. NOPSEMA. Key Matter Report. Available at: https://docs.nopsema.gov.au/A725504

Santulli, A., Modica, A., Messina, C., Ceffa, L., Curatolo, A., Rivas, G., Fabi, G. and D'Amelio, V., 1999. Biochemical responses of European Sea Bass (*Dicentrarchus labrax* L.) to the stress induced by off shore experimental seismic prospecting. Marine Pollution Bulletin 38: 1105–1114.

Saunders, T., Dawson, A., Trinnie, F. and Newman, S., 2018. Status of Australia Fish Stocks Reports – Species Profile: Goldband Snapper. Fisheries Research Development Corporation, Canberra.

Scholik, A.R. and Yan, H.Y. ,2002b. The effects of noise of the auditory sensitivity of the bluegill sunfish, *Lepomis macrochirus*. Comp. Biochem. Physiol. (A) 133: 43-52.

Scholik, A.R. and Yan, H.Y., 2001. Effects of underwater noise on auditory sensitivity of cyprinid fish. Hearing Research, 152(1), 17-24.

Scholik, A.R. and Yan, H.Y., 2002a. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environ. Biol. Fish. 63: 203-209.

Scholz, D., Michel, J., Shigenaka, G. and Hoff, R., 1992. Biological resources. In: Hayes M., Hoff R., Michel J., Scholz D. and Shigenaka G. Introduction to coastal habitats and biological resources for spill response, report HMRAD 92-4. National Oceanic and Atmospheric Administration, Seattle.

Schuck, J.B. and Smith, M.E., 2009. Cell proliferation follows acoustically-induced hair cell bundle loss in the zebrafish saccule. Hear Res. 2009; 253:67–76. doi: 10.1016/j.heares.2009.03.008.

Semeniuk, V., 1993. The Pilbara coast: a riverine coastal plain in a tropical arid setting, north-western Australia. Sedimentary Geology. 83(3-4):235-256.

Shimose, T. and Tachihara, K., 2005. Age, growth and maturation of the blackspot snapper *Lutjanus fulviflammus* around Okinawa Island, Japan. Fisheries Science. 71:48-55

Simmonds, M., Dolman, S. and Weilgart, L., 2004. Oceans of Noise. A Whale and Dolphin Conservation Society Science Report. The Whale and Dolphin Conservation Society. Chippernam, Wiltshire, United Kingdom.

Skjoldal, Hein Rune, et al., 2009. Arctic Marine Shipping Assessment. Background Research Report on Potential Environmental Impacts from Shipping in the Arctic. Draft Version July.

Sleeman, J.C., Meekan, M.G., Fitzpatrick, B.J., Steinberg, C.R., Ancel, R., Bradshaw, C.J.A., 2010. Oceanographic and atmospheric phenomena influence the abundance of whale sharks at Ningaloo Reef, Western Australia. Journal of Experimental Marine Biology and Ecology. 383:77-81.

Slotte, A., Hansen, K., Dalen, J. and Ona, E., 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. Fisheries Research 67: 143-150.

Smith, M.E., 2012. Predicting hearing loss in fishes. pp 571–574 in Popper, A.N. and Hawkins, A.D. (eds.). The effects of noise on aquatic life. Springer Science + Business Media, New York, USA.

Smith, M.E., 2015. The relationship between hair cell loss and hearing in fishes. In Popper, A.N. and Hawkins, A.D. (eds.). The effects of noise on aquatic life II. Springer Science+Business Media, New York, USA.

Smith, M.E., Coffin, A.B., Miller, D.L., Popper, A.N., 2006. Anatomical and functional recovery of the goldfish (*Carassius auratus*) ear following noise exposure. Journal of Experimental Biology 209:4193–4202.

Smith, M.E., Kane, A.S., Popper, A.N., 2004a. Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). Journal of Experimental Biology 207:427–435.

Smith, M.E., Kane, A.S., Popper, A.N., 2004b. Acoustical stress and hearing sensitivity in fishes: does the linear threshold shift hypothesis hold water? Journal of Experimental Biology 207:3591–3602.

Smith, M.E., Schuck, J.B., Gilley, R.R., Rogers, B.D., 2011. Structural and functional effects of acoustic exposure in goldfish: evidence for tonotopy in the teleost saccule. BMC Neuroscience 12:19.

Song, J., Mathieu, A., Soper, R.F. and Popper, A.N., 2006. Structure of the inner ear of bluefin tuna *Thunnus thynnus*. Journal of Fish Biology 68(6):1767–1781.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. and Tyack, P.L., 2007. Marine mammal sound exposure criteria: Initial scientific recommendations. Aquatic Mammals, vol. 33, iss. 4, pp. 411-509.

Southall, B.L., Nowacek, D.P., Miller, P.J.O. and Tyack, P.L., 2016. Experimental field studies to measure behavioural responses of cetaceans to sonar. Endangered Species Research. DOI: https://doi.org/10.3354/esr00764

Stevens, J.D., Pillans, R.D. and Salini, J., 2005. Conservation Assessment of Glyphis sp. A (Speartooth Shark), Glyphis sp. C (Northern River Shark), Pristis microdon (Freshwater Sawfish) and Pristis zijsron (Green Sawfish). Hobart, Tasmania: CSIRO Marine Research.

Stewardson, C., Andrews, J., Ashby, C., Haddon, M., Hartmann, K., Hone, P., Horvat, P., Mayfield, S., Roelofs, A., Sainsbury, K., Saunders, T., Stewart, J., Nichol S and Wise, B. (eds.), 2018. Status of Australian fish stocks reports (2018), Fisheries research and Development Corporation, Canberra.

Swan, G., 2005. Occasional count no. 7, Ashmore Reef, 21 to 30 January 2002. Stilt 47

Tang, K.W., Gladyshev, M.I., Dubovskaya, O.P., Kirillin, G., Grossart H-P., 2014. Zooplankton carcasses and non-predatory mortality in freshwater and inland sea environments. Journal of Plankton Research 36: 597-612.

Tavolga, W.N and Wodinsky, J., 1963. Auditory capacities in fishes. Pure tone thresholds in nine species of marine teleosts. Bull. Amer. Mus. Nat. Hist. 126:177-240.

Thums, M., Waayers, D., Huang, Z., Pattiaratchi, C., Bernus, J. and Meekan, M., 2017. Environmental predictors of foraging and transit behaviour of flatback turtles Natator depressus. Endangered Species Research, 32: 333-349.

Tiwi Land Council, 2013. Vernon Islands. Conservation Management Plans. Available at: https://tiwilandcouncil.com/documents/Uploads/Vernon%20Islands%20Conservation%20Management%20Plan%20May%202013lr.pdf

Tonks, M., Griffiths, S., Heales, D.S., Brewer, D. and Dell, Q., 2008. Species composition and temporal variation of prawn trawl bycatch in the Joseph Bonaparte Gulf, north-western Australia. Fisheries Research. 89. 276-293. 10.1016/j.fishres.2007.09.007.

Trinnie, F., Walton, L., Wakefield, C., Newman, S., 2020. Goldband Snapper. Fisheries Research & Development Corporation. Available at: https://fish.gov.au/report/352-Goldband-Snapper-2020?jurisdictionId=4

United States Department of the Navy, 2008. Northwest training range complex draft environmental impact statement/overseas environmental impact statement. Volume 1. Prepared by United States Department of the Navy, Washington, USA.

URS, 2001. Review of Environmental Impacts of Petroleum Exploration and Appraisal Activities in Commonwealth Waters, Report prepared for the Department of Science & Resources.

Van Waerebeek, K., Baker, A.N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G.P., Secchi, E., Sutaria, D., van Helden, A., Wang, Y., 2007. Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Latin American Journal of Aquatic Mammals 6(1): 43-69.

Wales, S. and Heitmeyer, R., 2002. An ensemble source spectra model for merchant ship-radiated noise. The Journal of the Acoustical Society of America 111, 1211.

Walker D.I. and McComb A.J. 1990. Salinity response of the seagrass *Amphibolus Antartica*: an experimental validation of field results. Aquatic Botany 36: 359–366.

Walker, D.I., Wells, F.E., Hanley, R., 1996. Survey of the marine biota of the eastern Kimberley, Western Australia. University of Western Australia, Western Australian Museum and Art Gallery of the Northern Territory.

Wardle, C.S., Carter, T.J., Urquhart, G.G., Johnstone, A.D.F., Ziolkowski, A.M., Hampson, G. and Mackie, D., 2001. Effects of seismic air guns on marine fish. Continental Shelf Research 21: 1005-1027.

Warner, G., C. Erbe, and D.E. Hannay. 2010. Underwater Sound Measurements. (Chapter 3) In Reiser, C.M., D.W. Funk, R. Rodrigues, and D. Hannay (eds.). Marine Mammal Monitoring and Mitigation during Open Water Shallow Hazards and Site Clearance Surveys by Shell Offshore Inc. in the Alaskan Chukchi Sea, July-October 2009: 90-Day Report. LGL Report P1112-1. Report by LGL Alaska Research Associates Inc. and JASCO Applied Sciences for Shell Offshore Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service. pp 1-54.

Warner, G.A., M. Austin, and A.O. MacGillivray. 2017. Hydroacoustic measurements and modeling of pile driving operations in Ketchikan, Alaska. Journal of the Acoustical Society of America 141(5): 3992. https://doi.org/10.1121/1.4989141.

Wartzok, D; Ketten, D. 1999. Marine mammal sensory systems. In: Reynolds, JE; Rommel, SA (eds.) The Biology of Marine Mammals. Smithsonian Institution Press, Washington, DC.

Webb, G.J.W., Whitehead, P.J. and Manolis, S.C., 1987. Crocodile management in the Northern Territory of Australia. **In:** Webb, G. J. W., S. C. Manolis & P. J. Whitehead, eds. *Wildlife Management: Crocodiles and Alligators*. Page(s) 107-124. Sydney, Surrey Beatty & Sons.

Webster, F.J., Wise, B.S., Fletcher, W.J. and Kemps, H., 2018. Risk Assessment of the potential impacts of seismic air gun surveys on marine finfish and invertebrates in Western Australia. Fisheries Research Report No. 288 Department of Primary Industries and Regional Development, Western Australia. 42 pp.

Welch, D.J., Buckworth, R.C., Ovenden, J.R., Newman, S.J., Broderick, D., Lester, R.J.G., Ballagh, A.C., Stapley, J., Charters, R.A., and Gribble, N.A., 2009 Determination of management units for grey mackerel fisheries in northern Australia. Report. James Cook University, Townsville, Queensland, Australia.

Wells, F. E., McDonald, J. I. and Huisman, J. M., 2009. Introduced Marine Species in Western Australia. Fisheries Occasional Publications No. 57. Department of Fisheries, Perth, Western Australia. 102 pp.

Western Australian *Fish Resources Management Act 1994*. Western Australian Legislation. Available at: https://www.legislation.wa.gov.au/legislation/statutes.nsf/main_mrtitle_345_homepage.html

Whiting, A.U., Chaloupka, M., Limpus, C.J., 2008. Sampling Error for Hatchling Turtle Measurements: Probing a Rule-of-Thumb. Copeia 2008(4):889-896

Whittock, P.A., Pendoley, K.L. and Hamann, M., 2016a. Using habitat suitability models in an industrial setting: the case for interesting flatback turtles. Ecosphere 7(11): e01551.

Whittock, P.A., Pendoley, K.L. and Hamann, M., 2016b. Flexible foraging: post-nesting flatback turtles on the Australian continental shelf. Journal of Experimental Marine Biology and Ecology 477(2016): 112-119.

Whittock, P.A., Pendoley, K.L., Hamann, M., 2014. Inter-nesting distribution of flatback turtles *Natator* depressus and industrial development in Western Australia. Endangered Species Research 26(1):25-38

Wiersma, P., 1996. C*haradriidae* (Plovers) species accounts. In: del Hoyo, J., A. Elliott & J. Sargatal, eds. Handbook of the Birds of the World. Volume 3. Hoatzin to Auks. Page(s) 411-442. Barcelona: Lynx Edicions.

Wilson, S.G., Polovina, J.J., Stewart, B.S. and Meekan, M.G., 2006. Movements of Whale Sharks (*Rhincodon typus*) tagged at Ningaloo Reef, Western Australia. Marine Biology. 148:1157-1166.

Woinarski, J., Brennan, K., Hempel, C., Armstrong, M., Milne, D. and Chatto, R., 2003. Biodiversity conservation on the Tiwi Islands, Northern Territory: Part 2. Fauna. Northern Territory Government, Darwin.

Woodside, 2004. Blacktip Project: Section 7 – Existing Marine Environment. Available at https://ntepa.nt.gov.au/__data/assets/pdf_file/0010/286471/Section207.pdf.

Woodside, 2008. Torosa South-1 Pilot Appraisal Well Environment Plan. Woodside Energy, Perth

Woodside, 2011a. Impacts of seismic airgun noise on fish behaviour: a coral reef case study. Maxima 3D MSS Monitoring Program Information Sheet 1. Woodside Energy Ltd., Perth, Western Australia.

Woodside. 2011b. Impacts of Seismic Airgun Noise on Fish Diversity and Abundance: A Coral Reef Case Study. Maxima 3D MSS Monitoring Program Information Sheet 3. 12 pp.

Woodside. 2011c. Impacts of Seismic Airgun Noise on Benthic Communities: A Coral Reef Case Study. Maxima 3D MSS Monitoring Program Information Sheet 4. 12 pp.

Wyatt, R., 2008. Joint Industry Programme on sound and marine life: Review of existing data on underwater sounds produced by the oil and gas industry. Issue 1. Seiche Measurements Limited.

Zykov, M.M. and MacDonnell, J.T., 2013. Sound Source Characterizations for the Collaborative Baseline Survey Offshore Massachusetts Final Report: Side Scan Sonar, Sub-Bottom Profiler, and the R/V Small Research Vessel experimental. Document Number 00413, Version 2.0. Technical report by JASCO Applied Sciences for Fugro GeoServices, Inc. and the (US) Bureau of Ocean Energy Management.

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 6.5** - Light emissions **Section 6.3** – Noise emissions **Section 6.6** – 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 **7.5** – 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 6.7** – 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 6.7** – 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 6.2** – 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 seabed, 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 6.7** – 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 6.2** – Interaction with other marine users **Section 6.6** – Planned operational discharges **Section 7.1** to **7.5** – 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 6.2** – 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 6.6** – Planned operational discharges **Section 7.1** to **7.5** – 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	**Section 6.3** – Noise emissions

International Agreements and Conventions	Summary	Relevant to Activity?	Relevant Aspects	EP Section
			migratory species) protected under the EPBC Act.	**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, seaports 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)
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 6.3** – 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	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	**Section 7.1 to 7.5** – for unplanned hydrocarbon and non-hydrocarbon/chemical spills **Section 7.7** – Introduction of IMS

International Agreements and Conventions	Summary	Relevant to Activity?	Relevant Aspects	EP Section
	of the Sea (Prevention of Pollution from Ships) Act 1983, the Navigation Act 2012 and several Parts of Marine Orders made under this legislation.		• 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	
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. 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.	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 to the environment (refer to table above for Navigation Act 2012)	**Section 7.1** – Hydrocarbon release (vessel collision)
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 into 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 6.7** – Atmospheric emissions

Appendix B: EPBC Act Protected Matters Search Reports

1. *Operational Area*
2. *EMBA*

Australian Government
Department of Agriculture, Water and the Environment

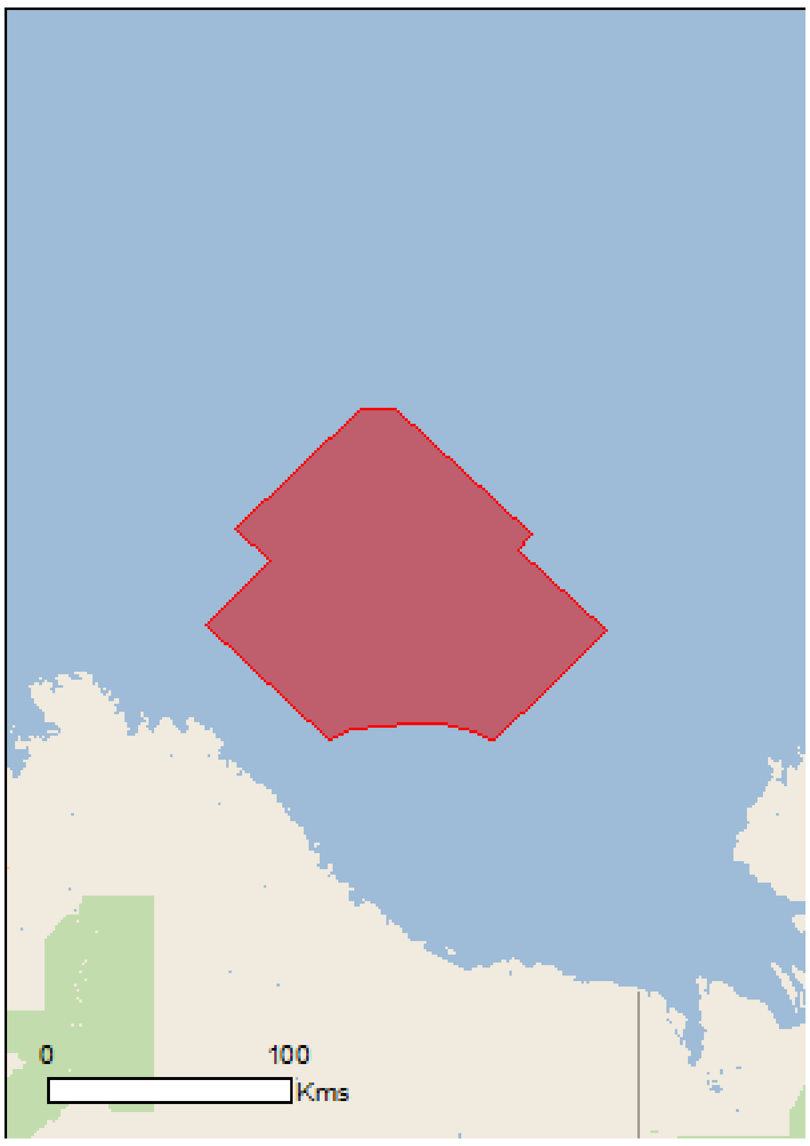
EPBC Act Protected Matters Report

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.

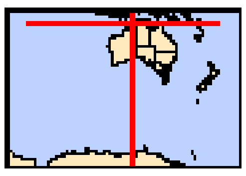
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 11/05/21 14:59:22



Coordinates
Buffer: 0.0Km



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:	36

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:	66
Whales and Other Cetaceans:	13
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)	2

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
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
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat may 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 may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
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
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat known 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
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	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	Species or species habitat may 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
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may 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 may occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may 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
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	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
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat known 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 likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area

Name	Threatened	Type of Presence
Orcinus orca Killer Whale, Orca [46]		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	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
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		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 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
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 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 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
Micrognathus micronotopterus Tidepool Pipefish [66255]		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

Name	Threatened	Type of Presence
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
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
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
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	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
Enhydrina schistosa Beaked Seasnake [1126]		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

Name	Threatened	Type of Presence
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		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 area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Species or species habitat known to 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 may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may 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 may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		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

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
Carbonate bank and terrace system of the Sahul	North-west
Pinnacles of the Bonaparte Basin	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

-12.79028 127.97056,-12.79028 128.10361,-13.24194 128.61139,-13.3 128.55694,-13.59417 128.88361,-13.98361 128.46667,-13.98139 128.46222,-13.95333 128.395,-13.92944 128.27472,-13.92583 128.16694,-13.93306 128.0575,-13.94333 127.94361,-13.97944 127.85028,-13.57139 127.39972,-13.34417 127.63722,-13.22833 127.50722,-12.79028 127.97056

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.

Department of Agriculture Water and the Environment
GPO Box 858
Canberra City ACT 2601 Australia
+61 2 6274 1111

Australian Government

Department of Agriculture, Water and the Environment

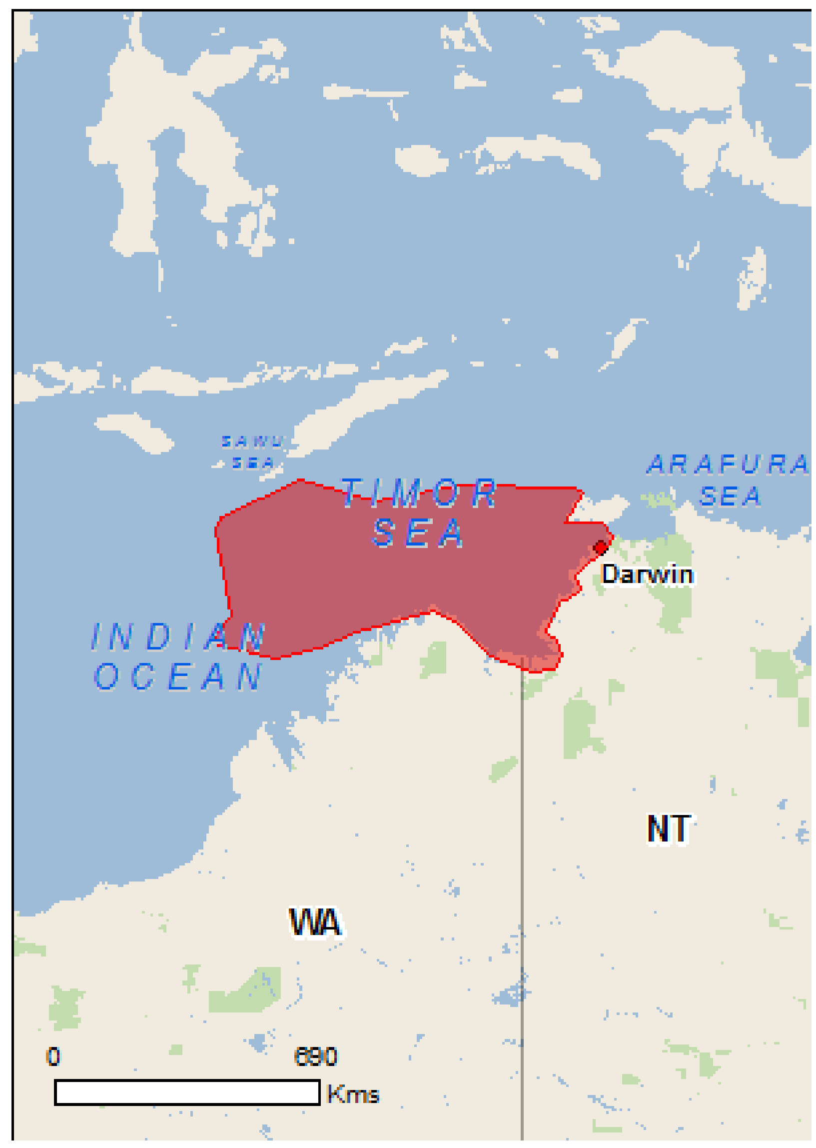
EPBC Act Protected Matters Report

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.

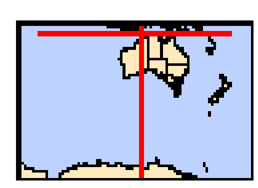
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 04/05/21 18:23:22



Coordinates

Buffer: 0.0Km



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:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	59
Listed Migratory Species:	85

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:	28
Commonwealth Heritage Places:	9
Listed Marine Species:	136
Whales and Other Cetaceans:	27
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	10

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	21
Regional Forest Agreements:	None
Invasive Species:	34
Nationally Important Wetlands:	8
Key Ecological Features (Marine)	8

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
Ashmore reef national nature reserve	Within Ramsar site
Ord river floodplain	Within Ramsar site

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
Extended Continental Shelf

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
North-west

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Anous tenuirostris melanops		
Australian Lesser Noddy [26000]	Vulnerable	Breeding 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 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
Erythrotriorchis radiatus		
Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Erythrura gouldiae		
Gouldian Finch [413]	Endangered	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Falcunculus frontatus whitei Crested Shrike-tit (northern), Northern Shrike-tit [26013]	Vulnerable	Species or species habitat likely to occur within area
Geophaps smithii blaauwi Partridge Pigeon (western) [66501]	Vulnerable	Species or species habitat likely to occur within area
Geophaps smithii smithii Partridge Pigeon (eastern) [64441]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica baueri Nunivak Bar-tailed Godwit, Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area
Melanodryas cucullata melvillensis Tiwi Islands Hooded Robin, Hooded Robin (Tiwi Islands) [67092]	Critically Endangered	Species or species habitat likely to 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
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat known to occur within area
Tyto novaehollandiae melvillensis Tiwi Masked Owl, Tiwi Islands Masked Owl [26049]	Endangered	Species or species habitat known to occur within area
Mammals		
Antechinus bellus Fawn Antechinus [344]	Vulnerable	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 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
Conilurus penicillatus Brush-tailed Rabbit-rat, Brush-tailed Tree-rat, Pakooma [132]	Vulnerable	Species or species habitat known to occur

Name	Status	Type of Presence
		within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Breeding likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesembriomys gouldii gouldii Black-footed Tree-rat (Kimberley and mainland Northern Territory), Djintamoonga, Manbul [87618]	Endangered	Species or species habitat known to occur within area
Mesembriomys gouldii melvillensis Black-footed Tree-rat (Melville Island) [87619]	Vulnerable	Species or species habitat known to occur within area
Petrogale concinna canescens Nabarlek (Top End) [87606]	Endangered	Species or species habitat likely to occur within area
Petrogale concinna concinna Nabarlek (Victoria River District) [87605]	Critically Endangered	Species or species habitat likely to occur within area
Petrogale concinna monastria Nabarlek (Kimberley) [87607]	Endangered	Species or species habitat known to occur within area
Phascogale pirata Northern Brush-tailed Phascogale [82954]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Sminthopsis butleri Butler's Dunnart [302]	Vulnerable	Species or species habitat likely to occur within area
Xeromys myoides Water Mouse, False Water Rat, Yirrkoo [66]	Vulnerable	Species or species habitat known to occur within area
Plants		
Burmannia sp. Bathurst Island (R.Fensham 1021) [82017]	Endangered	Species or species habitat likely to occur within area
Stylidium ensatum a triggerplant [86366]	Endangered	Species or species habitat known to occur within area
Typhonium jonesii a herb [62412]	Endangered	Species or species habitat likely to occur within area
Typhonium mirabile a herb [79227]	Endangered	Species or species habitat likely to occur within area
Xylopia monosperma a shrub [82030]	Endangered	Species or species habitat likely to occur within area
Reptiles		
Acanthophis hawkei Plains Death Adder [83821]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	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	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
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	Breeding known to occur within area
Glyphis glyphis Speartooth Shark [82453]	Critically Endangered	Species or species habitat known to 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	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]		Breeding known to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding known 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 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
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may 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	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

Name	Threatened	Type of Presence
		within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Breeding 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	Breeding known 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 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
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	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]		Breeding known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area
Migratory Terrestrial Species		
Cecropis daurica Red-rumped Swallow [80610]		Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to 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 known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
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 known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Roosting known to occur within area
Charadrius dubius Little Ringed Plover [896]		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 known 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
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 Greater Crested Tern [83000]		Breeding known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area
Tringa incana Wandering Tattler [831]		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
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Commonwealth Land - Australian Customs Service
Commonwealth Land - Australian Government Solicitor
Commonwealth Land - Department of Administrative Services
Commonwealth Land - Department of Community Services & Health
Commonwealth Land - Department of Immigration Local Government & Ethnic Affairs
Commonwealth Land - Department of Transport & Regional Development
Commonwealth Land - Deputy Crown Solicitor
Commonwealth Land - Director of Property Services Defence Estate
Defence - AUSTRALIAN ARMY BAND - DARWIN
Defence - BERRIMAH ONE
Defence - BRADSHAW FIELD TRAINING AREA
Defence - DARWIN - AP10 RADAR SITE - LEE POINT
Defence - DARWIN - AP3 RECEIVING STATION - LEE POINT
Defence - DARWIN RELOCATIONS CENTRE
Defence - DEFENCE FORCE CAREERS REFERENCE CENTRE
Defence - Esanda Builidng
Defence - HMAS COONAWARRA (Berrimah)
Defence - LARRAKEYAH BARRACKS
Defence - LEANYER BOMBING RANGE
Defence - MT GOODWIN RADAR SITE
Defence - Patrol Boat Base (DARWIN NAVAL BASE)
Defence - QUAIL ISLAND BOMBING RANGE
Defence - RAAF BASE DARWIN
Defence - SHOAL BAY RECEIVING STATION
Defence - STOKES HILL OIL FUEL INSTALLATION
Defence - WINNELLIE ONE
Defence - WINNELLIE TWO

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Ashmore Reef National Nature Reserve	EXT	Listed place
Bradshaw Defence Area	NT	Listed place
Historic		
Larrakeyah Barracks Headquarters Building	NT	Listed place
Larrakeyah Barracks Precinct	NT	Listed place
Larrakeyah Barracks Sergeants Mess	NT	Listed place
RAAF Base Commanding Officers Residence	NT	Listed place
RAAF Base Precinct	NT	Listed place
RAAF Base Tropical Housing Type 2	NT	Listed place
RAAF Base Tropical Housing Type 3	NT	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		
Acrocephalus orientalis Oriental Reed-Warbler [59570]		Species or species habitat known to occur within area
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous minutus Black Noddy [824]		Breeding known to occur within area
Anous stolidus Common Noddy [825]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Anous tenuirostris melanops Australian Lesser Noddy [26000]	Vulnerable	Breeding known to occur within area
Anseranas semipalmata Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely 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 known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris subminuta Long-toed Stint [861]		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 dubius Little Ringed Plover [896]		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 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

Name	Threatened	Type of Presence
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Breeding known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting known 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
Heteroscelus incanus Wandering Tattler [59547]		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 known to 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
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to 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

Name	Threatened	Type of Presence
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 known to occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Breeding 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
Rhipidura rufifrons		
Rufous Fantail [592]		Species or species habitat 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
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 glareola		
Wood Sandpiper [829]		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
Xenus cinereus		
Terek Sandpiper [59300]		Roosting known to occur

Name	Threatened	Type of Presence within area
Fish		
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		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 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 haematopterus Reef-top Pipefish [66201]		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
Festucalex cinctus Girdled Pipefish [66214]		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

Name	Threatened	Type of Presence
		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 cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys parvicarinatus Short-keel Pipefish, Short-keeled Pipefish [66230]		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
Micrognathus micronotopterus Tidepool Pipefish [66255]		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]		Breeding known to occur within area

Name	Threatened	Type of Presence
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 foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to 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 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, Johnstone's 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
Enhydrina schistosa Beaked Seasnake [1126]		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

Name	Threatened	Type of Presence
		area
Hydrophis atriceps Black-headed Seasnake [1101]		Species or species habitat may occur within area
Hydrophis coggeri Slender-necked Seasnake [25925]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis inornatus Plain Seasnake [1107]		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
Hydrophis pacificus Large-headed Seasnake, Pacific Seasnake [1112]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Parahydrophis mertoni Northern Mangrove Seasnake [1090]		Species or species habitat may 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	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

Name	Status	Type of Presence
		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	Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcaella brevirostris Irrawaddy Dolphin [45]		Species or species habitat known 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]		Breeding 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

Name	Status	Type of Presence
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known 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
Ashmore Reef	Recreational Use Zone (IUCN IV)
Ashmore Reef	Sanctuary Zone (IUCN Ia)
Cartier Island	Sanctuary Zone (IUCN Ia)
Joseph Bonaparte Gulf	Multiple Use Zone (IUCN VI)
Joseph Bonaparte Gulf	Special Purpose Zone (IUCN VI)
Kimberley	Multiple Use Zone (IUCN VI)
Oceanic Shoals	Habitat Protection Zone (IUCN IV)
Oceanic Shoals	Multiple Use Zone (IUCN VI)
Oceanic Shoals	National Park Zone (IUCN II)
Oceanic Shoals	Special Purpose Zone (Trawl) (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Balanggarra	WA
Browse Island	WA
Buffalo Creek	NT
Casuarina	NT
Channel Point	NT
Charles Darwin	NT
George Brown Darwin	NT
Holmes Jungle	NT
Keep River	NT
Knuckey Lagoons	NT
Lesueur Island	WA
Low Rocks	WA
Marri-Jabin (Thamurrurr - Stage 1)	NT
Mijing	WA
Ord River	WA
Pelican Island	WA
Shoal Bay	NT
Tree Point Conservation Area	NT
Unnamed WA41775	WA
Unnamed WA44677	WA
Uunguu	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		
Acridotheres tristis		
Common Myna, Indian Myna [387]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Bubalus bubalis Water Buffalo, Swamp Buffalo [1]		Species or species habitat likely to occur within area
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
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
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area
Plants		
Andropogon gayanus Gamba Grass [66895]		Species or species habitat likely to occur within area
Annona glabra Pond Apple, Pond-apple Tree, Alligator Apple, Bullock's Heart, Cherimoya, Monkey Apple, Bobwood, Corkwood [6311]		Species or species habitat may occur within area

Name	Status	Type of Presence
Brachiaria mutica Para Grass [5879]		Species or species habitat likely to occur within area
Cabomba caroliniana Cabomba, Fanwort, Carolina Watershield, Fish Grass, Washington Grass, Watershield, Carolina Fanwort, Common Cabomba [5171]		Species or species habitat likely to occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Dolichandra unguis-cati Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw Creeper, Funnel Creeper [85119]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Hymenachne amplexicaulis Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		Species or species habitat likely to occur within area
Jatropha gossypifolia Cotton-leaved Physic-Nut, Bellyache Bush, Cotton-leaf Physic Nut, Cotton-leaf Jatropha, Black Physic Nut [7507]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Mimosa pigra Mimosa, Giant Mimosa, Giant Sensitive Plant, ThornySensitive Plant, Black Mimosa, Catclaw Mimosa, Bashful Plant [11223]		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
Pennisetum polystachyon Mission Grass, Perennial Mission Grass, Missiongrass, Feathery Pennisetum, Feather Pennisetum, Thin Napier Grass, West Indian Pennisetum, Blue Buffel Grass [21194]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Vachellia nilotica Prickly Acacia, Blackthorn, Prickly Mimosa, Black Piquant, Babul [84351]		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
Lepidodactylus lugubris Mourning Gecko [1712]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat known to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Ashmore Reef	EXT
Daly-Reynolds Floodplain-Estuary System	NT
Finniss Floodplain and Fog Bay Systems	NT

Name	State
Legune Wetlands	NT
Moyle Floodplain and Hyland Bay System	NT
Ord Estuary System	WA
Port Darwin	NT
Shoal Bay - Micket Creek	NT

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
Carbonate bank and terrace system of the Van	North
Pinnacles of the Bonaparte Basin	North
Ancient coastline at 125 m depth contour	North-west
Ashmore Reef and Cartier Island and surrounding	North-west
Carbonate bank and terrace system of the Sahul	North-west
Continental Slope Demersal Fish Communities	North-west
Pinnacles of the Bonaparte Basin	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

-11.0439 130.2353,-10.9566 127.471,-11.3227 125.5171,-10.8629 123.7728,-11.7048 121.8721,-11.9801 121.7867,-13.972 122.1254,-14.3529 121.8266,-14.5889 121.7077,-14.9511 123.1727,-14.7238 124.2453,-14.3427 125.0715,-13.8653 126.9328,-14.118 127.4889,-14.8893 128.2337,-15.2174 129.2062,-15.1703 129.7083,-14.8488 129.9265,-14.5265 129.784,-14.3405 129.5399,-13.6239 129.9252,-13.5866 130.0535,-13.3382 130.3365,-13.0535 130.2342,-12.3383 131.0359,-12.1124 131.1147,-11.8525 130.8835,-11.8236 129.9975,-11.1678 130.4135,-11.0439 130.2353

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.

Department of Agriculture Water and the Environment
GPO Box 858
Canberra City ACT 2601 Australia
+61 2 6274 1111

Appendix C: Aboriginal Cultural Heritage Searches

Aboriginal Heritage Inquiry System

List of Other Heritage Places

Search Criteria

3 Other Heritage Places in Custom search area - Polygon - 128.99889348126°E, 14.8783651053468°S (GDA94) : 128.84508488751°E, 14.8571280789678°S (GDA94) : 128.652824145323°E, 14.7987154963842°S (GDA94) : 128.542960864073°E, 14.7774706525798°S (GDA94) : 128.416618090635°E, 14.7880933344264°S (GDA94) : 128.389152270323°E, 14.8199582592751°S (GDA94) : 128.372672778135°E, 14.8942915030009°S (GDA94) : 128.174918871885°E, 14.8358889642099°S (GDA94) : 128.213371020323°E, 14.719036624597°S (GDA94) : 127.971671801573°E, 14.6021216459212°S (GDA94) : 127.79039738751°E, 14.4053519033679°S (GDA94) : 127.74645207501°E, 14.2989174086433°S (GDA94) : 127.817863207823°E, 14.2403569242768°S (GDA94) : 127.94420598126°E, 14.4106722984949°S (GDA94) : 128.389152270323°E, 14.6340137354635°S (GDA94) : 129.004386645323°E, 14.6871569144032°S (GDA94) : 128.99889348126°E, 14.8783651053468°S (GDA94)

Disclaimer

The *Aboriginal Heritage Act 1972* preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

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 AboriginalHeritage@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.
Status:

- **Registered Site**: The place has been assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972.*
- **Other Heritage Place which includes:**
  - **Stored Data / Not a Site:** The place has been assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972.*
  - **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.
- **File Restricted = Yes:** Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- **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 4km²) 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.

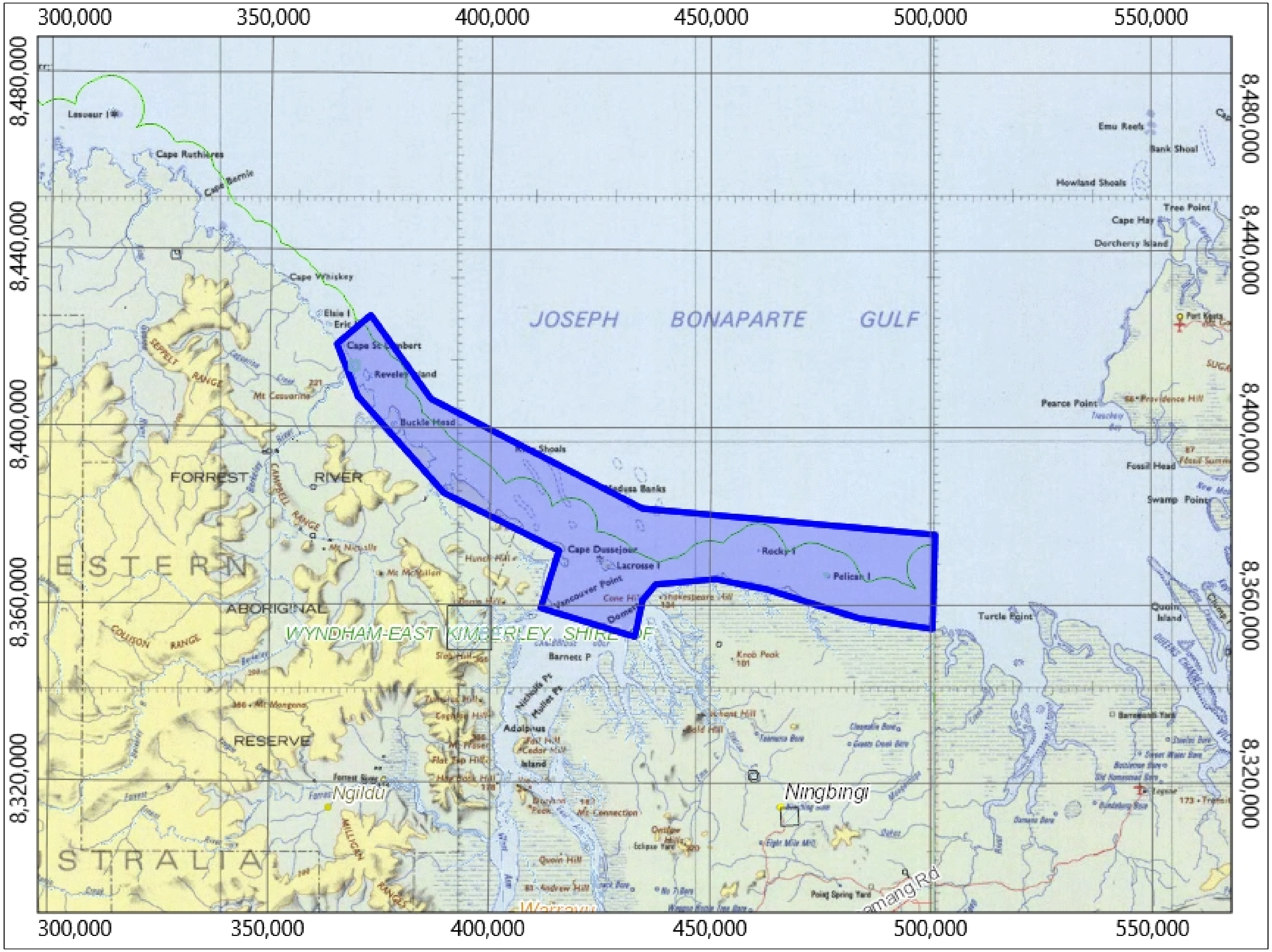
Aboriginal Heritage Inquiry System

List of Other Heritage Places

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12884	WHITE DUNES	Yes	Yes	No Gender Restrictions	Lodged	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02343
13637	BERKELEY RIVER 11	No	No	No Gender Restrictions	Lodged	Midden / Scatter	*Registered Knowledge Holder names available from DAA	368742mE 8412954mN Zone 52 [Reliable]	K01543
13846	PELICAN ISLET 2	No	No	No Gender Restrictions	Lodged	Midden / Scatter	*Registered Knowledge Holder names available from DAA	475743mE 8367204mN Zone 52 [Reliable]	K01278

Aboriginal Heritage Inquiry System

Map of Other Heritage Places



Legend

- Other Heritage Place
- Search Area
- Town
- Road
- River
- Local Government Authority

44.70 kilometres

Map Scale 1 : 1,350,000

MGA Zone 52 (GDA94)

Search Criteria

9 Registered Aboriginal Sites in Custom search area - Polygon - 128.99889348126°E, 14.8783651053468°S (GDA94) : 128.84508488751°E, 14.8571280789678°S (GDA94) : 128.652824145323°E, 14.7987154963842°S (GDA94) : 128.542960864073°E, 14.7774706525798°S (GDA94) : 128.416618090635°E, 14.7880933344264°S (GDA94) : 128.389152270323°E, 14.8199582592751°S (GDA94) : 128.372672778135°E, 14.8942915030009°S (GDA94) : 128.174918871885°E, 14.8358889642099°S (GDA94) : 128.213371020323°E, 14.719036624597°S (GDA94) : 127.971671801573°E, 14.6021216459212°S (GDA94) : 127.79039738751°E, 14.4053519033679°S (GDA94) : 127.74645207501°E, 14.2989174086433°S (GDA94) : 127.817863207823°E, 14.2403569242768°S (GDA94) : 127.94420598126°E, 14.4106722984949°S (GDA94) : 128.389152270323°E, 14.6340137354635°S (GDA94) : 129.004386645323°E, 14.6871569144032°S (GDA94) : 128.99889348126°E, 14.8783651053468°S (GDA94)

Disclaimer

The Aboriginal Heritage Act 1972 preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

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 AboriginalHeritage@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.

Status:

- Registered Site: The place has been assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Other Heritage Place which includes:
  - Stored Data / Not a Site: The place has been assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.
  - 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.
- File Restricted = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- 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 4km²) 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.

Basemap Copyright

Satellite, Hybrid, Road basemap sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, HERE, DeLorme, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community.

Topographic basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12737	BURRUNUNGU.	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Engraving, Grinding Patches / Grooves, Midden / Scatter, Mythological, Painting, Repository / Cache, Skeletal Material / Burial, Camp	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02466
12738	GANGGARRYU	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Mythological, Other: Failed PA 149	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02467
12785	NGARRMU/NGARRMIYU.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter, Mythological, Repository / Cache, Hunting Place, Other: Failed PA 148	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02461
12787	WUNDARRI.	Yes	Yes	No Gender Restrictions	Registered Site	Artefacts / Scatter, Ceremonial, Midden / Scatter, Mythological, Quarry, Camp, Hunting Place, Water Source, Other: Failed PA 150	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02463
12789	BALU-GUNANJARR COMPLEX.	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Engraving, Grinding Patches / Grooves, Midden / Scatter, Mythological, Painting, Repository / Cache, Skeletal Material / Burial, Hunting Place	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02465
12883	REVELEY ISLAND MIDDEN	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DAA	371634mE 8412664mN Zone 52 [Unreliable]	K02342
13006	BERKELEY RIVER DUNES	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K02198
13007	REVELEY ISLAND MIDDEN	No	No	No Gender Restrictions	Registered Site	Midden / Scatter	*Registered Knowledge Holder names available from DAA	371334mE 8412164mN Zone 52 [Unreliable]	K02199
13845	PELICAN ISLET 1	No	No	No Gender Restrictions	Registered Site	Engraving	*Registered Knowledge Holder names available from DAA	475733mE 8367365mN Zone 52 [Reliable]	K01277

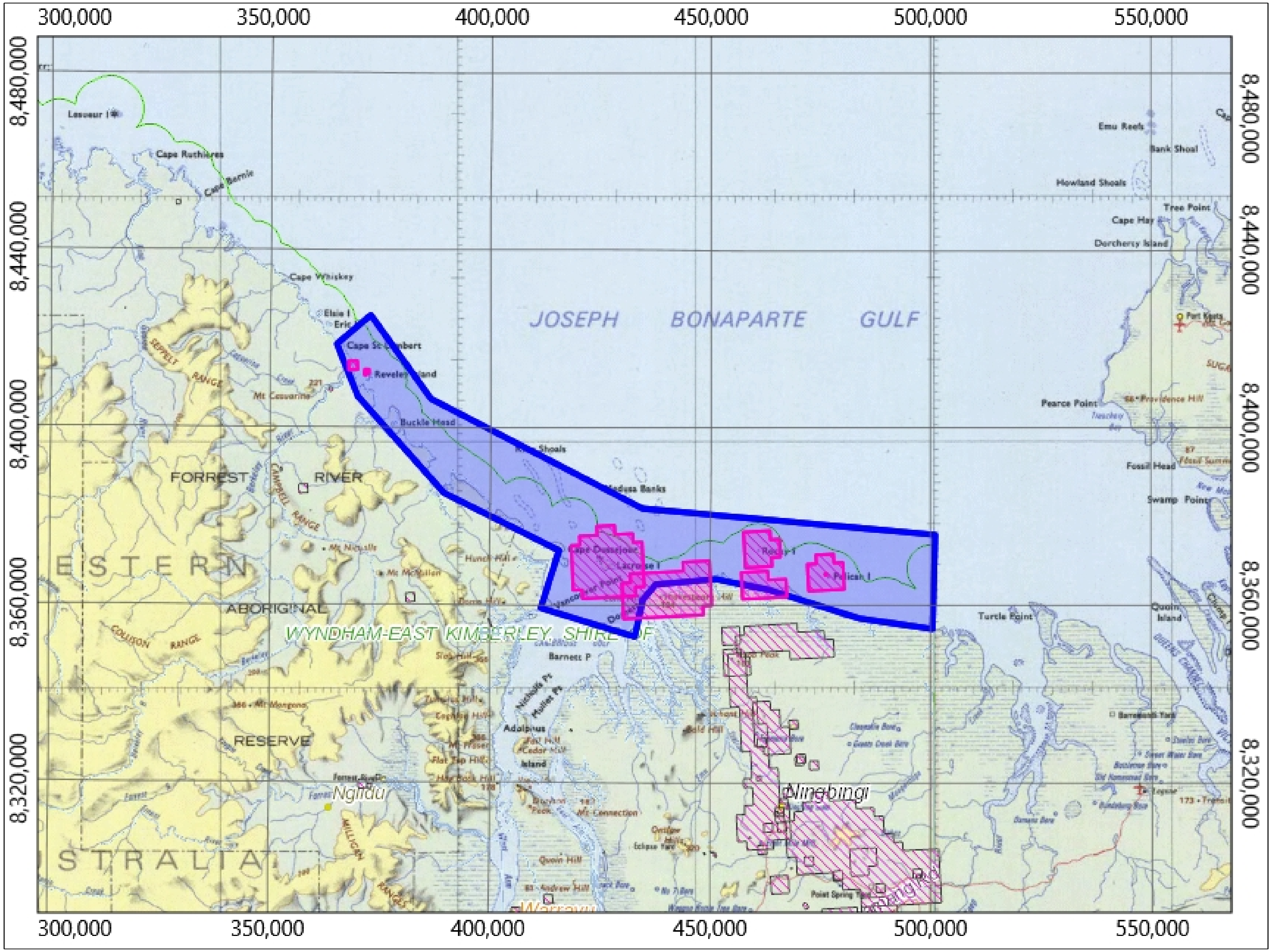
Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

Map of Registered Aboriginal Sites

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.dplh.wa.gov.au/about-this-website



Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

44.70 kilometres

Map Scale 1 : 1,350,000

MGA Zone 52 (GDA94)

Search Criteria

31 Other Heritage Places in Custom search area - Polygon - 127.762931567227°E, 14.3184785544765°S (GDA94) : 127.534965258633°E, 14.1134682384482°S (GDA94) : 127.436088305508°E, 14.0655170372148°S (GDA94) : 127.452567797696°E, 14.0015664641404°S (GDA94) : 127.381156664883°E, 13.9402637909386°S (GDA94) : 127.323478442227°E, 13.9775804052221°S (GDA94) : 127.208121996915°E, 13.9802456463935°S (GDA94) : 127.10924504379°E, 13.9829108566991°S (GDA94) : 127.048820239102°E, 13.9029411428629°S (GDA94) : 126.980155688321°E, 13.7909371445843°S (GDA94) : 126.760429125821°E, 13.8229437911077°S (GDA94) : 126.77965520004°E, 13.8736119818814°S (GDA94) : 126.532462817227°E, 13.9482607167381°S (GDA94) : 126.20836613754°E, 14.0175557794195°S (GDA94) : 125.969413500821°E, 14.0548598479039°S (GDA94) : 125.719474535978°E, 14.0548598479039°S (GDA94) : 125.722221118009°E, 13.5587582768704°S (GDA94) : 125.873283129728°E, 13.502680937872°S (GDA94) : 126.161674243009°E, 13.5000102591799°S (GDA94) : 126.169913989103°E, 13.6788793780315°S (GDA94) : 126.804374438321°E, 13.6788793780315°S (GDA94) : 126.862052660977°E, 13.6415149103041°S (GDA94) : 126.916984301602°E, 13.6254997555498°S (GDA94) : 127.290519457852°E, 13.7535905101046°S (GDA94) : 127.471793871914°E, 13.8949426489794°S (GDA94) : 127.823356371914°E, 14.2625850983888°S (GDA94) : 127.762931567227°E, 14.3184785544765°S (GDA94)

Disclaimer

The Aboriginal Heritage Act 1972 preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

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 AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

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.

Status:

- Registered Site: The place has been assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Other Heritage Place which includes:
  - Stored Data / Not a Site: The place has been assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.
  - 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.
- File Restricted = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- 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 4km²) 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.

Basemap Copyright

Satellite, Hybrid, Road basemap sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, HERE, DeLorme, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community.

Topographic basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14790	WOGARAGAL.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	195034mE 8452914mN Zone 52 [Reliable]	K00259
14792	AWADA.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	199134mE 8453564mN Zone 52 [Reliable]	K00261
14804	YAURU, PARRY HARBOUR	No	No	No Gender Restrictions	Stored Data / Not a Site		*Registered Knowledge Holder names available from DAA	177284mE 8446814mN Zone 52 [Unreliable]	K00273
14809	PARRY HARBOUR	No	No	No Gender Restrictions	Lodged	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DAA	179184mE 8446414mN Zone 52 [Reliable]	K00278
14810	BADAMAI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	178884mE 8450314mN Zone 52 [Reliable]	K00279
14811	DJIMI BADA BENDINGAI	No	No	No Gender Restrictions	Stored Data / Not a Site		*Registered Knowledge Holder names available from DAA	179034mE 8448264mN Zone 52 [Reliable]	K00280
14816	GURARINGAI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	177184mE 8458264mN Zone 52 [Reliable]	K00232
14819	DJALA BIANGGANGAI.	No	No	No Gender Restrictions	Stored Data / Not a Site	Hunting Place	*Registered Knowledge Holder names available from DAA	179584mE 8458564mN Zone 52 [Unreliable]	K00235
14820	KANAMBAI, PARRY HARBOUR.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	181635mE 8455664mN Zone 52 [Unreliable]	K00236
14821	DANDUL.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	180584mE 8457464mN Zone 52 [Reliable]	K00237
14822	WUNARAI, PARRY HARBOUR.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	182684mE 8454714mN Zone 52 [Reliable]	K00238
14824	YUMANGGU, PARRY HARBOUR.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	184584mE 8453414mN Zone 52 [Reliable]	K00240

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14825	KUALA BAY 1.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	184434mE 8457364mN Zone 52 [Reliable]	K00241
14826	BIMALAL.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	184884mE 8459064mN Zone 52 [Reliable]	K00242
14827	YALALARA.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	185534mE 8451614mN Zone 52 [Reliable]	K00243
14828	MENGERINGAI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	187634mE 8452714mN Zone 52 [Reliable]	K00244
14829	KUALA BAY 2.	No	No	No Gender Restrictions	Lodged	Artefacts / Scatter, Midden / Scatter, Camp	*Registered Knowledge Holder names available from DAA	186784mE 8457614mN Zone 52 [Reliable]	K00245
14831	RED ISLAND.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	187134mE 8461414mN Zone 52 [Reliable]	K00247
14832	MANDUREI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	188134mE 8457414mN Zone 52 [Reliable]	K00248
14833	KAN MANDJI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	190034mE 8451864mN Zone 52 [Reliable]	K00249
14834	LAININGAI 2	No	No	No Gender Restrictions	Lodged	Artefacts / Scatter, Midden / Scatter	*Registered Knowledge Holder names available from DAA	189234mE 8454264mN Zone 52 [Reliable]	K00250
14835	LANGU MANGEI.	No	No	No Gender Restrictions	Lodged	Man-Made Structure, Camp	*Registered Knowledge Holder names available from DAA	190084mE 8456464mN Zone 52 [Reliable]	K00251
14836	LAININGAI 1.	No	No	No Gender Restrictions	Lodged	Midden / Scatter, Camp	*Registered Knowledge Holder names available from DAA	190584mE 8454764mN Zone 52 [Reliable]	K00252
14837	WULUGU GUDANGAI	No	No	No Gender Restrictions	Stored Data / Not a Site		*Registered Knowledge Holder names available from DAA	190284mE 8458264mN Zone 52 [Reliable]	K00253

Aboriginal Heritage Inquiry System

List of Other Heritage Places

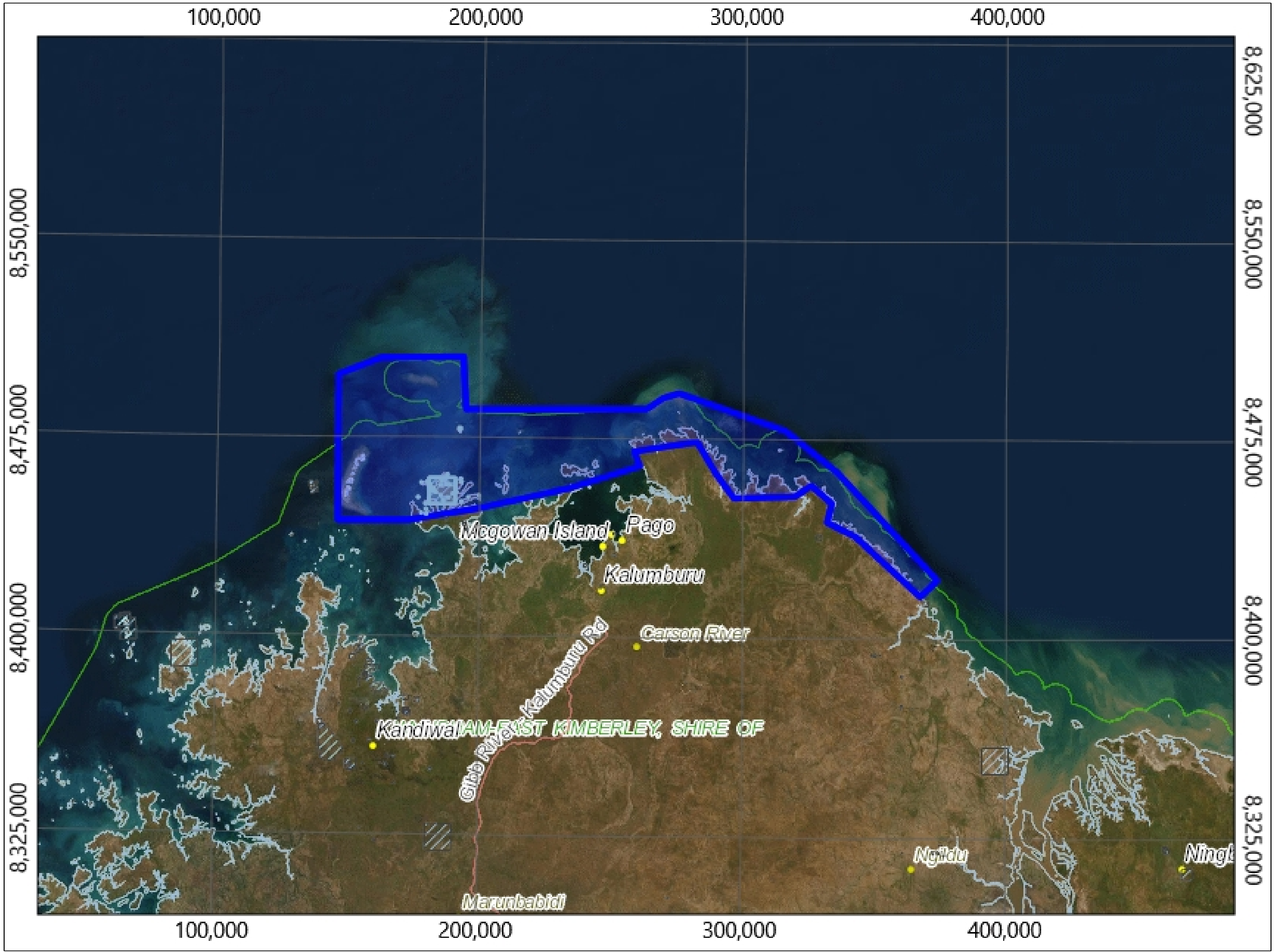
ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14838	MANGU LIMBI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	192434mE 8451214mN Zone 52 [Reliable]	K00254
14839	TROUGHTON ISLAND.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	191634mE 8478664mN Zone 52 [Unreliable]	K00255
14841	WARAMALANI.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	192334mE 8458464mN Zone 52 [Reliable]	K00257
14842	WALI PUANINGAI.	No	No	No Gender Restrictions	Lodged	Water Source	*Registered Knowledge Holder names available from DAA	192184mE 8459814mN Zone 52 [Reliable]	K00258
14867	MALAPURU, PARRY HARBOUR.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	185134mE 8455165mN Zone 52 [Unreliable]	K00229
14869	DAIBI, PARRY HARBOUR.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	185134mE 8455165mN Zone 52 [Unreliable]	K00231
14974	KULU ISLAND/ HECLA ISLAND.	No	No	No Gender Restrictions	Lodged	Camp	*Registered Knowledge Holder names available from DAA	176034mE 8452714mN Zone 52 [Reliable]	K00176

Department of Planning, Lands and Heritage

Aboriginal Heritage Inquiry System

Map of Other Heritage Places

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.dplh.wa.gov.au/about-this-website



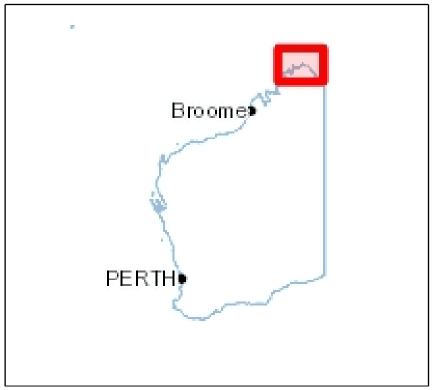
Legend

- Other Heritage Place
- Search Area
- Town
- Road
- River
- Local Government Authority

74.76 kilometres

Map Scale 1 : 2,270,000

MGA Zone 52 (GDA94)



Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.dplh.wa.gov.au/about-this-website

Search Criteria

18 Registered Aboriginal Sites in Custom search area - Polygon - 127.762931567227°E, 14.3184785544765°S (GDA94) : 127.534965258633°E, 14.1134682384482°S (GDA94) : 127.436088305508°E, 14.0655170372148°S (GDA94) : 127.452567797696°E, 14.0015664641404°S (GDA94) : 127.381156664883°E, 13.9402637909386°S (GDA94) : 127.323478442227°E, 13.9775804052221°S (GDA94) : 127.208121996915°E, 13.9802456463935°S (GDA94) : 127.10924504379°E, 13.9829108566991°S (GDA94) : 127.048820239102°E, 13.9029411428629°S (GDA94) : 126.980155688321°E, 13.7909371445843°S (GDA94) : 126.760429125821°E, 13.8229437911077°S (GDA94) : 126.77965520004°E, 13.8736119818814°S (GDA94) : 126.532462817227°E, 13.9482607167381°S (GDA94) : 126.20836613754°E, 14.0175557794195°S (GDA94) : 125.969413500821°E, 14.0548598479039°S (GDA94) : 125.719474535978°E, 14.0548598479039°S (GDA94) : 125.722221118009°E, 13.5587582768704°S (GDA94) : 125.873283129728°E, 13.502680937872°S (GDA94) : 126.161674243009°E, 13.5000102591799°S (GDA94) : 126.169913989103°E, 13.6788793780315°S (GDA94) : 126.804374438321°E, 13.6788793780315°S (GDA94) : 126.862052660977°E, 13.6415149103041°S (GDA94) : 126.916984301602°E, 13.6254997555498°S (GDA94) : 127.290519457852°E, 13.7535905101046°S (GDA94) : 127.471793871914°E, 13.8949426489794°S (GDA94) : 127.823356371914°E, 14.2625850983888°S (GDA94) : 127.762931567227°E, 14.3184785544765°S (GDA94)

Disclaimer

The Aboriginal Heritage Act 1972 preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

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 AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

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.

Status:

- Registered Site: The place has been assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Other Heritage Place which includes:
  - Stored Data / Not a Site: The place has been assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.
  - 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.
- File Restricted = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- 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.

Basemap Copyright

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14769	PARAN-GAR 1	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Fish Trap, Mythological	*Registered Knowledge Holder names available from DAA	189834mE 8447164mN Zone 52 [Reliable]	K00290
14770	PARAN-GAR 3.	No	No	No Gender Restrictions	Registered Site	Midden / Scatter, Camp	*Registered Knowledge Holder names available from DAA	189634mE 8447514mN Zone 52 [Reliable]	K00291
14791	WOGU WOGU ISLAND 1.	No	No	No Gender Restrictions	Registered Site	Man-Made Structure, Camp	*Registered Knowledge Holder names available from DAA	194534mE 8457364mN Zone 52 [Reliable]	K00260
14793	VANSITTART BAY 1-3	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Painting	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00262
14794	CHALANGDAL, VANSITTART BAY	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Painting	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00263
14796	ECLIPSE ISLANDS	No	No	No Gender Restrictions	Registered Site	Quarry	*Registered Knowledge Holder names available from DAA	208634mE 8461664mN Zone 52 [Unreliable]	K00265
14797	SIR GRAHAM MOORE ISLANDS	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Man-Made Structure, Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00266
14798	SIR GRAHAM MOORE ISLANDS	Yes	Yes	No Gender Restrictions	Registered Site	Man-Made Structure, Skeletal Material / Burial	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00267
14800	GALNGAURU	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Painting, Skeletal Material / Burial	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00269
14808	UNGGALU IS., PARRY HARBOUR	No	No	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	178234mE 8448914mN Zone 52 [Reliable]	K00277
14814	NANGIRITJI, PARRY HARBOUR.	No	No	No Gender Restrictions	Registered Site	Artefacts / Scatter, Engraving, Man-Made Structure, Camp	*Registered Knowledge Holder names available from DAA	182834mE 8449964mN Zone 52 [Reliable]	K00283
14817	PARRY HARBOUR	No	No	No Gender Restrictions	Registered Site	Engraving	*Registered Knowledge Holder names available from DAA	181635mE 8451664mN Zone 52 [Unreliable]	K00233

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
14823	NGALUMAL GUDANGARI.	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Mythological, Camp	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00239
14830	WADAI/ RED ISLAND.	Yes	Yes	No Gender Restrictions	Registered Site	Mythological, Camp	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00246
14840	WOGU WOGU ISLAND 2	No	No	No Gender Restrictions	Registered Site	Man-Made Structure	*Registered Knowledge Holder names available from DAA	192734mE 8455164mN Zone 52 [Reliable]	K00256
14971	BADANBIRI CLIFFS	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00173
14973	DIDJINA	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Engraving, Man-Made Structure, Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00175
14975	GUBARO REEF	Yes	Yes	No Gender Restrictions	Registered Site	Ceremonial, Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00177

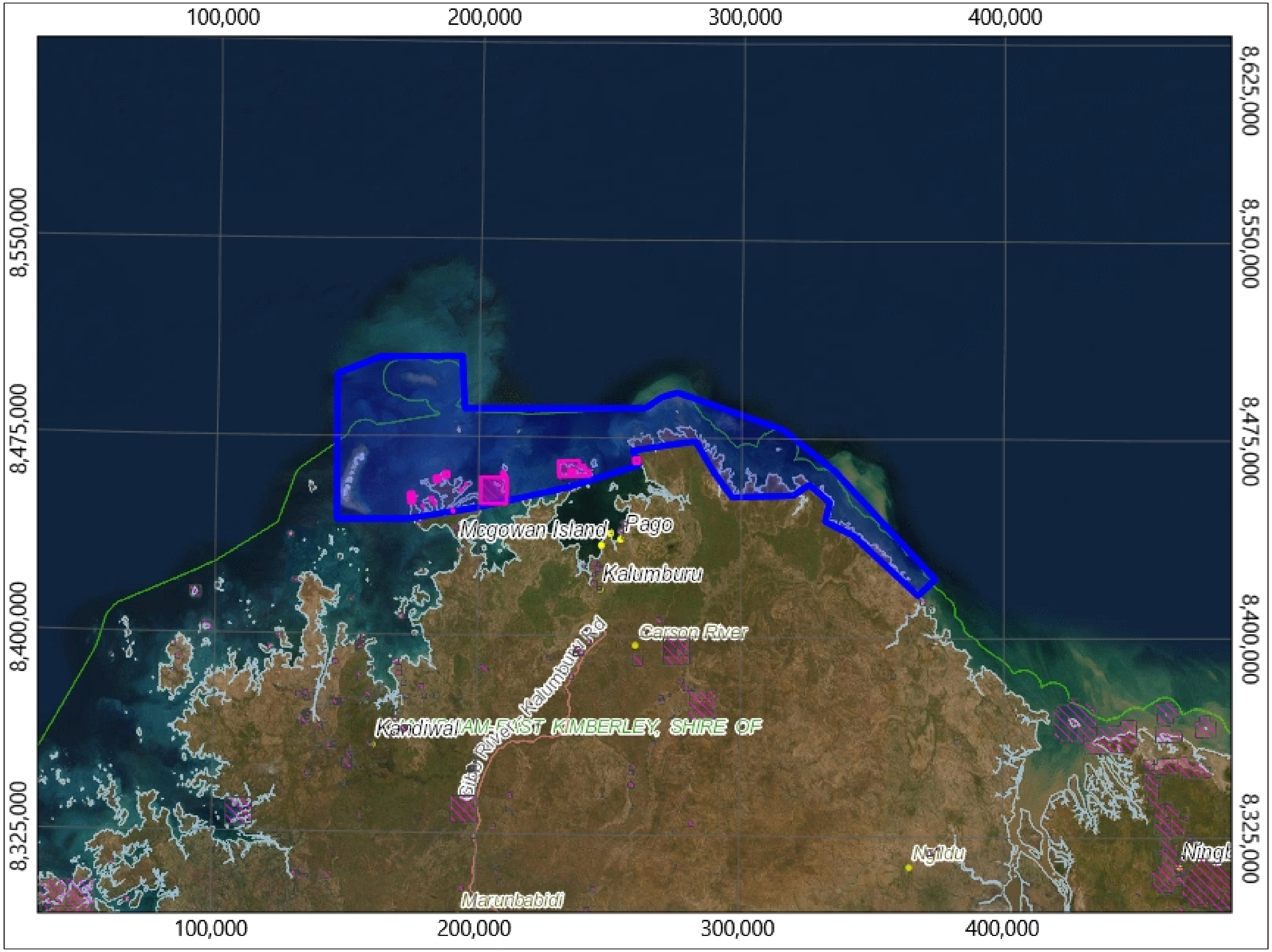
Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

Map of Registered Aboriginal Sites

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.dplh.wa.gov.au/about-this-website



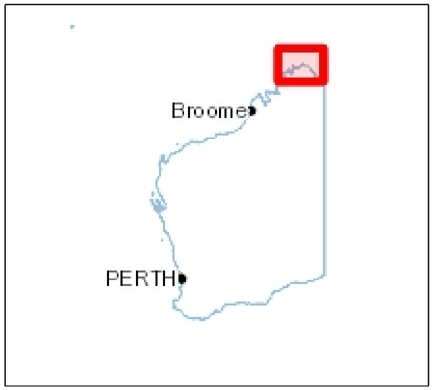
Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

74.76 kilometres

Map Scale 1 : 2,270,000

MGA Zone 52 (GDA94)



Aboriginal Heritage Inquiry System

List of Other Heritage Places

Search Criteria

10 Other Heritage Places in Custom search area - Polygon - 125.705741625822°E, 13.7936045329025°S (GDA94) : 125.713981371915°E, 14.1587462216616°S (GDA94) : 124.824088793791°E, 14.5605221138539°S (GDA94) : 124.911979418791°E, 14.3530722959616°S (GDA94) : 125.200370532072°E, 14.2306397528285°S (GDA94) : 125.499747973478°E, 14.0601885046154°S (GDA94) : 125.579398852384°E, 13.8816112120612°S (GDA94) : 125.705741625822°E, 13.7936045329025°S (GDA94)

Disclaimer

The Aboriginal Heritage Act 1972 preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

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 AboriginalHeritage@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.

Status:

- Registered Site: The place has been assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Other Heritage Place which includes:
  - Stored Data / Not a Site: The place has been assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.
  - 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.
- File Restricted = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- 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 4km²) 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.

Basemap Copyright

Satellite, Hybrid, Road basemap sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, HERE, DeLorme, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community.

Topographic basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12707	EAST MONTALIVET ISLAND	No	No	No Gender Restrictions	Lodged	Man-Made Structure	*Registered Knowledge Holder names available from DAA	747286mE 8419411mN Zone 51 [Unreliable]	K02543
12718	CASSINI ISLAND.	No	No	No Gender Restrictions	Stored Data / Not a Site	Camp, Hunting Place, Named Place, Plant Resource	*Registered Knowledge Holder names available from DAA	784501mE 8457031mN Zone 51 [Reliable]	K02501
12719	DULI COVE CAVES.	No	No	No Gender Restrictions	Lodged	Artefacts / Scatter, Arch Deposit, Other: ?	*Registered Knowledge Holder names available from DAA	784636mE 8456661mN Zone 51 [Unreliable]	K02502
12721	DULI BAY.	No	No	No Gender Restrictions	Stored Data / Not a Site	Named Place	*Registered Knowledge Holder names available from DAA	785636mE 8456661mN Zone 51 [Unreliable]	K02504
12723	KARENA BAY.	No	No	No Gender Restrictions	Stored Data / Not a Site	Named Place	*Registered Knowledge Holder names available from DAA	785636mE 8455661mN Zone 51 [Unreliable]	K02506
12724	BELELE.	No	No	No Gender Restrictions	Stored Data / Not a Site	Named Place	*Registered Knowledge Holder names available from DAA	785636mE 8458661mN Zone 51 [Unreliable]	K02507
14504	CONDILLAC MIDDEN.	No	No	No Gender Restrictions	Lodged	Midden / Scatter, Camp	*Registered Knowledge Holder names available from DAA	776236mE 8438961mN Zone 51 [Unreliable]	K00550
14952	CASSINI ISLAND	No	No	No Gender Restrictions	Lodged	Man-Made Structure	*Registered Knowledge Holder names available from DAA	784323mE 8456687mN Zone 51 [Reliable]	K00154
24152	Saltwater Country - reef sites and fish traps (Maret Island)	Yes	Yes	No Gender Restrictions	Lodged	Ceremonial, Fish Trap, Historical, Mythological, Rockshelter, Arch Deposit, Camp, Hunting Place, Meeting Place, Named Place, Natural Feature, Ochre, Plant Resource, Shell, Water Source	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	
24153	Jaradanyingga - Jaajaal	Yes	Yes	Other Restrictions	Lodged	Ceremonial, Historical, Quarry, Rockshelter, Arch Deposit, Camp, Hunting Place, Meeting Place, Named Place, Natural Feature, Ochre, Plant Resource, Shell, Water Source	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	

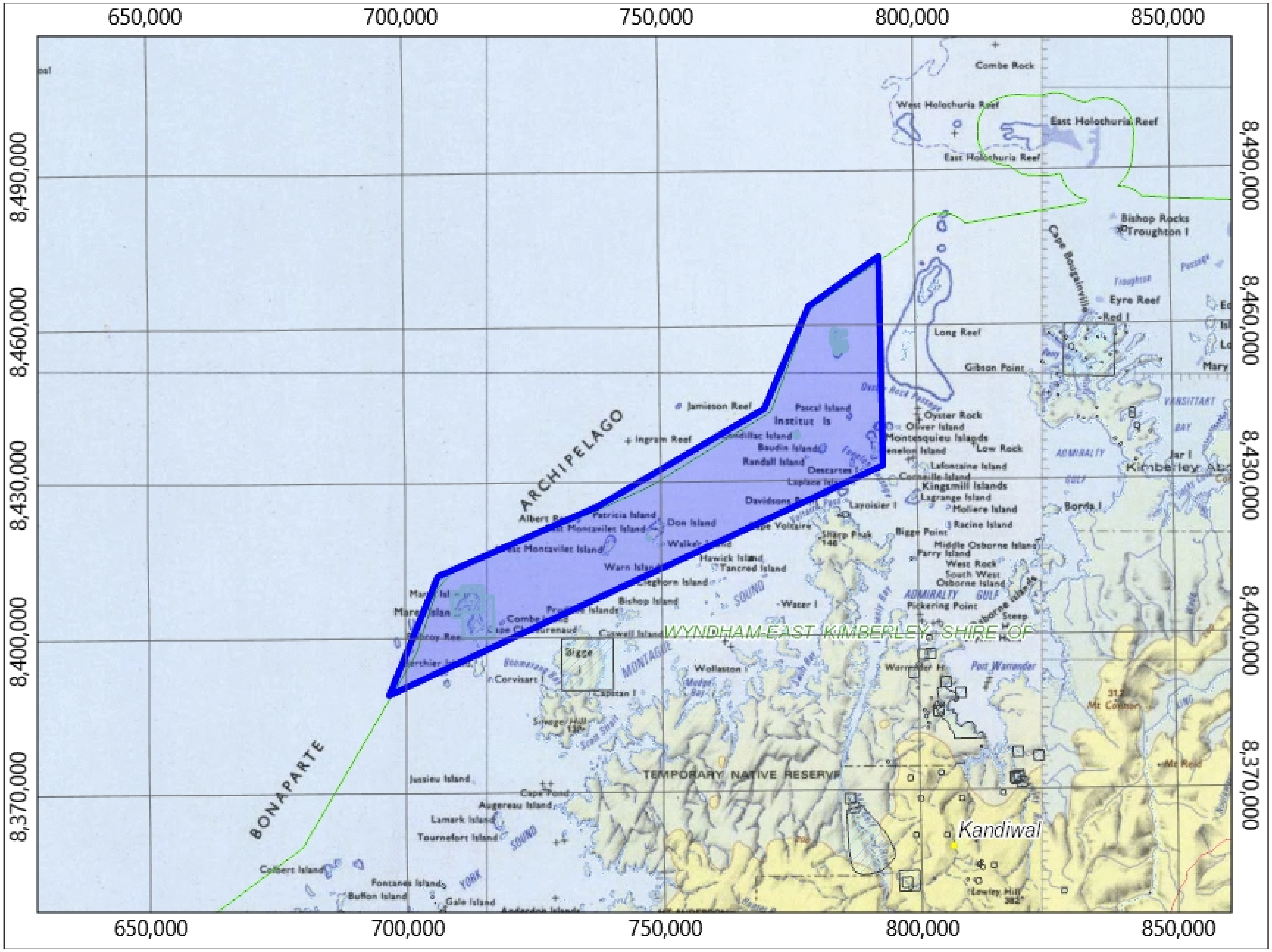
Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

Map of Other Heritage Places

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.dplh.wa.gov.au/about-this-website



Legend

- Other Heritage Place
- Search Area
- Town
- Road
- River
- Local Government Authority

38.33 kilometres

Map Scale 1 : 1,160,000

MGA Zone 51 (GDA94)

Map created: 19/05/2021 4:48:52 PM by: GIS_NET_USER

Identifier: 533495

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

Search Criteria

11 Registered Aboriginal Sites in Custom search area - Polygon - 125.705741625822°E, 13.7936045329025°S (GDA94) : 125.713981371915°E, 14.1587462216616°S (GDA94) : 124.824088793791°E, 14.5605221138539°S (GDA94) : 124.911979418791°E, 14.3530722959616°S (GDA94) : 125.200370532072°E, 14.2306397528285°S (GDA94) : 125.499747973478°E, 14.0601885046154°S (GDA94) : 125.579398852384°E, 13.8816112120612°S (GDA94) : 125.705741625822°E, 13.7936045329025°S (GDA94)

Disclaimer

The Aboriginal Heritage Act 1972 preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

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 AboriginalHeritage@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.
Status:

- Registered Site: The place has been assessed as meeting Section 5 of the Aboriginal Heritage Act 1972.
- Other Heritage Place which includes:
  - Stored Data / Not a Site: The place has been assessed as not meeting Section 5 of the Aboriginal Heritage Act 1972.
  - 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.
- File Restricted = Yes: Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- 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 4km²) 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.

Basemap Copyright

Satellite, Hybrid, Road basemap sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, HERE, DeLorme, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community.

Topographic basemap sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community.

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

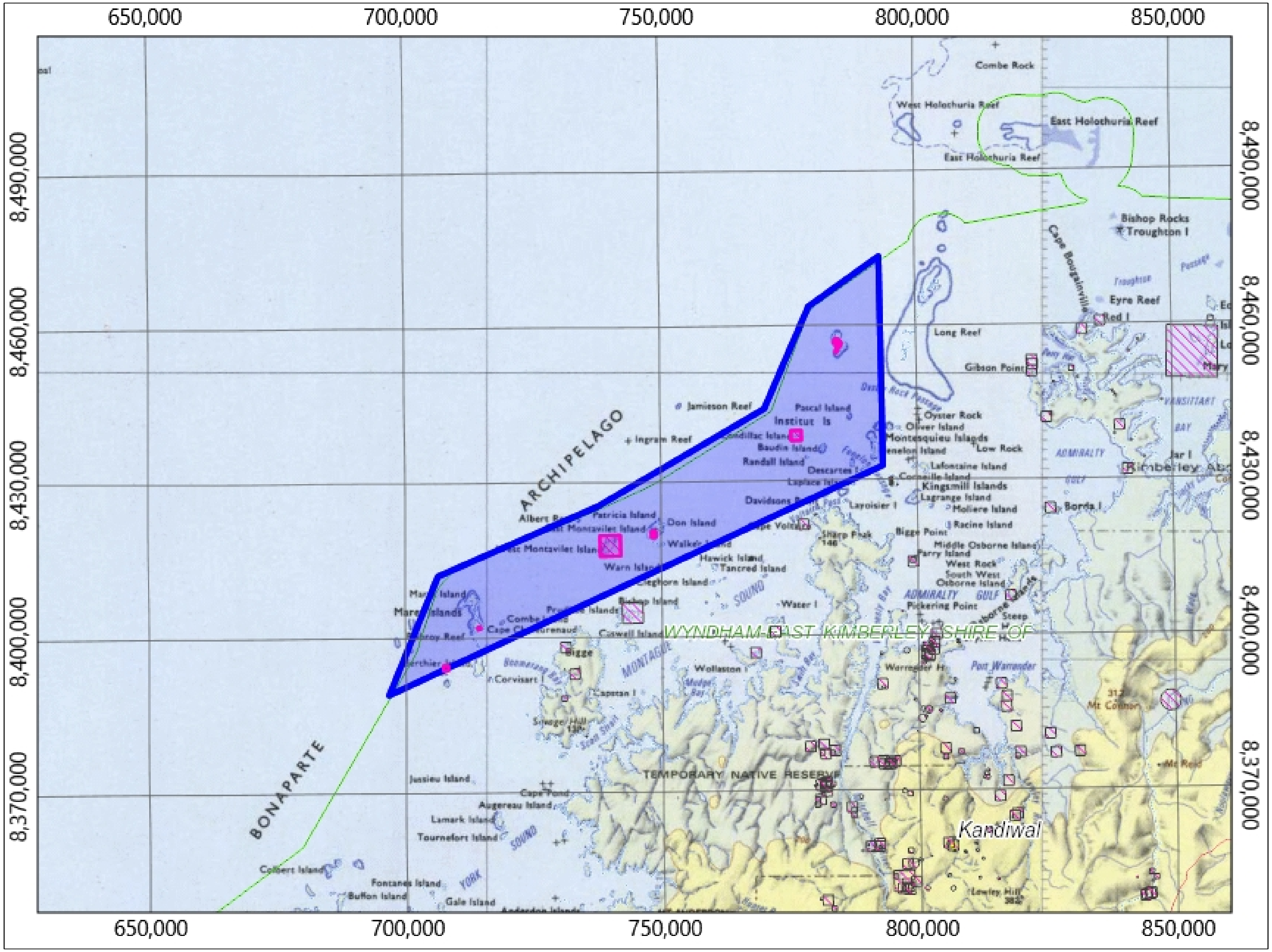
ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
12720	DULI CAVE.	No	No	No Gender Restrictions	Registered Site	Ceremonial, Mythological, Rockshelter, Camp	*Registered Knowledge Holder names available from DAA	784636mE 8456661mN Zone 51 [Unreliable]	K02503
12722	DIDJI POINT.	No	No	No Gender Restrictions	Registered Site	Man-Made Structure, Mythological, Named Place	*Registered Knowledge Holder names available from DAA	784147mE 8455259mN Zone 51 [Unreliable]	K02505
12725	DIDJI WELLS.	No	No	No Gender Restrictions	Registered Site	Mythological, Water Source	*Registered Knowledge Holder names available from DAA	784136mE 8457161mN Zone 51 [Unreliable]	K02508
12726	CASSINI STONE LINE	No	No	No Gender Restrictions	Registered Site	Man-Made Structure, Mythological	*Registered Knowledge Holder names available from DAA	784036mE 8456942mN Zone 51 [Reliable]	K02509
12727	CASSINI STONE CIRCLES	No	No	No Gender Restrictions	Registered Site	Man-Made Structure, Mythological	*Registered Knowledge Holder names available from DAA	784436mE 8456161mN Zone 51 [Unreliable]	K02510
14556	NGAMILI, CONDILLAC ISLAND	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00549
14929	ALBERT ISLAND	No	No	No Gender Restrictions	Registered Site	Engraving	*Registered Knowledge Holder names available from DAA	707636mE 8394661mN Zone 51 [Unreliable]	K00131
14930	SOUTH MARET ISLAND	No	No	No Gender Restrictions	Registered Site	Man-Made Structure	*Registered Knowledge Holder names available from DAA	714136mE 8402311mN Zone 51 [Reliable]	K00132
14934	WEST MONTALIVET ISLAND	Yes	Yes	No Gender Restrictions	Registered Site	Man-Made Structure, Mythological, Painting	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	K00136
14936	EAST MONTALIVET ISLAND	No	No	No Gender Restrictions	Registered Site	Man-Made Structure	*Registered Knowledge Holder names available from DAA	748226mE 8419974mN Zone 51 [Unreliable]	K00138
14937	EAST MONTALIVET ISLAND	No	No	No Gender Restrictions	Registered Site	Man-Made Structure	*Registered Knowledge Holder names available from DAA	748243mE 8420625mN Zone 51 [Unreliable]	K00139

Department of Planning, Lands and Heritage

GOVERNMENT OF WESTERN AUSTRALIA

Aboriginal Heritage Inquiry System

Map of Registered Aboriginal Sites



Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

38.33 kilometres

Map Scale 1 : 1,160,000

MGA Zone 51 (GDA94)

Appendix D: Stakeholder Consultation

Santos

STAKEHOLDER CONSULTATION

Petrel Sub-basin SW 3D Marine Seismic Survey

Environment Plan

STAKEHOLDER CONSULTATION

Consultation Correspondence

Consultation, Santos

From:	Consultation, Santos
Sent:	Friday, 7 May 2021 8:46 AM
Subject:	Santos Consultation - Petrel Sub-basin Marine Seismic Survey
Attachments:	SCMa6283_PetrelSub-Basin3D_survey_loc_map.png; Santos Petrel Sub-basin MSS_Stakeholder Consultation Fact Sheet_7 May 2021.pdf

Good morning,

On behalf of Santos, please find attached consultation material outlining the Petrel Sub-basin 3D Marine Seismic Survey. The offshore survey is proposed in Commonwealth waters north-east from the WA coastline.

Santos is preparing an Environment Plan (EP) in accordance with the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cth). The EP will then be submitted to NOPSEMA for formal assessment.

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.

Please also note the following information provided by NOPSEMA:

- Effective 25 April 2019, amendments to the Offshore Petroleum and Greenhouse Gas Storage Environment Regulations 2009 (Environment Regulations) took effect introducing a 30-day public comment period for seismic and exploratory drilling proposals. When the public comment period is underway, seismic and exploration drilling environment plans will be published in full on NOPSEMA's website at www.nopsema.gov.au This will provide an additional opportunity for interested parties to comment on the environment plan.

- The Environment Regulations require NOPSEMA to publish the environment plan submitted by the titleholder for assessment, and to publish the final accepted version of an environment plan. Environment plans are published in full, with the exception of sensitive information from the consultation process and transcripts of correspondence between stakeholders and the titleholder. This information is used by NOPSEMA during the assessment, but is not published for wider review.

If you do not wish for your comments to be published in this environment plan, or wish to provide your comments anonymously, please make this known to Santos as soon as possible.

We look forward to hearing from you.

Kind regards

[redacted]

Santos Limited, 100 St George's Terrace, Perth WA 6000

[redacted]

https://www.santos.com/

[redacted]

From: [redacted]
Sent: Monday, 10 May 2021 11:52 AM
Cc: Marren, Michael (Michael)
Subject: ![EXT]: Petrel Sub-basin 3D Marine Seismic Survey
Attachments: Santos Petrel Sub-basin MSS_ Additional Information for Mackerel Managed Fishery_7052021.pdf; SCMa6283_PetrelSub-Basin3D_survey_loc_map.png; Petrel Sub-basin Survey coordinates.xlsx

Good Morning Commercial Fishers

On behalf of Santos, please find attached consultation material outlining the Petrel Sub-basin 3D Marine Seismic Survey. A summary table is provided below. The offshore survey is proposed in Commonwealth waters north-east from the WA coastline. As an identified relevant stakeholder under this EP, please be advised of the proposed marine seismic survey.

Activity:	3D Marine Seismic Survey
Location:	Commonwealth waters of the southern Bonaparte Basin (i.e. Petrel Sub-basin). Proposed operational area is ~28 km north-east from the Western Australian (WA) coastline and ~80 km north-west from the Northern Territory (NT) coastline, at their closest points.
Permits:	WA-454-P, WA-27-R, WA-40-R WA-69-R, NT/P84
Earliest start date:	1 October 2021, pending regulatory and business approvals and vessel availability.
Estimated timing	Santos intends to acquire the full survey between 1 October 2021 and 31 March 2022. However, should this not be achievable, then some or all of the survey may instead be acquired the following year, between 1 October 2022 and 31 March 2023. The total survey duration for Areas A, B and C, including contingency is 100 days. Santos will endeavour to limit the survey to the October-March window, however, if this is not possible for operational reasons then Area A of the survey may need to be acquired, over ~30 days, at a different time. Operations will be undertaken on a 24-hour basis.
Water depth:	Range between 59 and 103 metres in Fullfold Acquisition Area.
Area of avoidance:	Three (3) nautical miles requested around the survey vessel and streamers.
Total acquisition area:	3,584 km2.
Total operational area:	12,832 km2.
Source volume:	Less than 3,500 cubic inches

WAFIC is sending this information to you on a fee-for-service basis to ensure commercial fishers receive this in a timely manner via an accurate list. If you have any questions/comments regarding the proposed seismic survey please contact [redacted] Email: Offshore.Consultation@Santos.com before the 11 June 2021.

Kind regards

[redacted]

WAFIC

[redacted]

STAKEHOLDER CONSULTATION

Consultation Material

Santos

Petrel Sub-basin

Marine Seismic Survey (MSS)

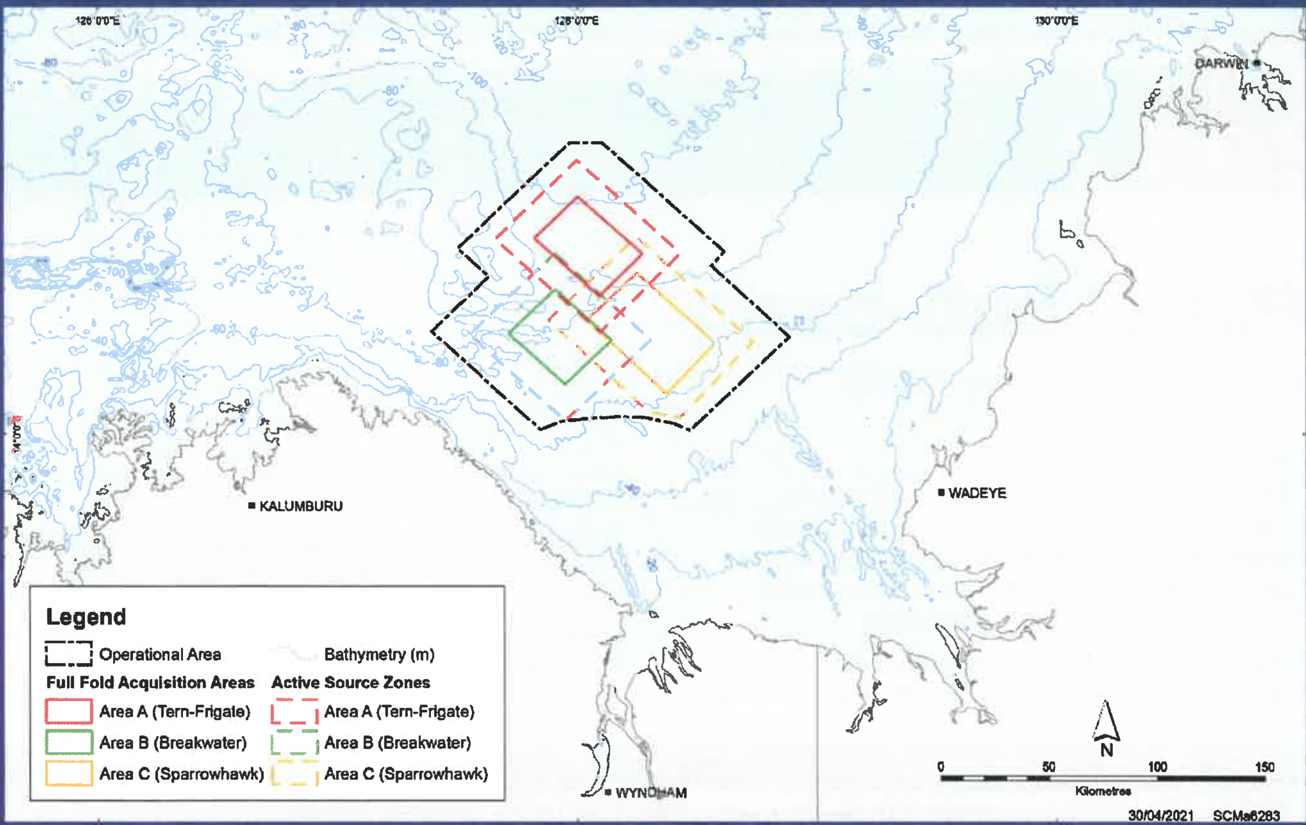
Santos is seeking to acquire subsurface data via a 3D Marine Seismic Survey (MSS) in Commonwealth waters of the southern Bonaparte Basin. The proposed operational area is located approximately 28 km north-east from the Western Australian (WA) coastline and 80 km north-west from the Northern Territory (NT) coastline, at their closest points.

The proposed activity is required to complete exploration and appraisal of the hydrocarbon resources within Santos' petroleum permits (WA-454-P, WA-27-R, WA-40-R, NT/P84) in the Petrel Sub-basin.

Results from previous exploration drilling and seismic acquisition undertaken in the area have highlighted potential for further oil and gas resources. In order to evaluate this potential and provide adequate coverage and data quality, Santos requires additional subsurface data via a seismic survey.

PETREL SUB-BASIN 3D MSS INFORMATION		
Earliest commencement date	1 October 2021, pending regulatory and business approvals and vessel availability.	
Estimated timing and duration	Santos intends to acquire the full survey between 1 October 2021 and 31 March 2022. However, should this not be achievable, then some or all of the survey may instead be acquired the following year, between 1 October 2022 and 31 March 2023. The total survey duration for Areas A, B and C, including contingency is 100 days. Santos will endeavour to limit the survey to the October-March window, however, if this is not possible for operational reasons then Area A of the survey may need to be acquired, over ~30 days, at a different time. Operations will be undertaken on a 24-hour basis.	
Water depth	The water depths of the Full-fold Acquisition Areas range between 59 and 103 metres (m).	
Anticipated worst case oil spill scenario	Vessel collision causing release from fuel tank. 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 the activity-specific Oil Pollution Emergency Plan (OPEP) arrangements described in the EP.	
Survey vessels	One survey vessel, with up to two support vessels. Vessel details are unknown at this point in time.	
Aircraft	Aircraft (including helicopters and drones) may be used for crew changes, critical equipment supply and emergency response.	
Area of avoidance	Three (3) nautical miles requested around the survey vessel and streamers.	
Proximity to regional features	**Regional Feature**	**Distance (km)**
	Nearest WA mainland point	28 km south-west
	Nearest NT mainland point	80 km south-east
	Kulumburu, WA	115 km south-west
	Wyndham, WA	170 km south
	Wadeye, NT	99 km south-east
	Darwin, NT	260 km east north-east
	Oceanic Shoals Australian Marine Park	10 km north
	Joseph Bonaparte Gulf Australian Marine Park	15 km south-east
	Kimberley Australian Marine Park	105 km west
	North Kimberley Marine Park (WA)	22 km south-west

Petrel Sub-basin Seismic Survey location map



		GDA 94 MGA Zone 52		GDA 94	
		Easting (m)	Northing (m)	Latitude	Longitude
FULL-FOLD ACQUISITION AREA	Area A	391704.285	8561195.187	13° 00' 47.416" S	128° 00' 04.810" E
		420634.125	8534780.986	13° 15' 10.422" S	128° 16' 02.607" E
		401431.420	8515494.426	13° 25' 36.122" S	128° 05' 22.187" E
		372501.580	8541908.627	13° 11' 12.458" S	127° 49' 24.428" E
	Area B	361244.998	8498076.455	13° 34' 57.167" S	127° 43' 02.997" E
		381943.745	8518433.074	13° 23' 57.906" S	127° 54' 34.648" E
		407147.178	8495282.409	13° 36' 34.665" S	128° 08' 29.890" E
		386448.431	8474868.769	13° 47' 36.418" S	127° 56' 58.167" E
	Area C	396139.004	8504607.349	13° 31' 29.821" S	128° 02' 24.796" E
		418198.564	8526204.121	13° 19' 49.364" S	128° 14' 40.812" E
		453678.975	8494040.357	13° 37' 19.097" S	128° 34' 18.334" E
		431696.546	8470693.094	13° 49' 57.490" S	128° 22' 04.702" E
		Easting (m)	Northing (m)	Latitude	Longitude
ACTIVE SOURCE ZONES	Area A	437978.942	8535193.888	13° 14' 58.455" S	128° 25' 38.998" E
		401826.843	8498883.916	13° 34' 36.815" S	128° 5' 33.293" E
		355156.762	8541495.721	13° 11' 23.071" S	127° 39' 48.254" E
		391308.861	8577805.693	12° 51' 46.712" S	127° 59' 53.843" E
	Area B	381661.529	8534986.417	13° 14' 59.104" S	127° 54' 27.684" E
		424549.840	8495591.275	13° 36' 26.421" S	128° 18' 9.040" E
		386732.431	8458294.765	13° 56' 35.876" S	127° 57' 5.203" E
		343840.366	8497790.395	13° 35' 3.311" S	127° 33' 23.933" E
	Area C	417882.111	8542687.800	13° 10' 52.785" S	128° 14' 31.955" E
		470798.740	8494717.724	13° 36' 57.847" S	128° 43' 48.137" E
		437711.176	8459575.837	13° 55' 59.849" S	128° 25' 24.157" E
		431967.212	8460733.159	13° 55' 21.705" S	128° 22' 12.843" E
		423726.904	8462259.142	13° 54' 31.284" S	128° 17' 38.404" E
		378870.568	8504494.678	13° 31' 31.103" S	127° 52' 50.372" E
		Easting (m)	Northing (m)	Latitude	Longitude
OPERATIONAL AREA		388279.539	8585821.554	12° 47' 25.415" S	127° 58' 14.408" E
		402719.404	8585875.502	12° 47' 25.408" S	128° 6' 13.317" E
		457915.415	8536051.280	13° 14' 31.792" S	128° 36' 41.531" E
		452034.900	8529637.779	13° 18' 0.247" S	128° 33' 25.748" E
		487425.397	8497123.380	13° 35' 39.968" S	128° 53' 1.534" E
		442425.995	8454007.098	13° 59' 1.469" S	128° 28' 0.862" E
		441925.560	8454237.535	13° 58' 53.931" S	128° 27' 44.199" E
		434663.167	8457343.459	13° 57' 12.266" S	128° 23' 42.394" E
		421675.712	8459933.612	13° 55' 46.776" S	128° 16' 29.821" E
		410014.756	8460299.186	13° 55' 33.635" S	128° 10' 1.287" E
		398211.227	8459453.368	13° 55' 59.732" S	128° 3' 27.864" E
		385899.154	8458286.796	13° 56' 36.016" S	127° 56' 37.435" E
		375829.379	8454229.300	13° 58' 46.545" S	127° 51' 1.238" E
		326863.713	8499094.393	13° 34' 17.433" S	127° 23' 59.483" E
		352436.940	8524385.920	13° 20' 39.415" S	127° 38' 14.817" E
		338270.286	8537123.060	13° 13' 42.271" S	127° 30' 26.542" E

Proposed Activity

The 'Full-fold Acquisition' is planned to be undertaken within three defined Areas (A, B and C), covering a total combined area of approximately 3,584 km². An 'Active Source Area' within which some underwater sound may be emitted from a seismic source, surrounds each Full-fold Acquisition Area and Active Source Area. Further allowance for vessel manoeuvring which provides for a total 'Operational Area' of 12,832 km².

Seismic acquisition will be via methods and procedures similar to other seismic surveys conducted in Australian waters. The survey vessel will travel along a series of pre-determined lines towing a seismic source and a series of 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 emitted from the seismic source and 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 seismic source used during the survey will have a total volume less than 3,500 cubic inches and be towed approximately 5-10 m below sea surface. The streamers will be approximately 9 km long, towed approximately 15 m below the ocean surface and always greater than 10 m above the seabed.

While undertaking the survey, the vessel will traverse pre-determined sail lines separated by approximately 560 m. Sail lines over each of the areas will either be orientated NW-SE or NE-SW. The vessel will travel back and forth along the sail lines in a 'race-track' pattern, whereby the vessel turns at the end of each sail line and returns in the opposite direction along a different sail line. This pattern is repeated until acquisition is complete.

The survey vessel will tow the seismic source at a speed of approximately 4.5 knots with the seismic source emitting a pulse of sound approximately every 8.3 m. Support vessels will be on standby to direct any shipping traffic away from the survey vessel and towed streamers.

Timing

Santos intends to acquire the full survey between 1 October 2021 and 31 March 2022. However, should this not be achievable, then some or all of the survey may instead be acquired the following year, between 1 October 2022 and 31 March 2023. The total survey duration for Areas A, B and C, including contingency is 100 days.

Santos will endeavour to limit the survey to the October-March window, however, if this is not possible for operational reasons then Area A of the survey may need to be acquired, over ~30 days, at a different time. Operations will be undertaken on a 24-hour basis.

Santos commits to informing stakeholders of the precise survey dates once known. The timing of the survey is dependent upon vessel availability, weather conditions, the receipt of the required statutory approvals and the control measures within the EP.

The full survey is estimated to take a total of 95 days to acquire. An additional five days of contingency time within the Operational Area is needed as part of the environmental assessment. Therefore, including contingency time, the survey is estimated to take up to 100 days to complete. Santos commits to ongoing consultation with relevant stakeholders prior to activity commencement and during the activity, at a frequency suited to individual stakeholders.

Santos commits to ongoing consultation with relevant stakeholders prior to activity commencement and during the activity, 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 by **11th June 2021**. Consultation for this activity will be ongoing post regulatory acceptance, until the activity is completed.

Environmental Approval

Petroleum activities, which include 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 EPs submitted to NOPSEMA must be published on their website for a 30-day public comment period. Santos anticipates that the EP will be available for public comment between June and July 2021 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 the preparation of an EP. As such, all stakeholders are encouraged to review this material and to make contact with Santos.

General Commitments

In the development of the survey EP, Santos will incorporate similar control measures to those made in the Archer Seismic Survey Environment Plan, accepted by NOPSEMA on 3 March 2021 and the Keraudren Extension Seismic Survey Environment Plan, accepted by NOPSEMA on 09 April 2020.

Any additional control measures identified during stakeholder engagement and the public comment period will be considered for inclusion in the EP. A summary of key control measures proposed for the survey are summarised below.

POTENTIAL AREA OF INTEREST	SANTOS COMMITMENTS
Maritime notices • **Notice to Mariners (NTM)** • **AUSCOAST warnings**	A notification will be provided prior to survey vessel arrival in the Operational Area and following its departure. Notifications are provided to the Australian Maritime Safety Authority Joint Rescue Coordination Centre, Australian Hydrographic Office and designated port authorities so the maritime industry is aware of seismic survey activities.
Stakeholder consultation	Relevant persons identified during stakeholder consultation and listed in the EP will be provided a commencement notification at least two weeks prior to the survey commencing. The Santos Consultation Coordinator will remain available before, during and after the survey to ensure stakeholder feedback is recorded, evaluated and responded to.
Area of avoidance requested to reduce potential for collision or interference with other marine user activities	An area 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 and therefore restricted in its ability to manoeuvre. 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 survey activities in marine turtle inter-nesting areas during nesting periods	Consistent with the requirements of the Recovery Plan for Marine Turtles in Australia, a precautionary approach will be applied, such that no operation of the seismic source will take place within important turtle inter-nesting habitat areas during their nesting periods. The Operational Area has been designed to exclude all defined turtle inter-nesting biologically important areas and therefore avoids these habitats at all times.

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

Michael Marren
Telephone: 08 9266 0542
Email: Offshore.Consultation@Santos.com

Santos

STAKEHOLDER CONSULTATION

Quarterly Consultation Update

Quarterly Consultation Update

Santos

July 2021

This update outlines planned activities by Santos Limited (Santos) in Western Australia through Q3 2021 to Q4 2021. It is intended to provide advance 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, using the contact details provided below.

Please note that the scheduling of activities can change for reasons including vessel and equipment availability and regulatory approvals. If there are any significant changes made to scheduling, 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 mariner access to an area during a proposed activity. Santos recommends stakeholders assess all information provided and seek additional information if required.

Operational activities relate to operations at Varanus Island, Burrup Pipeline, Devil Creek and the *Ningaloo Vision* Floating Production Storage and Offloading (FPSO) facilities. 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 7095
Email: offshore.consultation@santos.com
Web: http://Santos.com/

Santos

Proposed Western Australia offshore activities

This table gives key information on upcoming activities that are proposed to occur from Q3 2021

Activity Name	Type of Activity	Permit Number	Latitude	Longitude	Water Depth (approx.)	Start date estimate	End date estimate	Exclusion zone details
Vessel Based Activity (Commonwealth Waters)	Geophysical & Geotechnical Multi-Site Surveys & Multi-year	WA-437-P WA-438-P WA-541-P WA-1-P WA-209-P WA-41-L WA-33-R WA-510-P	Coordinates available on request		40 m to 110 m	Q2 2021	Q2 2026	N/A
Varanus Island A Tank Demolition (Onshore)	Demolition	PL-29	Coordinates available on request		N/A	Q3 2021	Q3 2021	N/A
Pavo-1 (Bedout Basin) (Commonwealth Waters)	Exploration Drilling	WA-438-P	Coordinates available on request		40 m to 110 m	Q1 2022	Estimated completion up to 80 days after start date	500m around MODU
Dancer-1 (Commonwealth Waters)	Exploration Drilling	WA-1-P	19° 58' 19.30" S	116° 20' 56.51" E	Approx. 63 m	Q4 2021	Estimated completion up to 75 days after start date	500m around MODU
Stairway -1 (Commonwealth Waters)	Geophysical & Geotechnical Site Survey	AC/P50	12° 30' 28.575" S / 12° 30' 27.412" S / 12° 33' 10.095" S / 12° 33' 11.262" S /	124° 52' 03.378" E 124° 54' 48.955" E 124° 54' 50.155" E 124° 52' 04.550" E	80 – 100 m	Q4 2021 to Q3 2022	Estimated completion up to 10 days after start date	N/A
Yoorn-1 (Commonwealth and State waters)	Geophysical & Geotechnical Site Survey	WA-499-P TL-5 TP-27 TP-8	Coordinates available on request		40 – 50 m	Q1/Q2 2022	2-10 days after start date	N/A

Santos

Activity Name	Type of Activity	Permit Number	Latitude Longitude	Water Depth (approx.)	Start date estimate	End date estimate	Exclusion zone details
Petrel (Commonwealth waters)	Seismic Survey	WA-454-P, WA-27-R, WA-40-R, NT/P84	Coordinates available on request	59 m to 103 m	Between 1 Dec 2021 and 31 March 2022 or 1 Dec 2022 and 31 March 2023		3 nm Area of Avoidance requested around vessel and streamers
Apus-1 (Bedout Basin) (Commonwealth Waters)	Exploration Drilling	WA-437-P	Coordinates available on request	40 m to 110 m	Q1 2022	Estimated completion up to 80 days after start date	500m around MODU
Stairway-1 (Commonwealth Waters)	Exploration Drilling	AC/P50	Coordinates available on request	80 – 100 m	Q2 2022 and Q4 2023	Estimated completion up to 80 days after start date	500m around MODU
Spartan-2 (Commonwealth Waters)	Production well and Tie In	WA-33-R	20° 32' 4.4706" S / 115° 14'52.8985" E	60 m	Q3 2022	Q1 2023	500 m around MODU and John Brookes facility
Harriet Joint Venture (Harriet Alpha, Simpson Alpha, Simpson Bravo, Bambra Sea Pole) (State waters)	Plug & Abandonment	TL/1	Harriet Alpha: 20° 36' 06.47" S, 115° 36' 51.12" E Simpson Alpha: 20° 40' 20.00" S, 115° 35' 07.76" E Simpson Bravo: 20° 40' 24.27" S, 115° 35' 05.66" E Bambra Sea Pole: 20° 32' 50.45" S, 115° 36' 16.88" E	6 to 27 m	Q1 2022	Within 5 years of commence ment of EP	500 m around each facility, well and MODU.
Yoorn, Parnassus and Jelen (Commonwealth Waters)	Exploration Drilling and Geotechnical Survey	WA-499-P WA-208-P WA-546-P	Coordinates available on request	40 – 60 m	Q2 2022 (Yoorn-1) Q3/4 Parnassus and Jelen	Estimated completion up to 80 days after start date of each well	500m around MODU. Survey areas are 500m around well centers

Santos

Current offshore activities

Santos provides an update on ongoing activities in Q3 2021.

Activity Name	Type of Activity	Permit Number	Latitude	Longitude	Water Depth (approx.)	Start date	End date estimate	Exclusion zone details
Varanus Island Compression Project (Onshore)	Compression Facility Installation	PL-29 PL-12	Coordinates available on request		N/A	Q4 2021 to Q1 2022	Estimated Completion Q1 2022	N/A
Keraudren Extension (Commonwealth Waters)	Seismic Survey	WA-435-P WA-436-P WA-437-P WA-438-P	Coordinates available on request		>50 to 200 m	Q2 2021	31 July 2021	3 nautical miles around vessel and streamers
Sinbad Campbell Asset Removal (State Waters)	Asset removal	TL/5	Sinbad 20° 28' 52.62" S, 115° 42' 44.36 E Campbell 20° 24' 46.67" S, 115° 43' 51.56" E		40 m	Q4 2020 – Q3 2021	Estimated completion up to 60 days after start of removal campaign for each asset	500m around vessel
Van Gogh (Phase 2) (Commonwealth Waters)	Infill Drilling	WA-35-L	21° 20' 57.29" S	114° 04' 23.613" E	380 m	Q2 2021	Q4 2021	500m around MODU
Van Gogh (Phase 2) (Commonwealth Waters)	Installation & Commissioning	WA-35-L	21° 20' 57.29" S	114° 04' 23.613" E	380 m	Q2 2021	Q4 2021	500m around installation vessel

Santos

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
Archer (Commonwealth Waters)	Seismic Survey	WA-437-P WA-541-P	70 to 96 m	Coordinates available on request	
Legendre (Commonwealth Waters)	Site Survey	WA-20-L	Approx. 52m	Coordinates available on request	

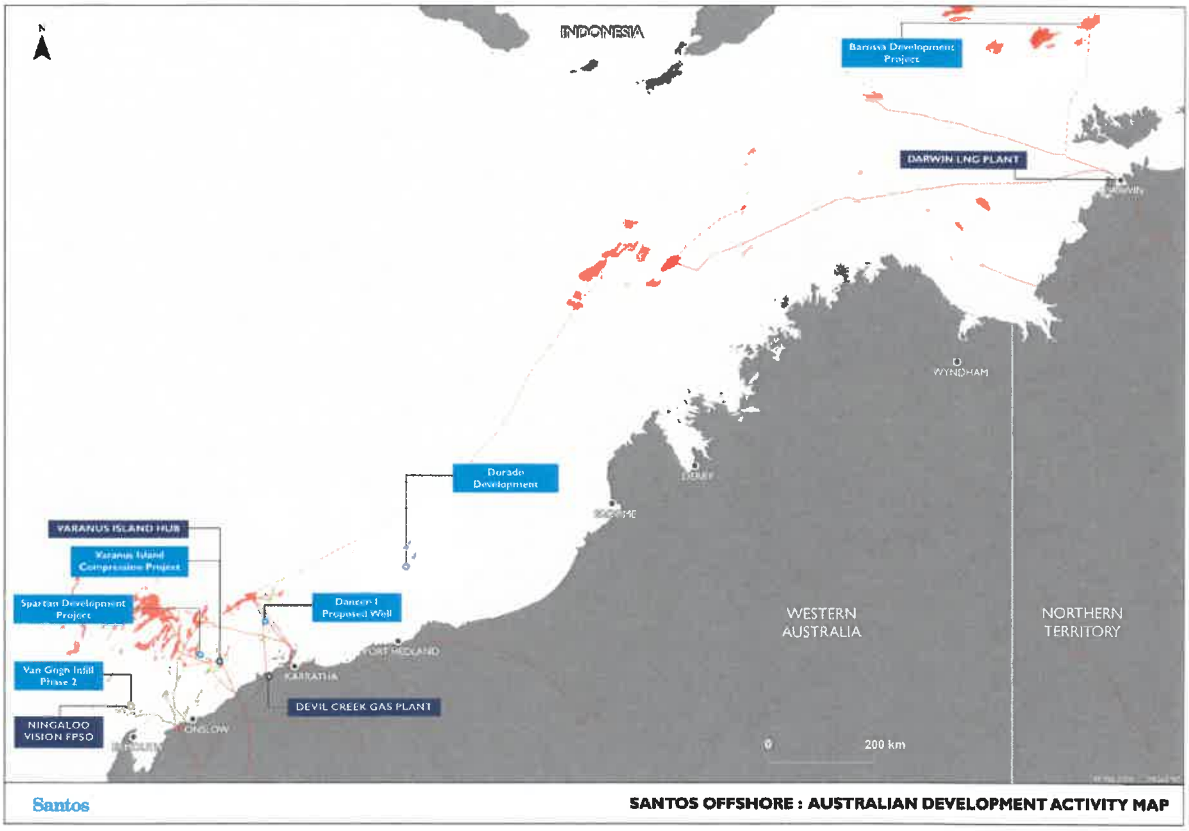
Santos

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.
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.
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.

Santos



INDONESIA
N
Barossa Development Project
DARWIN LNG PLANT
DARWIN
WYNDHAM
DERBY
BROOME
Dorado Development
VARANUS ISLAND HUB
Varanus Island Compression Project
Spartan Development Project
Dancer-1 Proposed Well
PORT HEDLAND
KARRATHA
Van Gogh Infill Phase 2
DEVIL CREEK GAS PLANT
NINGALOO VISION FPSO
ONSLOW
WESTERN AUSTRALIA
NORTHERN TERRITORY
0
200 km
Santos
SANTOS OFFSHORE : AUSTRALIAN DEVELOPMENT ACTIVITY MAP

Appendix E: Santos Risk Matrix and Consequence Table

Santos Risk Matrix

Consequence

	I	II	III	IV	V	VI
Safety	**Negligible Harm** + No bodily damage or minimal harm or impairment (hours to days)	**Minor Harm** + Short term impairment (days to weeks)	**Moderate Harm** + Temporary disablement or medium term impairment (weeks to months)	**Severe Harm** + Long term/life altering disablement or impairment	**Single Fatality OR Critical Life Threatening Injuries**	**Multiple Fatalities**
Environment	+ No impact to Environmental Value (EV).	+ Small-scale impact to EV(s) of conservation significance + Potential surface or groundwater impact.	+ Moderate-scale impact to EV(s) of conservation significance + Localised surface or groundwater impact.	+ Large-scale impact to EV(s) of conservation significance + Moderate-scale surface water impact; + Localised impact to groundwater with potential or known beneficial use.	+ Extensive population or community scale impact to EV(s) of conservation significance + Extensive impact to other EV(s).	+ Irreversible impact to EV(s).
Community & Reputation	+ No actual or potential community criticism + Details remain within Santos sites and/or offices	+ Minor level local community criticism (< week) + No reputation impact	+ Local community criticism (> week) or one-day community protest + Local company reputation impacted	+ State-level community criticism or protest over multiple days/locations + State-based company reputation impacted + Very short-term share price impact (< week)	+ National community criticism or large scale protest + Company reputation and approvals impacted + Shareholder intervention or short-term share price impact (< month)	+ Sustained national community criticism or widespread protest + Industry reputation and approvals impacted + Changes at executive/board level or long-term share price impact (> month)
Financial (A$)	< $30k	$30k to $300k	$300k to $3m	$3m to $30m	$30m to $300m	> $300m
Workforce	+ Will require some staff attention over several days. + No actual or potential impact to culture	+ Will require several days local management time. + Minor impact to employee engagement and limited staff turnover	+ Will require head office staff and take several weeks of site management time. + Moderate impact to employee engagement and staff turnover above industry average with some key roles	+ Will require several weeks of senior management time + Impact to employee engagement (< 6 months), moderate turnover of key roles and no succession	+ Will require several months of senior management time + Impact to employee engagement (< 18 months), high staff turnover and attraction issues	+ Will require more than a year of senior management involvement and operations severely disrupted + Impact to employee engagement (> 18 months), significant key role turnover and attraction issues
Compliance	+ Non-conformance with legislation, instruments (e.g. tenure licence) or contract + No regulatory or punitive action	+ Minor breach of legislation, instruments or contract + Notification/report to; request for information by; and/or administrative/ warning notice from the regulator + LOCI Tier 3 or non-hydrocarbon releases notifiable to the regulator	+ Limited number of minor breaches of legislation, instruments or contract + Statutory notice from the regulator + LOCI Tier 2 or non-hydrocarbon releases immediately reportable to the regulator	+ Systemic minor breaches (or one moderate breach) of legislation, instruments or contract + Company charged with an offence with minor penalty/fine + LOCI Tier 1 or cumulative regulator notification of non-hydrocarbon releases	+ Systemic moderate breaches (OR single material breach) of legislation, instruments or contract + Company charged with an offence with moderate penalty/fine	+ Material breaches of legislation, instruments or contract + Company or officers charged with an offence with material penalty/fine, or loss of tenure/operatorship

Likelihood

		I	II	III	IV	V	VI
ALMOST CERTAIN (< 4 monthly) Occurs in almost all circumstances OR could occur *within days to weeks*	f	Low	Medium	High	Very High	Very High	Very High
LIKELY (4 monthly - 1 yearly) Occurs in most circumstances OR could occur *within weeks to months*	e	Low	Medium	High	High	Very High	Very High
OCCASIONAL (1 - 3 yearly) Has occurred before in Santos OR could occur *within months to years*	d	Low	Low	Medium	High	High	Very High
POSSIBLE (3 - 10 yearly) Has occurred before in the industry OR could occur *within the next few years*	c	Very Low	Low	Low	Medium	High	Very High
UNLIKELY (10 - 30 yearly) Has occurred elsewhere OR could occur *within decades*	b	Very Low	Very Low	Low	Low	Medium	High
REMOTE (30 - 100 yearly) Requires exceptional circumstances and is unlikely even in the long term OR only occurs as a *"one in 100 year event"*	a	Very Low	Very Low	Very Low	Low	Medium	Medium

Operational Risk Assessment Requirements

Risk Level	Action	Governance Mechanism	Authority for Continued Tolerance of Risk	Control Development and Timeframe	Control Ownership
Very High	+ Following verification of the risk at 'Very High' activity must stop + Activity cannot recommence until controls are implemented to reduce risk to 'High' or lower + For incidents, a dedicated multi-disciplinary incident investigation team will be formed + Level 3 Manager or Excom member will be included in the investigation team	+ Controls will be governed at the Operations Committee meeting or equivalent forum + Sponsorship of incident investigation by EVP or Level 2 Manager	+ CEO	+ Intolerable Risk Level + Develop and implement controls urgently to reduce risk to 'High' or lower as soon as practicable	+ Level 2 Manager (e.g. Executive Vice President)
High	+ Assess risk to determine if it is reduced So Far As Is Reasonably Practicable (SFAIRP) + If SFAIRP, activities related to maintenance of controls will be prioritised and managed + If not SFAIRP, improve existing controls and/or implement new control(s) + For incidents, a dedicated multi-disciplinary incident investigation team will be formed	+ Controls will be governed at Divisional level meeting or equivalent forum + Sponsorship of incident investigation by Level 3 Manager	+ EVP or Level 2 Manager	+ Action to reduce risk level to 'Medium' or below	+ Level 3 Manager (e.g. General Manager)
Medium	+ Assess risk to determine if SFAIRP + If SFAIRP, activities related to maintenance of controls will be prioritised and managed + If not SFAIRP, improve existing controls and/or implement new control(s) + Incidents are assessed using Mining the Diamond and investigated relative to the incident potential	+ Controls will be governed at Area level meeting or equivalent forum + Sponsorship of incident investigation at Level 4 Manager	+ General Manager or Level 3 Manager	+ Manage and monitor risk efficiently in accordance with business management plans	+ Level 4 Manager (e.g. Asset or Functional Manager)
Low	+ Assess risk to determine if SFAIRP + If SFAIRP, activities related to maintenance of controls will be prioritised and managed + If not SFAIRP, improve existing controls and/or implement new control(s) + Incidents are assessed using Mining the Diamond and investigated relative to the incident potential	+ Controls will be governed at site level meeting or equivalent forum + Sponsorship for incident investigation at Level 5 Manager	+ Level 4 Manager	+ Manage and monitor risk efficiently in accordance with business management plans	+ Level 5 Manager (e.g. Area Manager, Team Leader, Superintendent or equivalent)
Very Low	+ Risk to be managed as stipulated by the related work processes	+ Governed if required	+ Level 5 Manager	+ Manage and monitor risk efficiently in accordance with business management plans	+ Any individual contributor

Appendix F: JASCO Applied Sciences - Petrel Sub-Basin SW 3D MSS Acoustic Modelling

Petrel Sub-Basin SW 3D Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

Submitted to:

Michael Giles

Santos WA Energy Limited
PO: 4800004807

Authors:

Matthew Koessler
Craig McPherson

5 July 2021

P001524-001
Document 02115
Version 1.0

JASCO Applied Sciences (Australia) Pty Ltd
Unit 1, 14 Hook Street
Capalaba, Queensland, 4157
Tel: +61 7 3823 2620
www.jasco.com

Suggested citation:

Koessler, M.W. and C.R. McPherson. 2021 *Petrel Sub-Basin SW 3D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures.* Document 02115, Version 1.0. Technical report by JASCO Applied Sciences for Santos WA Energy Limited.

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.

Contents

Figures

Tables

Executive Summary

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned Petrel Sub-Basin SW 3D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on marine fauna including marine mammals, fish, turtles, crustaceans, sponges, and coral. The Petrel Sub-Basin SW MSS will consist of three individual Full Fold Acquisition Areas: A, B, and C respectively, within the wider Operational Area.

Modelling considered two seismic sources with volumes of 2495 and 3480 in^3. Both arrays 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 the 3480 in^3 seismic source with a 6 m tow depth. This array was considered in the modelling, operating in a triple source configuration, towed 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 six defined locations within the Full Fold Acquisition Areas, and accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 hours within the three Full Fold Acquisition Areas.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the two 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.

As pertains to the results below, the SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels, based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure since, more realistically, marine fauna such as mammals, turtles, and fish would not stay in the same location or at the same distance from a sound source for an extended period. Therefore, a reported radius for SEL_{24h} criteria does not mean that any animal travelling within this radius from the source *will* be injured, but rather that it *could* be injured if it remained within that range during a 24 hour period.

Marine mammal injury and behaviour

- The maximum distance where the (NOAA 2019) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 7.86 and 8.46 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 for low-frequency cetaceans were associated with Full Fold Acquisition Area A, in deeper water for low-frequency cetaceans.

Table 1. Summary of maximum marine mammal PTS onset distances for modelled scenarios.

Hearing group	Area A		Area B		Area C	
	Metric associated with longest distance to PTS onset	R_{max} (km)	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}	4.89	SEL_{24h}	4.50	SEL_{24h}	4.77
Mid-frequency cetaceans	—	—	—	—	—	—
High-frequency cetaceans	PK	0.31	PK	0.36	PK	0.33
Sirenians (Dugongs)	—	—	—	—	—	—
Turtles	SEL_{24h}	0.04	SEL_{24h}	0.04	SEL_{24h}	0.04

† The model does not account for shutdowns.
A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Turtles

- The maximum distance to PTS onset in turtles (Finneran et al. 2017) of 50 m is based on the SEL_{24h} metric, as was the distance to TTS onset of 2.57 km. 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.
- The distances to where the NMFS criterion (NSF 2011) for behavioural response in turtles of turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000a, McCauley et al. 2000b) could be exceeded are summarised in Table 2.

Table 2. Summary of distances to turtle behavioural response criteria.

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Minimum	Maximum
175†	1.71	1.97
166‡	4.59	5.06

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000a, McCauley et al. 2000b).
‡ 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 and 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 injury 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	0.08
	TTS	SEL_{24h}	6.66	SEL_{24h}	6.17
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.16	PK	0.21
	TTS	SEL_{24h}	6.66	SEL_{24h}	6.17
Fish eggs, and larvae	Injury	PK	0.16	PK	0.21

Crustaceans, Sponges, and Coral

To assist with assessing the potential effects on these receptors, the following results were determined:

- 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 604 and 638 m depending on the modelled site.
- Sponges and coral: the PK sound level at the seafloor directly underneath the seismic source was estimated at two representative modelled sites and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); it was not reached at any of the modelled sites considered.
- Plankton: the distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at three modelled sites through full-waveform modelling; the results ranged from 6.8 to 8.4 km.

1. Introduction

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned Petrel Sub-Basin SW 3D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on key regional receptors including potential acoustic impact on marine fauna including marine mammals, fish, turtles, crustaceans, sponges, and coral.

The modelling study considered the worst-case seismic source out of two potential options for the survey. JASCO's specialised Airgun Array Source Model (AASM) was used to predict acoustic signatures and spectra for a 2495 in^3 and a 3480 in^3 seismic source under initial consideration for the Petrel Sub-Basin SW MSS. AASM accounts for individual airgun volumes, airgun bubble interactions, and array geometry to yield accurate source predictions. For these two arrays, a single nominal source location within the Full Fold Acquisition Area was used to compare single impulse 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 three defined locations within the Operational Area, and accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 h with the worst-case source. A conservative sound speed profile that would be most supportive of sound propagation conditions for the potential survey period was defined and applied throughout.

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 4 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

The Santos Petrel Sub-Basin SW MSS will be acquired in one of two potential survey line orientations either north-west to south-east orientation or in a north-east to south-west orientation. The survey consist of three individual Full Fold Acquisition Areas; A, B, and C respectively, within the wider Operational Area, see Figure 1. Additionally, there is an option for line plan variation where the sail lines for areas A and B are combined, see panel in left lower corner in Figure 1.

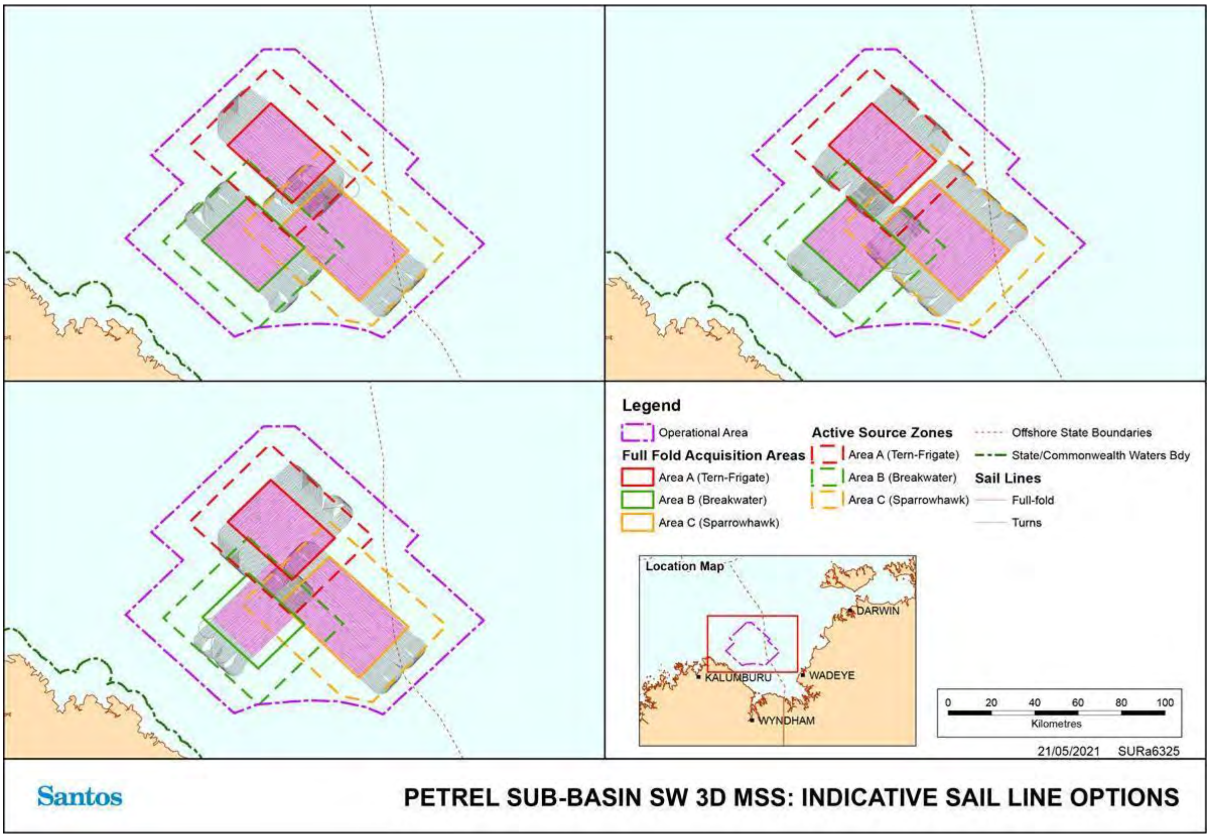


Figure 1. Indicative line plan potential options for the Santos Petrel Sub-Basin SW 3D MSS as provided by Santos.

Six standalone single impulse sites and three likely survey scenarios for survey operations over 24 h were defined to respectively assess per-pulse and accumulated sound exposure noise emissions. Considering the potential sail line options, the accumulated sound exposure scenarios were selected for modelling to assess acquisition in both directions. The geographic locations of all modelled sites are provided in Table 4. All sites and the acquisition lines are shown in Figures 2–5 along with the survey boundaries.

The orientations of the modelled seismic source at single impulse sites and sail line scenarios were selected to assess the furthest sound propagation distance broadside (generally the loudest horizontal direction from the source) from the seismic source towards receptors in both shallow water and deep-water as relevant to the survey. These receptors include but are not limited to, humpback whales and pygmy blue whales in deeper waters and internesting marine turtles, dolphin and dugongs habitat in nearshore waters. The specific reasoning for selecting each scenario is as follows:

- Area A: Scenario 1 comprised three full lines plus an additional partial line orientated north-east to south-west. The sail orientation was selected to assess the broadside sound propagation into deeper basin waters and to assess the north-west to south-east orientation. Furthermore, this sail line orientation maximizes the number of consecutive lines as opposed to the north-west, south-east direction. Several consecutive lines generally result in large distances to thresholds for the accumulated sound exposure scenarios, as opposed to a single line, due to the additive increase in sound energy from relatively close sources.

- Area B: Scenario 2 comprised three full lines plus an additional partial line orientated north-west to south-east. The orientation of the sail lines for this scenario was selected to examine the broadside sound propagation towards coastal and shallow water receptors including important areas for turtle internesting areas as well as inshore dolphin and dugong habitats. The selected lines as shown below were based on an earlier line plan and as such, two lines do not lie within the Full Fold Acquisition Area. The selection of these lines and the associated modelled results are still valid, however, as the water depths are similar inside and outside of this part of Full Fold Acquisition Area B, and the modelled lines are closer to nearshore receptors than the current line plan.
- Area C: Scenario 3 comprised two full lines plus an additional partial line orientated north-west to south-east. Water depths ranged from approximately 60 m to 80 m covering the both the deeper and shallow waters towards the shore. The orientation of the sail lines for this scenario was selected to examine the broadside sound propagation (the loudest horizontal source level direction) important shallow water areas particularly turtle interesting areas.

The single impulse sites and accumulated SEL scenarios were selected based on a proposed survey line plans for each Full Fold Acquisition Area. The locations of these sites and scenarios are considered representative of the range of water depths that will be covered during the survey and the potential sound propagation characteristics that may arise at various locations within the three Full Fold Acquisition areas.

Table 4. Location details for the single impulse modelled sites.

Area	Site	Latitude (S)	Longitude (E)	MGA Zone 52		Water depth (m)	Tow direction (°)
				X (m)	Y (m)		
A	1	13° 13' 01.0537"	127° 52' 20.5513"	377819	8538596	86	42/222
	2	13° 00' 40.2952"	128° 00' 12.7345"	391942	8561415	103	
B	3	13° 42' 00.9104"	127° 52' 07.6871"	377677	8485138	71	132/312
	4[a]	13° 47' 00.2256"	127° 56' 54.0479"	386320	8475980	62	
C	5	13° 22' 33.2544"	128° 14' 41.5972"	418238	8521169	79	
	6	13° 38' 26.6335"	128° 28' 25.1859"	443073	8491945	62	

[a]Seafloor receptors modelled site only (VSTACK)

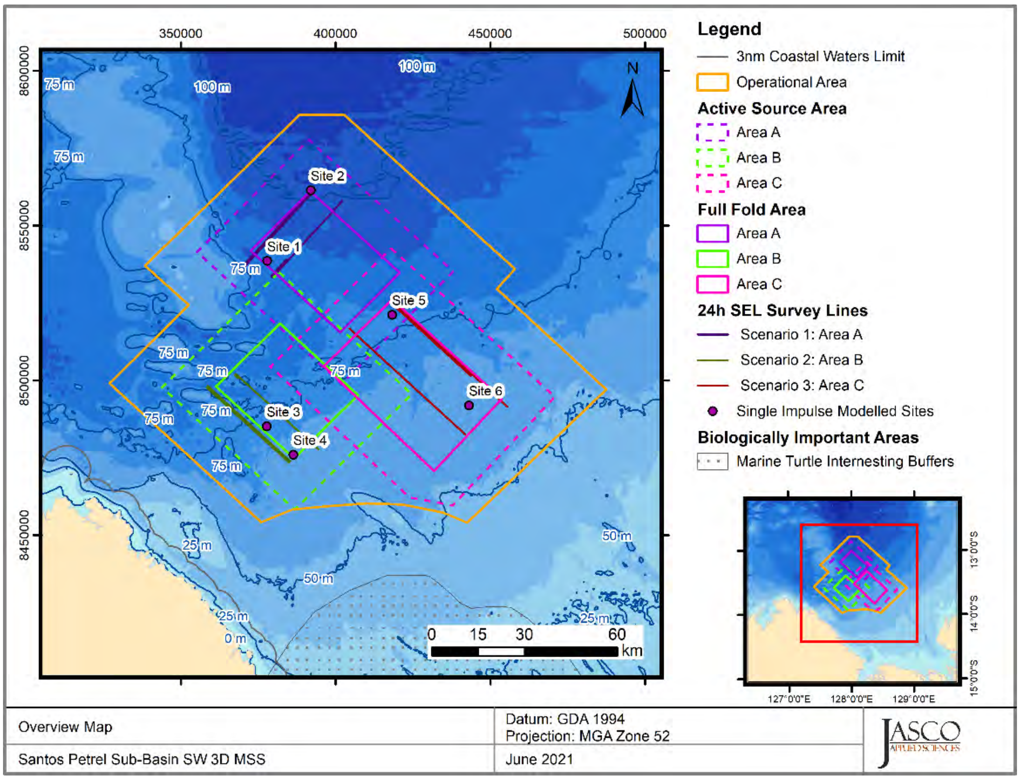


Figure 2. Overview of the modelled sites, acquisition lines, and features for the Santos Petrel Sub-Basin SW3 MSS.

The modelling assumed that the survey vessel sailed along the survey lines at ~4.5 knots, with an impulse interval of 8.33 m. Three representative acquisition scenarios, Scenarios 1–3 for Areas A–C were considered for 24 hours of operation. For Scenario 1 (Figure 3), acquisition of four lines took ~4.1 h (each) to traverse. For Scenario 2 (Figure 4), three full lines plus an additional partial line were required for modelling sound emissions for a 24-hour period. The first three acquisition lines line took 4.3 h (each) to traverse and the fourth, which is a partial segment of a full acquisition line, took 0.2 h to traverse. For Scenario 3 (Figure 5) two full lines plus an additional partial line were required for modelling sound emissions for a 24-hour period. The first two acquisition lines line took 6.2 h (each) to traverse and the third, which is a partial segment of a full acquisition line, took 4.2 h to traverse. The time to complete turns for all scenarios was ~3.5 h each.

These scenarios accounted for 13168 impulses for Scenario 1, 13178 impulses for Scenario 2, and 16582 impulses for Scenario 3 during the respective 24 h periods of acquisition. During line turns the seismic source was not in operation. Five of the six single impulse sites were modelled with a range dependent modelling method; however, a range independent modelling method was used to determine close range levels and thresholds for seafloor receptors at Site 4, which was located at the shallowest point within Area B.

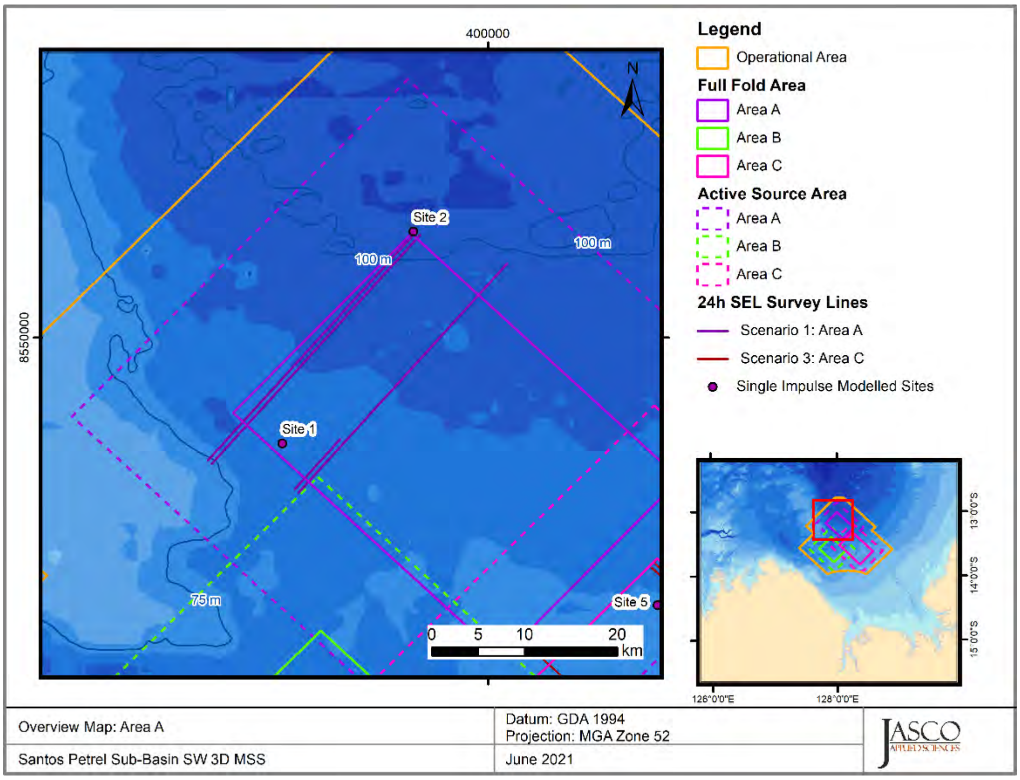


Figure 3. Overview of the Scenario 1 (Area A) modelled sites, acquisition lines.

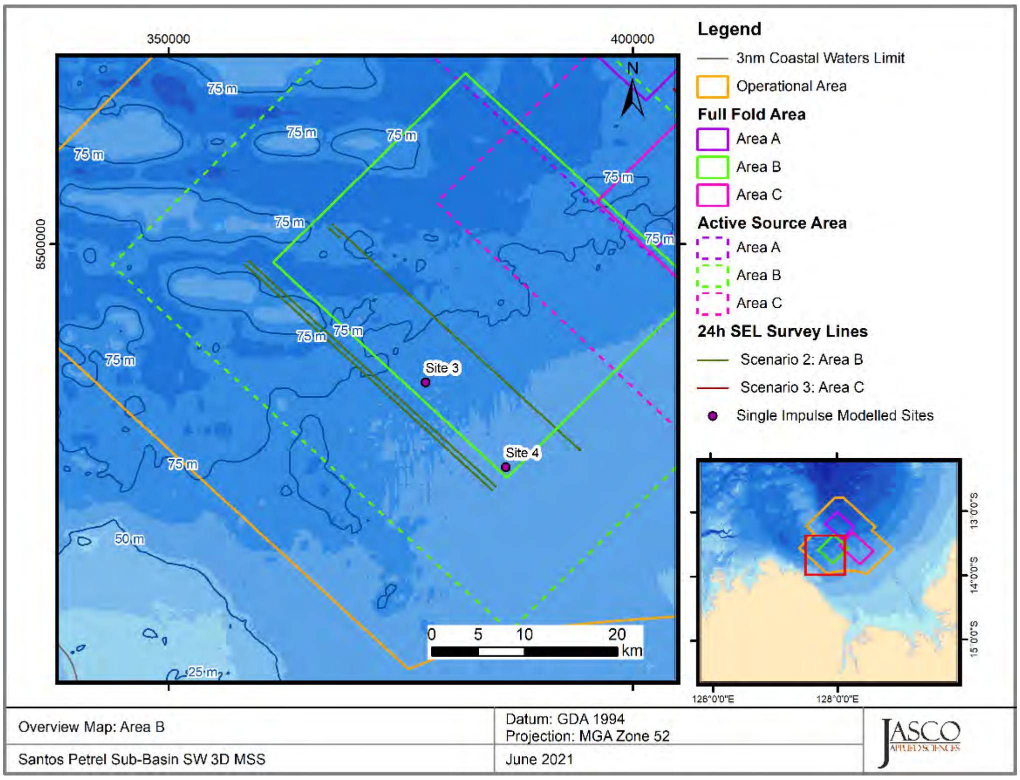


Figure 4. Overview of the Scenario 2 (Area B) modelled sites, acquisition lines.

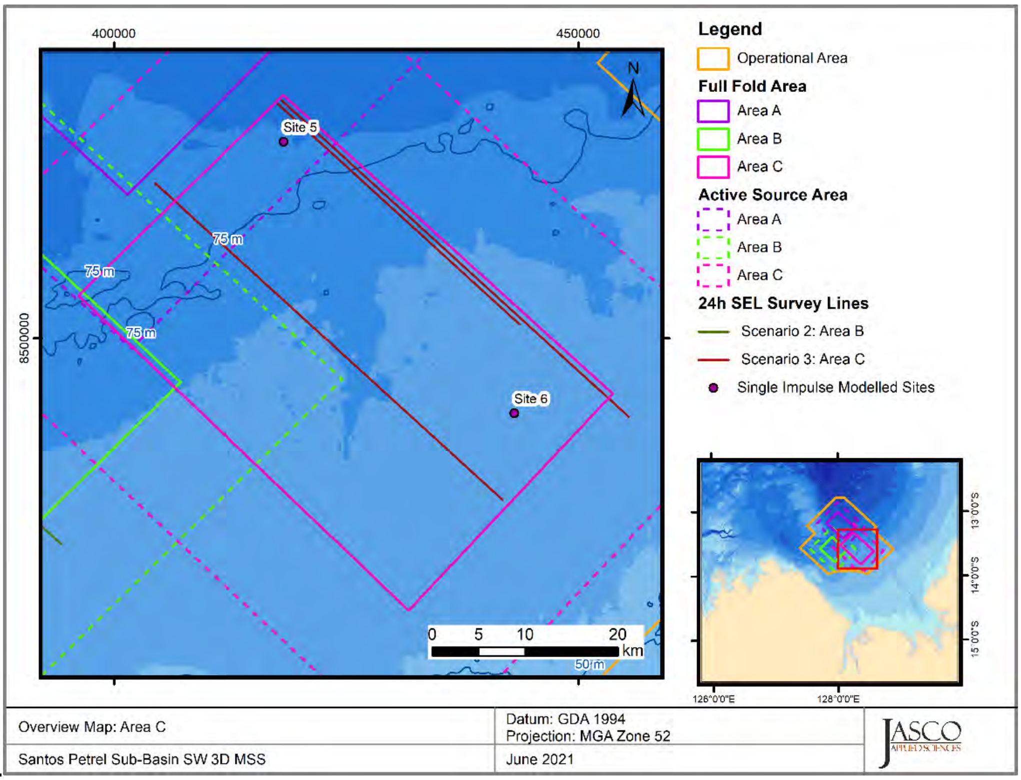


Figure 5. Overview of the Scenario 3 (Area C) modelled sites, acquisition lines.

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 Oceanic and Atmospheric Administration (NOAA 2019) criterion for marine mammals of 160 dB re 1 µPa 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. 2000a, 2000b).
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; $L_{pk\text{-}pk}$) at the seafloor to help assess effects of noise on crustaceans 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 section expands on the thresholds and sound levels for marine mammals, fish, turtles, fish eggs, and fish larvae and crustaceans.

3.1. Marine Mammals

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 help assess the potential for the possible injury and hearing sensitivity changes in marine mammals, this report applies the criteria recommended by NMFS (2018), considering both PTS and TTS. These criteria, along with the applied behavioural criteria (NOAA 2019), are summarised in Table 5, with descriptions included in Appendix A.2.1 (auditory impairment) and Appendix A.2.2 (behavioural response), with frequency weighting explained in Appendix A.3.

Table 5. Acoustic effects of impulsive noise on marine mammals: Unweighted SPL, SEL_{24h}, and PK thresholds

Hearing group	NOAA (2019)	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 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
High-frequency cetaceans		185	230	170	224
Very-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.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

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 µPa^2·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).

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: 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: 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: 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. (2000a) 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), and is recommended in the Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017). 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. 2000a, McCauley et al. 2000b), 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 µPa^2·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. 2000a, McCauley et al. 2000b) (Table 7).

Table 7. Acoustic effects of impulsive noise on turtles: Unweighted SPL, SEL_{24h}, and PK thresholds

NSF (2011)	McCauley et al. (2000b)	Finneran et al. (2017)			
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 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
160	175	204	232	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–peak sound pressure 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 µPa^{2}s.

3.3. Benthic Invertebrates (Crustaceans)

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 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. (2016b), 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 therefore applied in the assessment. Additionally for context, the PK-PK sound levels determined for crustaceans in Day et al. (2016b), 209–212 dB re 1 µPa, are also included.

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 B 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 June 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 slight upward refracting sound speed profile.

Seabed sediments in the Full Fold Acquisition Areas were modelled as a single seabed type. The seabed was modelled as a succession from soft to hard sediments (unconsolidated sediment transitioning to more compact and cemented sediments deeper below the seafloor, Table D-1).

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, 5 Hz to 25 kHz).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 5 Hz to 2048 Hz).
- Wavenumber integration model (VSTACK, 5 Hz 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 and PK-PK levels along transects at the seafloor from the loudest direction of the seismic source at the shallowest modelled sites within each Full Fold Acquisition Area (Sites 1 and 4).

4.4. Accumulated SEL

During a seismic survey, new sound energy is introduced into the 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 period of time, defined in this report as 24 h. An accurate assessment of the accumulated sound energy depends not only on the parameters of each seismic pulse impulse, but also on the number of impulses delivered in a period 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.

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 two source arrays which might be used for the Petrel Sub-Basin SW 3D MSS. The 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 3480 in^3 seismic source with a 6 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 500 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 3480 in^3 seismic source, for a 6 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 µ**Pa^{2}m^{2}s)	
		10–2000 Hz	2000–25000 Hz
Broadside	248.6	225.3	185.6
Endfire	247.6	225.2	190.5
Vertical	258.1	230.9	197.8
Vertical (surface affected source level)	258.1	233.5	200.8

5.2. Per-pulse Sound Fields

5.2.1. Tabulated Results

Tables 9–14 list per-pulse results for the 3480 in³ seismic source towed at 6 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 3480 in³ seismic source to modelled maximum-over-depth unweighted per-pulse SEL isopleths from the three modelled single impulse sites, with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 1 (86 m)		Site 2 (103 m)		Site 3 (71 m)		Site 5 (79 m)		Site 6 (62 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
180	0.23	0.15	0.15	0.14	0.27	0.23	0.24	0.2	0.27	0.23
170	0.96	0.82	0.93	0.77	1.09	0.88	1.05	0.88	1.18	0.91
160†	4.18	3.16	3.93	3.1	3.8	3.03	4.03	3.27	3.8	3.06
150	9.75	7.79	10.1	8.12	9.6	7.57	9.9	7.93	9.31	7.49
140	23.80	18.9	23.3	18.2	24.4	19	25.4	19.4	24.4	18.2
130	63.90	51.7	65.3	50.3	67.5	54.1	75.4	58.4	79.4	56.2
120	>100	/	>100	/	>100	/	>100	/	>100	/

† 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 3480 in³ seismic source to modelled maximum-over-depth SPL isopleths from the three modelled single impulse sites, with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 1 (86 m)		Site 2 (103 m)		Site 3 (71 m)		Site 5 (79 m)		Site 6 (62 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
190	0.14	0.13	0.14	0.13	0.21	0.16	0.13	0.13	0.24	0.19
180	0.83	0.72	0.74	0.58	0.89	0.75	0.85	0.72	0.96	0.81
175#	1.83	1.52	1.71	1.44	1.91	1.54	1.97	1.54	2.28	1.63
170	3.44	2.63	3.24	2.62	3.24	2.71	3.61	2.76	3.16	2.68
166†	4.59	3.88	5.01	3.91	4.71	3.83	5.06	4.0	4.7	3.91
160‡	8.46	6.52	8.32	6.74	8.23	6.57	8.44	6.79	7.86	6.43
150	20.80	16.3	19.6	15.7	21.2	16.6	22.8	17.3	20.2	15.7
140	57.50	45.9	54.4	42.5	59.2	47.5	65.7	51.4	70.6	49.5
130	>100	/	>100	/	>100	/	>100	/	>100	/

Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000a).
† 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 (km) from the 3480 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 two modelled sites (Table 4), with water depth indicated.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (km)		
		Site 2 (103 m)	Site 3 (70 m)	Site 5 (62 m)
Low-frequency cetaceans (PTS)	219	0.03	0.03	0.03
Low-frequency cetaceans (TTS)	213	0.06	0.07	0.06
Mid-frequency cetaceans (PTS)	230	–	–	–
Mid-frequency cetaceans (TTS)	224	0.02	0.02	0.00
High-frequency cetaceans (PTS)	202	0.31	0.36	0.33
High-frequency cetaceans (TTS)	196	0.64	0.79	0.63
Sirenians (PTS)	226	–	–	–
Sirenians (TTS)	220	0.03	0.03	0.03
Turtles (PTS)	232	–	–	–
Turtles (TTS)	226	–	–	–
Fish: No swim bladder (also applied to sharks)	213	0.06	0.07	0.06
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.13	0.16	0.11

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 3480 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 modelling sites (Table 4), with water depth indicated.

PK-PK ($L_{pk\text{-}pk}$; dB re 1 µPa)	Distance R_{max} (km)		
	Site 2 (103 m)	Site 3 (70 m)	Site 5 (62 m)
178	6.8	8.4	7.5

5.2.1.2. Seafloor

Table 13. Maximum (R_{max}) horizontal distances (in m) from the 3480 in^3 array to modelled seafloor peak pressure level thresholds (PK) from two single-impulse modelling sites (Table 4), with water depth indicated.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)	
		Site 2 (103 m)	Site 4 (62 m)
Sound levels for sponges and corals[†]	226	*	*
Fish: No swim bladder (also applied to sharks)	213	69	79
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	143	207

[†] 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 3480 in^3 seismic source to modelled seafloor peak-peak pressure levels (PK-PK) from two single-impulse modelling sites (Table 4), with water depth indicated. Results included in relation to benthic invertebrates (Section 3.3).

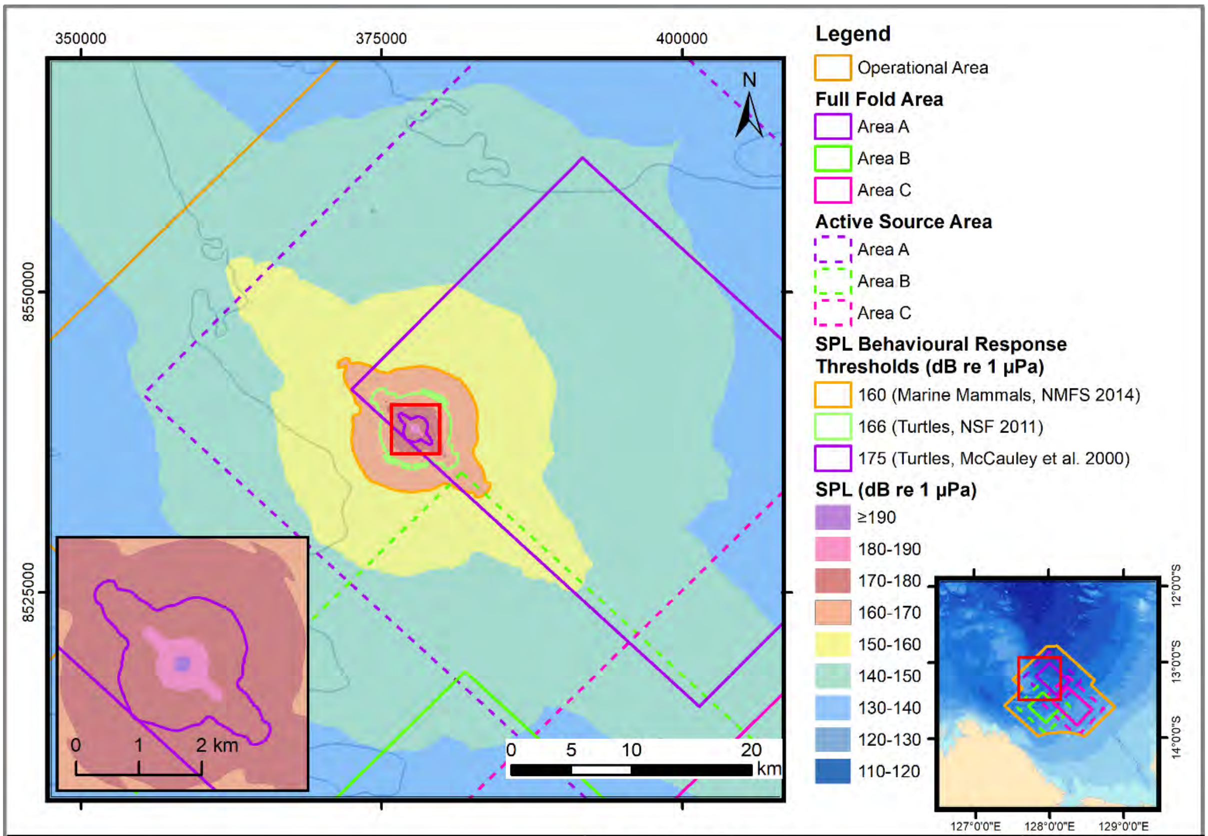
PK-PK (L_{pk-pk}; dB re 1 µPa)	Distance R_{max} (km)	
	Site 2 (103 m)	Site 4 (62 m)
213[a,b,c]	132	193
212[b,c]	144	219
210[a,b]	211	252
209[a,b]	318	267
202[d]	512	604

[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 6–10 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).



Site 1, SPL: Modelled maximum-over-depth sound field	Datum: GDA 1994 Projection: MGA Zone 52
Santos Petrel Sub-Basin SW 3D MSS	June 2021

Figure 6. *Site 1, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

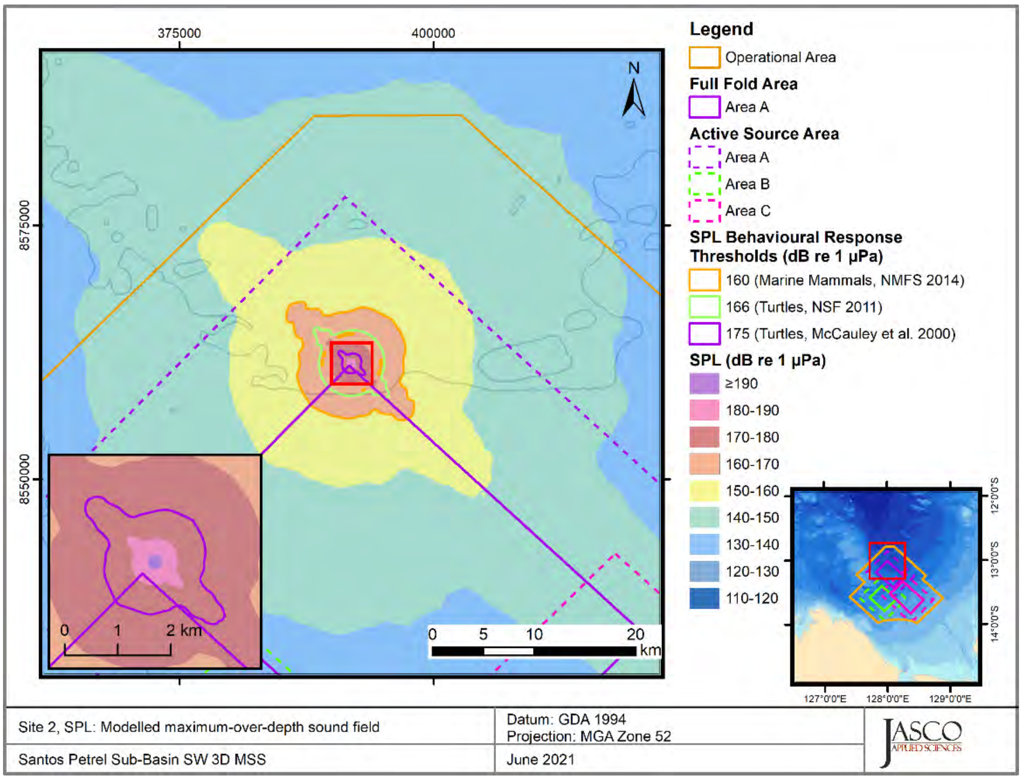


Figure 7. *Site 2, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

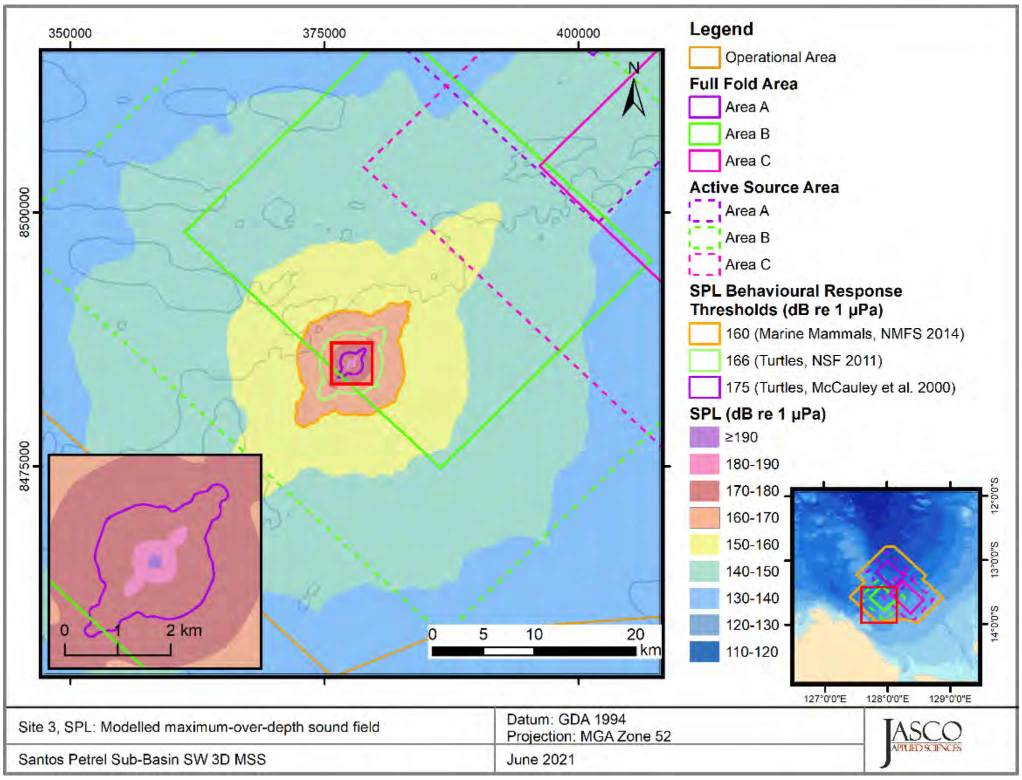


Figure 8. *Site 3, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

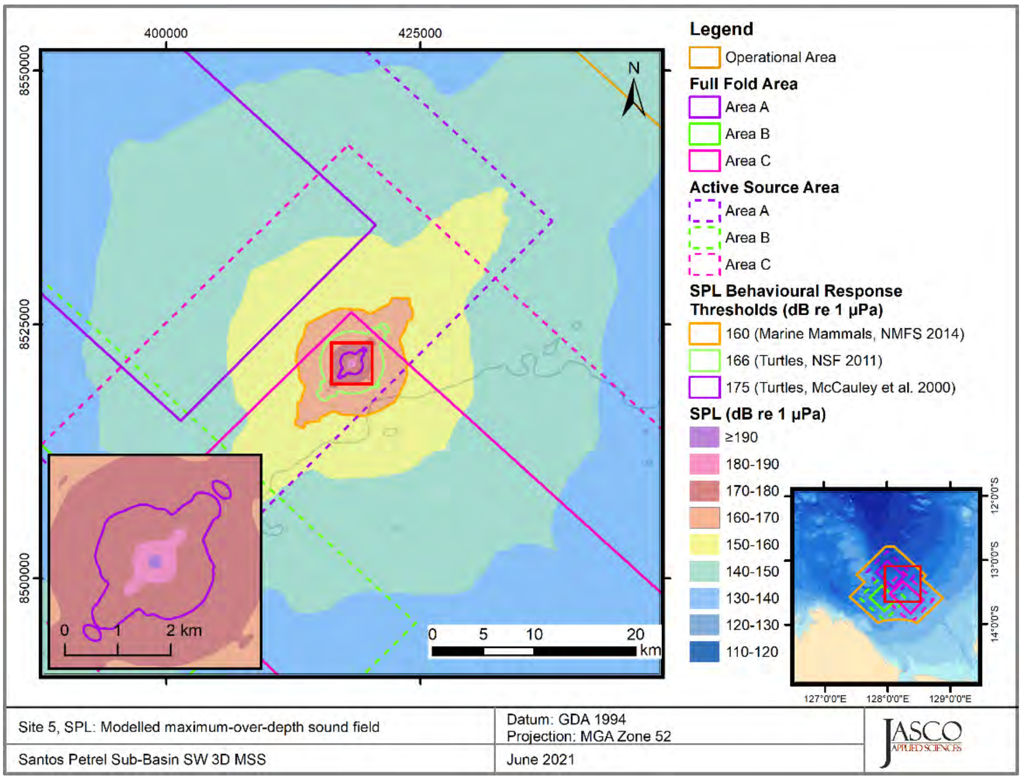


Figure 9. *Site 5, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

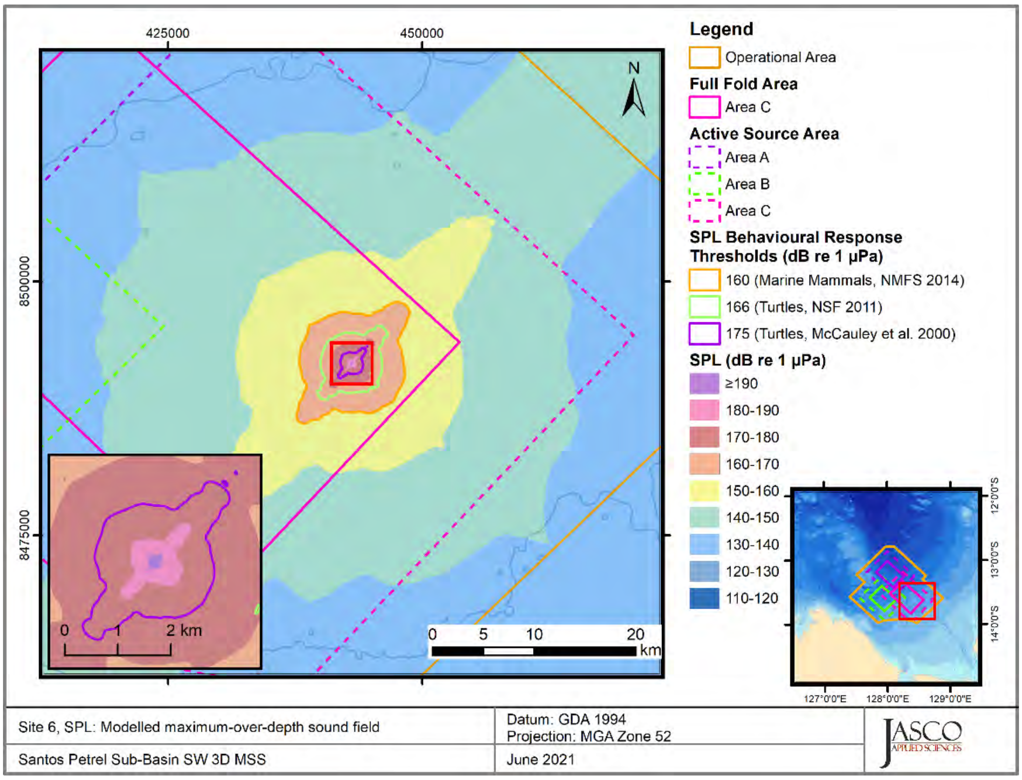


Figure 10. *Site 6, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

5.2.2.2. Vertical Slices of Modelled Sound Fields

Figures 11–15 show vertical slices of the SPL sound fields for the 3480 in^3 seismic source.

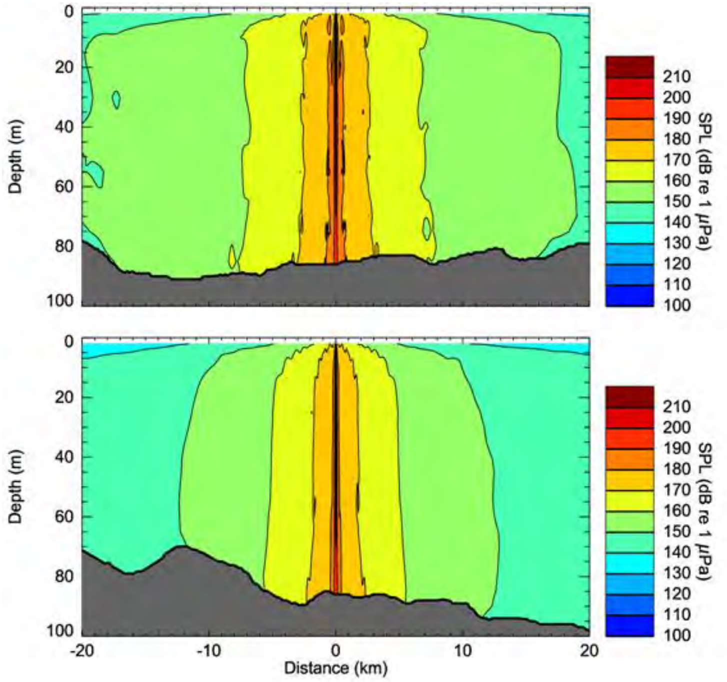


Figure 11. *Site 1, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

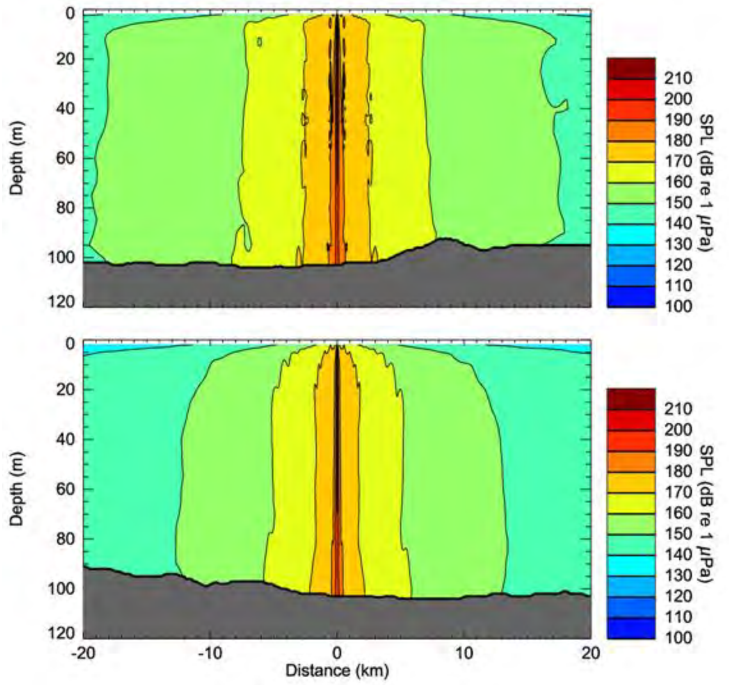


Figure 12. *Site 2, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

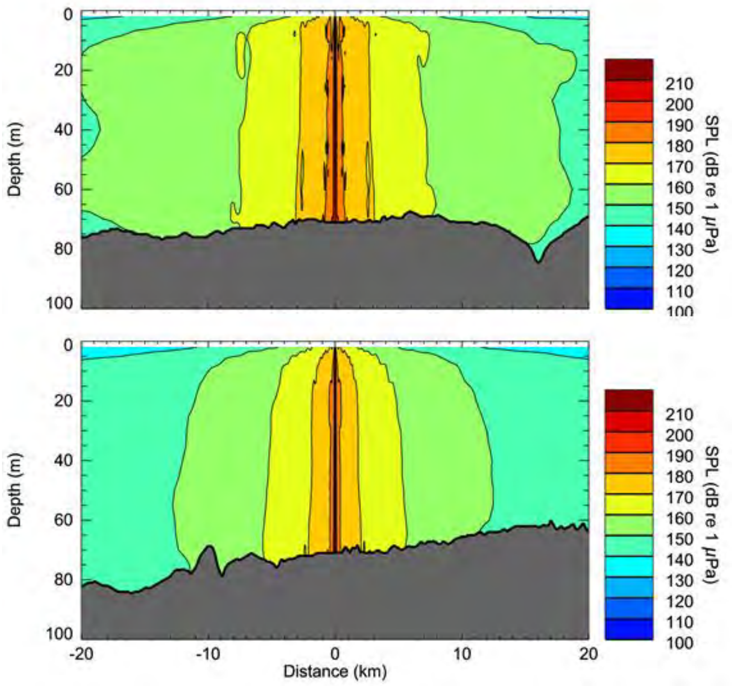


Figure 13. *Site 3 SPL*: Vertical slice of the predicted SPL for the 3480 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

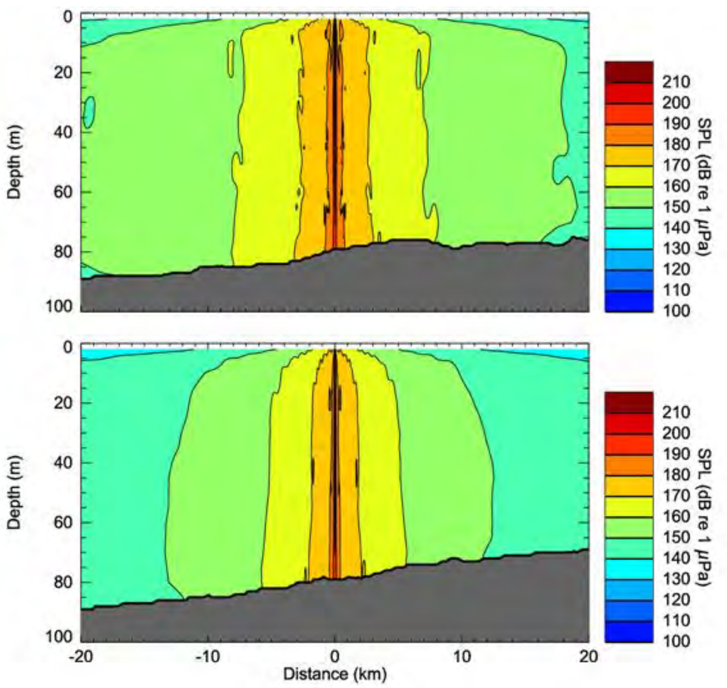


Figure 14. *Site 5 SPL*: Vertical slice of the predicted SPL for the 3480 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

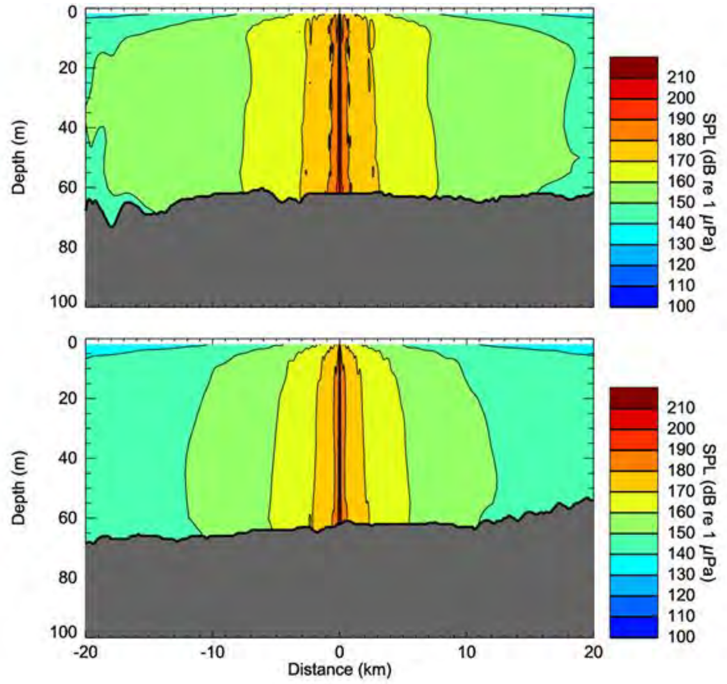


Figure 15. *Site 6 SPL*: Vertical slice of the predicted SPL for the 3480 in^3 seismic source. Levels are shown along the broadside (top) and endfire (bottom) directions.

5.3. Multiple Pulse Sound Fields

The SEL_{24h} results for the proposed survey are presented for Areas A–C within the Operational Area. Tables 15–17 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. Estimates of the maximum-over-depth sound fields, including threshold contours relating to marine mammals and fish, are presented in Figures 16, 18 and 20, while estimates of the sound field at the seafloor and threshold contours relevant to fish are presented in Figures 17, 19 and 21.

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)	Area A		Area B		Area C	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS							
Low-frequency cetaceans	183	4.89	571	4.50	598	4.77	703
Mid-frequency cetaceans	185	-	-	-	-	-	-
High-frequency cetaceans	155	0.05	2.97	0.05	2.64	0.05	3.27
Turtles	204	0.05	3.86	0.05	2.64	0.05	3.96
Sirenians (Dugongs)	190	-	-	-	-	-	-
TTS							
Low-frequency cetaceans	168	49.4	4454	52.9	4805	62.2	6577
Mid-frequency cetaceans	170	0.04	1.29	0.04	1.32	0.04	1.64
High-frequency cetaceans	140	3.56	301	2.98	312	2.72	370
Turtles	189	2.72	251	2.39	268	2.37	314
Sirenians (Dugongs)	175	0.04	1.29	0.05	2.62	0.05	2.58

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					
		Area A		Area B		Area C	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	Area (km²)	R_{max} (km)
Mortality and potential mortal injury							
I	219	0.05	2.99	0.05	2.64	0.05	3.27
II, fish eggs and fish larvae	210	0.05	3.86	0.05	2.64	0.05	3.96
III	207	0.05	3.86	0.05	2.77	0.05	3.97
Fish recoverable injury							
I	216	0.05	3.86	0.05	2.64	0.05	3.96
II, III	203	0.07	10.7	0.07	11.7	0.07	14.3
Fish TTS							
I, II, III	186	6.48	744	5.85	747	6.66	1023

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					
		Area A		Area B		Area C	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	Area (km²)	R_{max} (km)
Mortality and potential mortal injury							
I	219	*	*	*	*	*	*
II, fish eggs and fish larvae	210	*	*	*	*	*	*
III	207	*	*	*	*	*	*
Fish recoverable injury							
I	216	*	*	*	*		
II, III	203	0.05	3.46	0.06	9.20	0.06	10.6
Fish TTS							
I, II, III	186	6.17	714	5.36	708	5.93	919

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

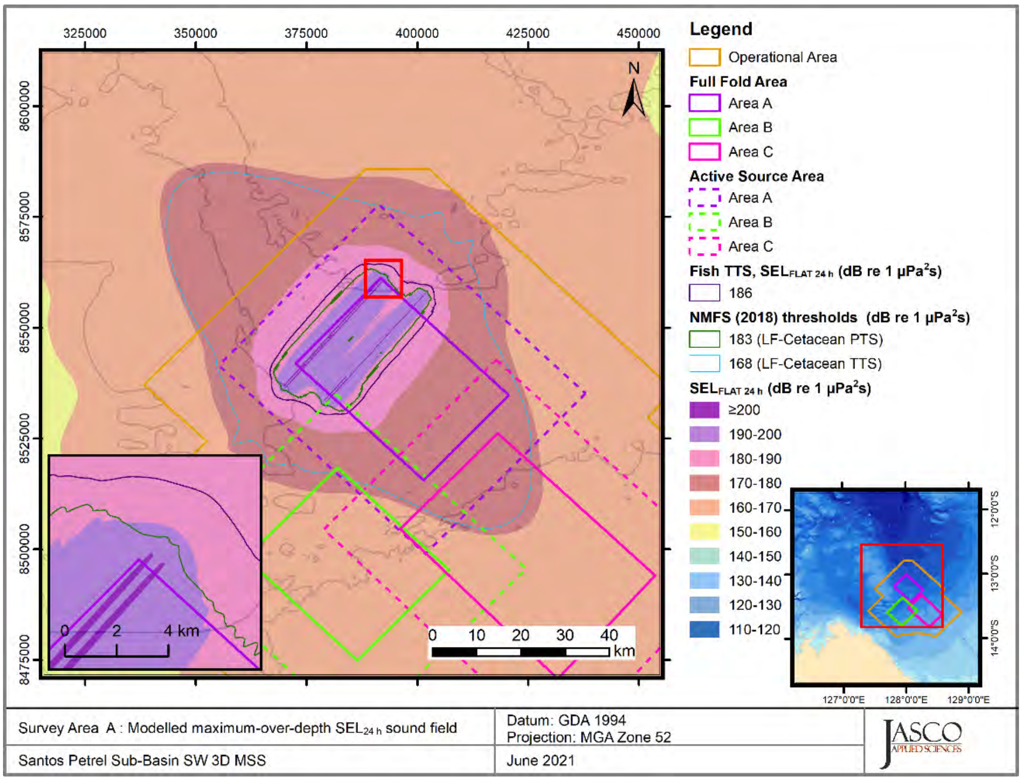


Figure 16. *Scenario 1, Area A*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetaceans and fish TTS. Where contours are too small to identify on the map refer to the radii in Table 15 for distances.

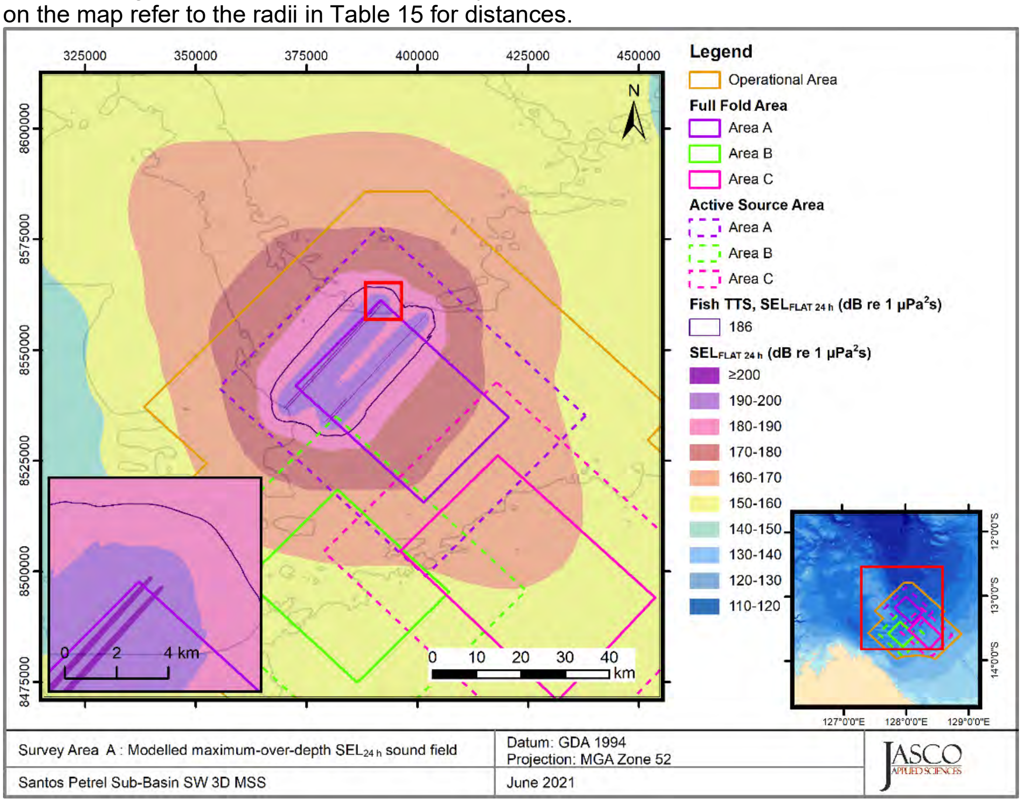


Figure 17. *Scenario 1, Area A:* Sound level contour map showing unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS. Where contours are too small to identify on the map refer to the radii in Table 16 for distances.

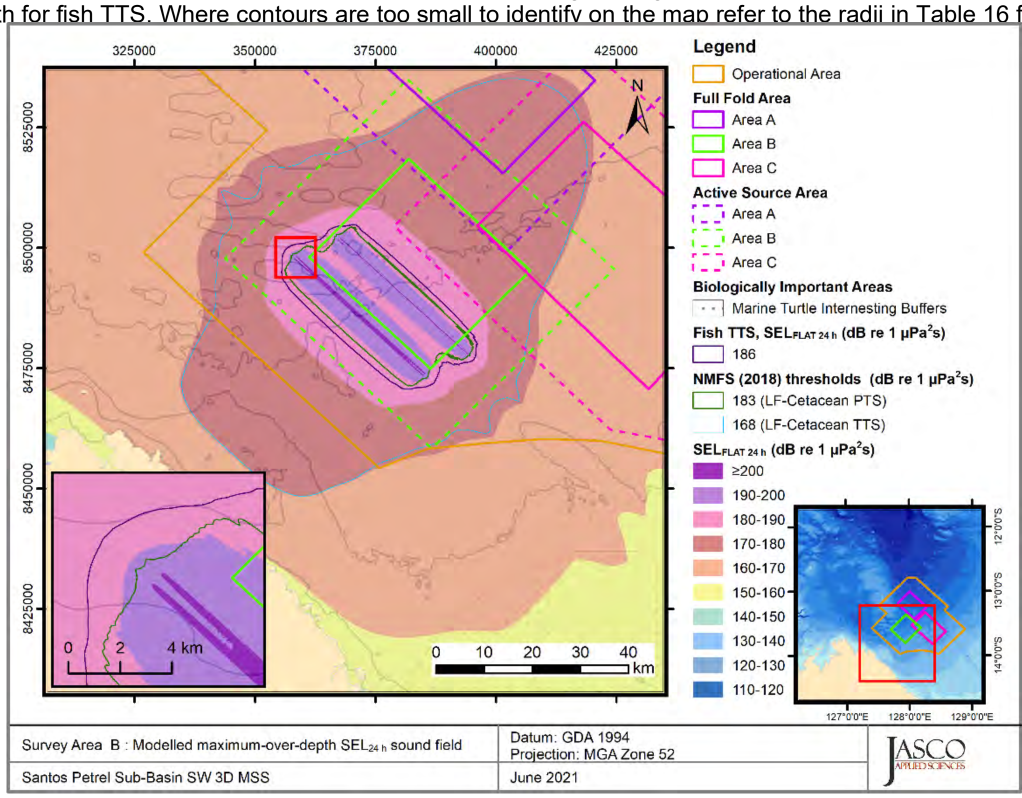


Figure 18. *Scenario 2, Area B:* Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetaceans and fish TTS. Where contours are too small to identify on the map refer to the radii in Table 15 for distances.

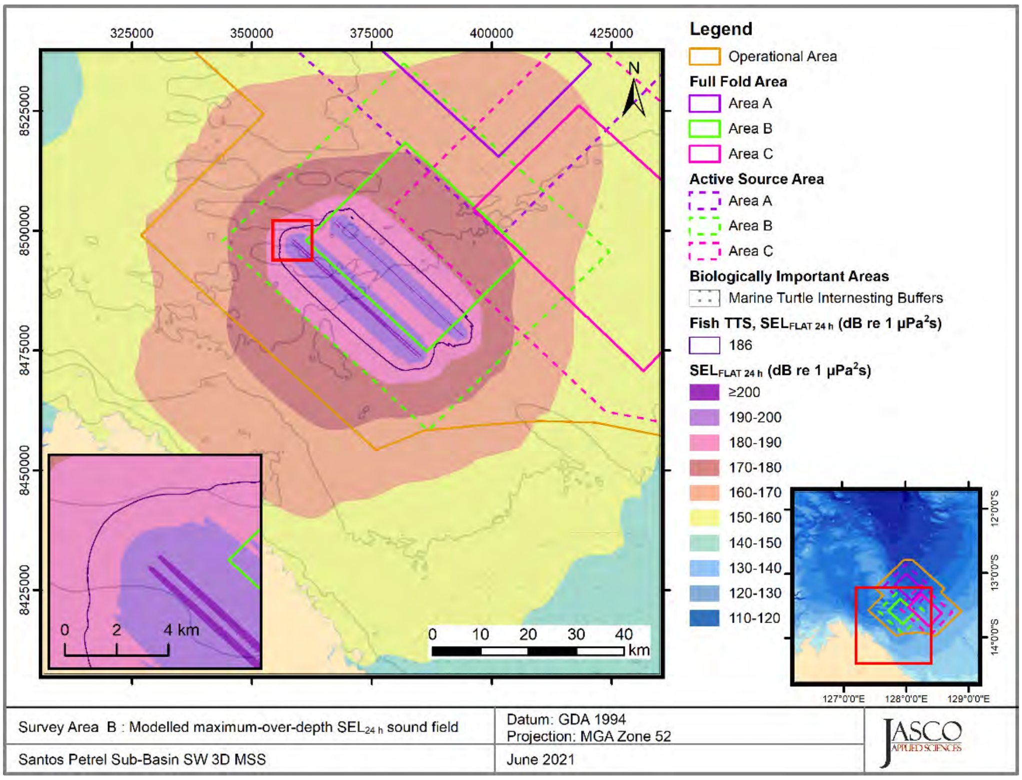


Figure 19. *Scenario 2, Area B:* Sound level contour map showing unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS. Where contours are too small to identify on the map refer to the radii in Table 16 for distances.

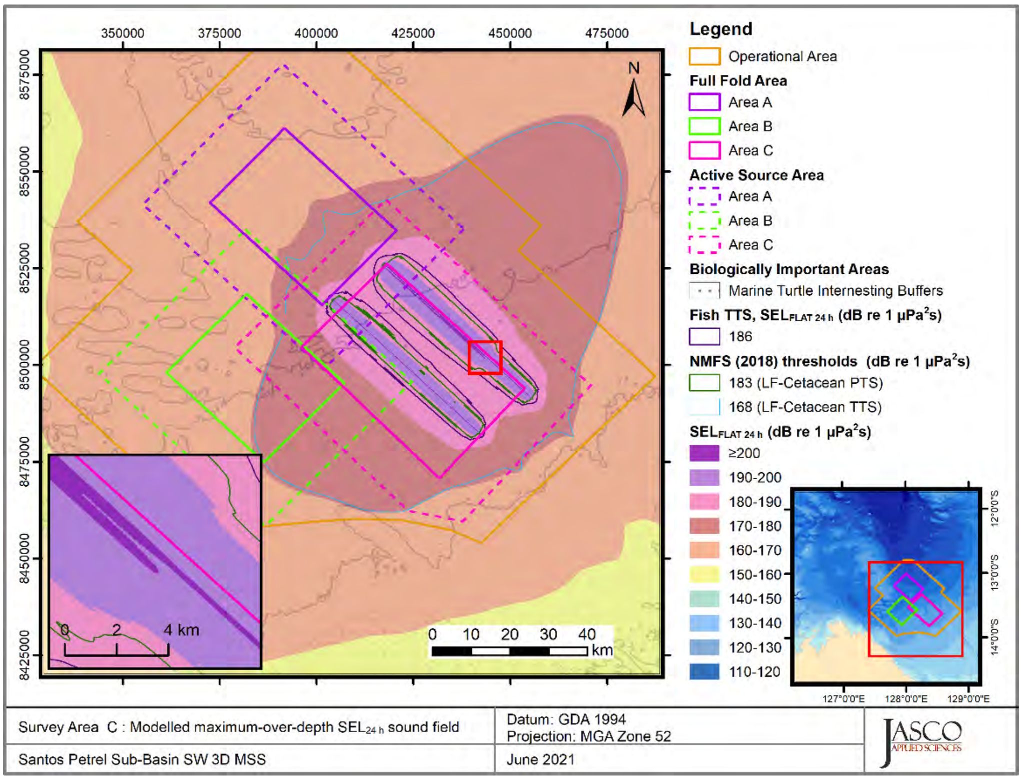


Figure 20. *Scenario 3, Area C:* Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetaceans and fish TTS. Where contours are too small to identify on the map refer to the radii in Table 15 for distances.

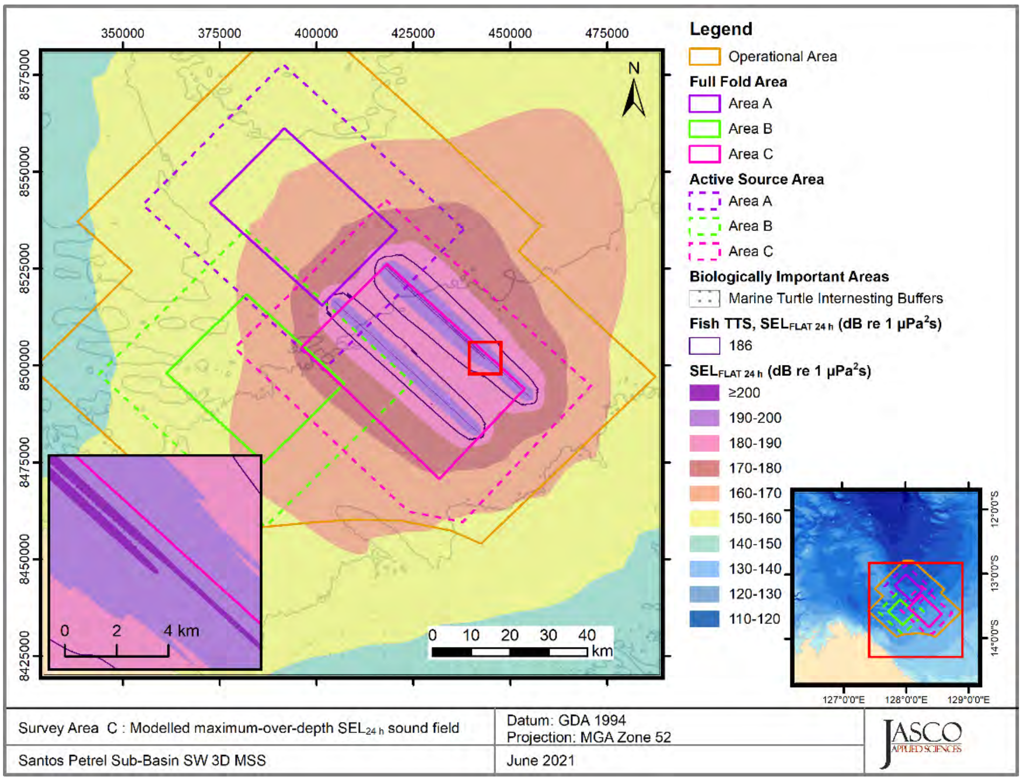


Figure 21. *Scenario 3, Area C:* Sound level contour map showing unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS. Where contours are too small to identify on the map refer to the radii in Table 16 for distances.

6. Discussion

6.1. Overview and Source Levels

This modelling study predicted underwater sound levels associated with the planned Petrel Sub-Basin SW 3D MSS. The underwater sound field was modelled for a 3480 in^3 seismic source (Appendix B), selected as a worst-case option based on a comparison of a 2495 in^3 and a 3480 in^3 seismic source for operation within the Operational Area.

An analysis of seasonal sound speed profiles, the results of which are presented in Appendix D.3.2, indicated that June 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 the seismic source is output at lower frequencies, in the tens to hundreds of hertz. The array had a pronounced broadside directivity for 1/3-octave-bands between approximately 159 to about 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 3480 in^3 seismic source operating at 6 m depth was 225.3 dB 1 μPa^{2}m^{2}s in the broadside direction and 225.1 dB 1 μPa^{2}m^{2}s in the endfire direction. The peak pressure level in the same directions was 248.6 and 247.5 dB re 1 μPa m, respectively (Table 8).

6.2. Per-Pulse Sound Fields

The sound speed profile for June (Figure D-5) was primarily downward refracting apart from a slight upward refracting layer, which extended to approximately 60 m from the sea surface. The slight upward refracting layer in the sound speed profile, will only effective trap frequencies above 403 Hz (Jensen et al. 2011). The presence of this layer has the potential to trap levels at higher frequencies which would otherwise dissipate more rapidly in range due to propagation, absorption, and seabed losses.

The array directionality and frequency content coupled with bathymetry, resulted in shallow water propagation phenomena where the water column sound field is significantly influence by variations and interactions with the seabed. Generally larger lobes of sound energy extending into the deeper waters to the north of the Operational Area where the bathymetry transitions into a deeper water environment, allowing more energy to be trapped between the sea surface and the seabed. The bathymetry generally decreased to the south of the Operational Area, which has the opposite effect of deeper water. As water depth decreases more energy is transmitted into the seabed where it attenuates more rapidly with distance as compared to the water column. The vertical slice plots (Section 5.2.2.2) assist in demonstrating the influence of the regional bathymetry, source location and directionality on sound propagation from the seismic source.

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 sound propagation in shallow water. However, the number of modelling sites and gradual changes in water depth considered within the Operational Area, provides a good representation of potential variability for seabed receptors.

6.3. Multiple Pulse Sound Fields

The accumulated SEL over 24 h of seismic source operation was modelled considering two representative scenarios with realistic acquisition patterns for the Petrel Sub-Basin SW 3D 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 within the Full Fold Acquisition Areas are primarily influenced by the high levels in the broadside direction and the gradually variations in bathymetry as discussed above. For the two 24 h scenarios considered, the maximum ranges to species specific thresholds are associated with the broadside source levels and near constant bathymetry.

6.4. 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.

As pertains to the results below, the SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels, based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure since, more realistically, marine fauna such as mammals, turtles, and fish would not stay in the same location or at the same distance from a sound source for an extended period. Therefore, a reported radius for SEL_{24h} criteria does not mean that any animal travelling within this radius from the source *will* be injured, but rather that it *could* be injured if it remained within that range during a 24 h period.

Marine mammal injury and behaviour

- The maximum distance where the (NOAA 2019) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 7.86 and 8.46 km (Site 6 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 18 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 1 (Area A), in deeper water for low-frequency cetaceans.

Table 18. Summary of maximum marine mammal PTS onset distances for modelled scenarios (PK values from Table 11 and SEL_{24h} values from Table 15). The model does not account for shutdowns.

Hearing group	Area A		Area B		Area C	
	Metric associated with longest distance to PTS onset	R_{max} (km)	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}	4.89	SEL_{24h}	4.50	SEL_{24h}	4.77
Mid-frequency cetaceans	—	—	—	—	—	—
High-frequency cetaceans	PK	0.31	PK	0.36	PK	0.33
Sirenians (Dugongs)	—	—	—	—	—	—
Turtles	SEL_{24h}	0.04	SEL_{24h}	0.04	SEL_{24h}	0.04

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 greater than 20 m (horizontal modelling resolution for FWRAM) from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metric for PTS onset was 50 m and 2.57 km for TTS onset (Finneran et al. 2017).
- The distances to where the NMFS criterion (NSF 2011) for behavioural response in turtles of turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000a, McCauley et al. 2000b) could be exceeded are summarised in Table 19.

Table 19. Summary of distances to turtle behavioural response criteria (from Table 10).

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Minimum	Maximum
175†	1.71	1.97
166‡	4.59	5.06

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000a, McCauley et al. 2000b).
‡ 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 and 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 20 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.

Table 20. 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	0.08
	TTS	SEL_{24h}	6.66	SEL_{24h}	6.17
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.16	PK	0.21
	TTS	SEL_{24h}	6.66	SEL_{24h}	6.17
Fish eggs, and larvae	Injury	PK	0.16	PK	0.21

Crustaceans, Sponges, and Coral

To assist with assessing the potential effects on these receptors, the following have been determined:

- 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 604 and 638 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); it was not reached at any of the modelled sites (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 three modelled sites through full-waveform modelling; the results ranged from 6.8 to 8.4 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.

Literature Cited

[DEWHA] Department of the Environment Water Heritage and the Arts. 2008. *EPBC Act Policy Statement 2.1 - Interaction Between Offshore Seismic Exploration and Whales*. *In*: Australian Government - Department of the Environment, Water, Heritage and the Arts. 14 p. http://www.environment.gov.au/resource/epbc-act-policy-statement-21-interaction-between-offshore-seismic-exploration-and-whales.

[HESS] High Energy Seismic Survey. 1999. *High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore Southern California*. Prepared for the California State Lands Commission and the United States Minerals Management Service Pacific Outer Continental Shelf Region by the High Energy Seismic Survey Team, Camarillo, CA, USA. 98 p. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2001100103.xhtml.

[ISO] International Organization for Standardization. 2017. *ISO 18405:2017. Underwater acoustics – Terminology*. Geneva. https://www.iso.org/standard/62406.html.

[NMFS] National Marine Fisheries Service. 2014. *Marine Mammals: Interim Sound Threshold Guidance* (webpage). National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. http://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html.

[NMFS] National Marine Fisheries Service (US). 1998. *Acoustic Criteria Workshop*. Dr. Roger Gentry and Dr. Jeanette Thomas Co-Chairs.

[NMFS] National Marine Fisheries Service (US). 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55. 178 p.

[NMFS] National Marine Fisheries Service (US). 2018. *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. US Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 p. https://www.fisheries.noaa.gov/webdam/download/75962998.

[NOAA] National Oceanic and Atmospheric Administration (US). 2013. *Draft guidance for assessing the effects of anthropogenic sound on marine mammals: Acoustic threshold levels for onset of permanent and temporary threshold shifts*. National Oceanic and Atmospheric Administration, US Department of Commerce, and NMFS Office of Protected Resources, Silver Spring, MD, USA. 76 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2015. *Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*. NMFS Office of Protected Resources, Silver Spring, MD, USA. 180 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2016. *Document Containing Proposed Changes to the NOAA Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts*. National Oceanic and Atmospheric Administration and US Department of Commerce. 24 p.

[NOAA] National Oceanic and Atmospheric Administration (US). 2018. Takes of Marine Mammals Incidental to Specified Activities; Taking Marine Mammals Incidental to Marine Site Characterization Surveys off of Delaware. *Federal Register* 83(65): 14417-14443. https://www.federalregister.gov/d/2018-12225.

[NOAA] National Oceanic and Atmospheric Administration (US). 2019. *ESA Section 7 Consultation Tools for Marine Mammals on the West Coast* (webpage), 27 Sep 2019. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west. (Accessed 10 Mar 2020).

[NSF] National Science Foundation (US), Geological Survey (US), and [NOAA] National Oceanic and Atmospheric Administration (US). 2011. *Final Programmatic Environmental Impact Statement/Overseas. Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the US Geological Survey*. National Science Foundation, Arlington, VA, USA. https://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/nsf-usgs-final-eis-oeis_3june2011.pdf.

[ONR] Office of Naval Research. 1998. *ONR Workshop on the Effect of Anthropogenic Noise in the Marine Environment*. Dr. R. Gisiner, Chair.

Aerts, L.A.M., M. Blees, S.B. Blackwell, C.R. Greene, Jr., K.H. Kim, D.E. Hannay, and M.E. Austin. 2008. *Marine mammal monitoring and mitigation during BP Liberty OBC seismic survey in Foggy Island Bay, Beaufort Sea, July-August 2008: 90-day report*. Document Number P1011-1. Report by LGL Alaska Research Associates Inc., LGL Ltd., Greeneridge Sciences Inc., and JASCO Applied Sciences for BP Exploration Alaska. 199 p. ftp://ftp.library.noaa.gov/noaa_documents.lib/NMFS/Auke%20Bay/AukeBayScans/Removable%20Disk/P1011-1.pdf.

ANSI S12.7-1986. R2006. *American National Standard Methods for Measurements of Impulsive Noise*. American National Standards Institute, NY, USA.

ANSI S1.1-1994. R2004. *American National Standard Acoustical Terminology*. American National Standards Institute, NY, USA.

ANSI S1.1-2013. R2013. *American National Standard Acoustical Terminology*. American National Standards Institute, NY, USA.

Austin, M.E. and G.A. Warner. 2012. *Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey*. Version 2.0. Technical report by JASCO Applied Sciences for Fairweather LLC and Apache Corporation.

Austin, M.E. and L. Bailey. 2013. *Sound Source Verification: TGS Chukchi Sea Seismic Survey Program 2013*. Document Number 00706, Version 1.0. Technical report by JASCO Applied Sciences for TGS-NOPEC Geophysical Company.

Austin, M.E., A. McCrodan, C. O'Neill, Z. Li, and A.O. MacGillivray. 2013. *Marine mammal monitoring and mitigation during exploratory drilling by Shell in the Alaskan Chukchi and Beaufort Seas, July–November 2012: 90-Day Report*. *In*: Funk, D.W., C.M. Reiser, and W.R. Koski (eds.). Underwater Sound Measurements. LGL Rep. P1272D–1. Report from LGL Alaska Research Associates Inc. and JASCO Applied Sciences, for Shell Offshore Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. 266 pp plus appendices.

Austin, M.E. 2014. Underwater noise emissions from drillships in the Arctic. *In*: Papadakis, J.S. and L. Bjørnø (eds.). *UA2014 - 2nd International Conference and Exhibition on Underwater Acoustics*. 22-27 Jun 2014, Rhodes, Greece. pp. 257-263.

Austin, M.E., H. Yurk, and R. Mills. 2015. *Acoustic Measurements and Animal Exclusion Zone Distance Verification for Furie's 2015 Kitchen Light Pile Driving Operations in Cook Inlet*. Version 2.0. Technical report by JASCO Applied Sciences for Jacobs LLC and Furie Alaska.

Austin, M.E. and Z. Li. 2016. *Marine Mammal Monitoring and Mitigation During Exploratory Drilling by Shell in the Alaskan Chukchi Sea, July–October 2015: Draft 90-day report*. *In*: Ireland, D.S. and L.N. Bisson (eds.). Underwater Sound Measurements. LGL Rep. P1363D. Report from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. For Shell

Gulf of Mexico Inc, National Marine Fisheries Service, and US Fish and Wildlife Service. 188 pp + appendices.

Carnes, M.R. 2009. *Description and Evaluation of GDEM-V 3.0*. US Naval Research Laboratory, Stennis Space Center, MS. NRL Memorandum Report 7330-09-9165. 21 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/a494306.pdf.

Collins, M.D. 1993. A split-step Padé solution for the parabolic equation method. *Journal of the Acoustical Society of America* 93(4): 1736-1742. https://doi.org/10.1121/1.406739.

Collins, M.D., R.J. Cederberg, D.B. King, and S. Chin-Bing. 1996. Comparison of algorithms for solving parabolic wave equations. *Journal of the Acoustical Society of America* 100(1): 178-182. https://doi.org/10.1121/1.415921.

Coppens, A.B. 1981. Simple equations for the speed of sound in Neptunian waters. *Journal of the Acoustical Society of America* 69(3): 862-863. https://doi.org/10.1121/1.382038.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, J.M. Semmens, and Institute for Marine and Antarctic Studies. 2016a. *Assessing the Impact of Marine Seismic Surveys on Southeast Australian Scallop and Lobster Fisheries*. Impacts of Marine Seismic Surveys on Scallop and Lobster Fisheries. Fisheries Ressearch & Development Corporation. FRDC Project No 2012/008, University of Tasmania, Hobart. 159 p.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, and J.M. Semmens. 2016b. Seismic air gun exposure during early-stage embryonic development does not negatively affect spiny lobster *Jasus edwardsii larvae* (Decapoda:Palinuridae). *Scientific Reports* 6: 1-9. https://doi.org/10.1038/srep22723.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2017. Exposure to seismic air gun signals causes physiological harm and alters behavior in the scallop *Pecten fumatus*. *Proceedings of the National Academy of Sciences* 114(40): E8537-E8546. https://doi.org/10.1073/pnas.1700564114.

Day, R.D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, and J.M. Semmens. 2019. Seismic air guns damage rock lobster mechanosensory organs and impair righting reflex. *Proc. R. Soc. B* 286(1907): 10.

Department of the Environment and Energy, NSW Government, and Queensland Government. 2017. *Recovery Plan for Marine Turtles in Australia*. https://www.environment.gov.au/marine/publications/recovery-plan-marine-turtles-australia-2017.

Dragoset, W.H. 1984. A comprehensive method for evaluating the design of airguns and airgun arrays. *16th Annual Offshore Technology Conference* Volume 3, 7-9 May 1984. OTC 4747, Houston, TX, USA. pp. 75–84. https://doi.org/10.4043/4783-MS.

Ellison, W.T. and P.J. Stein. 1999. *SURTASS LFA High Frequency Marine Mammal Monitoring (HF/M3) Sonar: Sustem Description and Test & Evaluation*. Under US Navy Contract N66604-98-D-5725. http://www.surtass-lfa-eis.com/wp-content/uploads/2018/02/HF-M3-Ellison-Report-2-4a.pdf.

Ellison, W.T. and A.S. Frankel. 2012. A common sense approach to source metrics. *In* Popper, A.N. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life*. Volume 730. Springer, New York. pp. 433-438. https://doi.org/10.1007/978-1-4419-7311-5_98.

Finneran, J.J. and A.K. Jenkins. 2012. *Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis*. SPAWAR Systems Center Pacific, San Diego, CA, USA. 64 p.

Finneran, J.J. 2015. *Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores*. Technical report by SSC Pacific, San Diego, CA, USA.

Finneran, J.J. 2016. *Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise*. Technical Report for Space and Naval Warfare Systems Center Pacific, San Diego, CA, USA. 49 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/1026445.pdf.

Finneran, J.J., E.E. Henderson, D.S. Houser, K. Jenkins, S. Kotecki, and J. Mulsow. 2017. *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*. Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 p. https://apps.dtic.mil/dtic/tr/fulltext/u2/a561707.pdf.

Fisher, F.H. and V.P. Simmons. 1977. Sound absorption in sea water. *Journal of the Acoustical Society of America* 62(3): 558-564. https://doi.org/10.1121/1.381574.

Funk, D.W., D.E. Hannay, D.S. Ireland, R. Rodrigues, and W.R. Koski. 2008. *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day report*. LGL Report P969-1. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for Shell Offshore Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. 218 p.

Gedamke, J., N. Gales, and S. Frydman. 2011. Assessing risk of baleen whale hearing loss from seismic surveys: The effect of uncertainty and individual variation. *Journal of the Acoustical Society of America* 129(1): 496-506. https://doi.org/10.1121/1.3493445.

Hannay, D.E. and R.G. Racca. 2005. *Acoustic Model Validation*. Document Number 0000-S-90-04-T-7006-00-E, Revision 02. Technical report by JASCO Research Ltd. for Sakhalin Energy Investment Company Ltd. 34 p.

Heyward, A., J. Colquhoun, E. Cripps, D. McCorry, M. Stowar, B. Radford, K. Miller, I. Miller, and C. Battershill. 2018. No evidence of damage to the soft tissue or skeletal integrity of mesophotic corals exposed to a 3D marine seismic survey. *Marine Pollution Bulletin* 129(1): 8-13. https://doi.org/10.1016/j.marpolbul.2018.01.057.

Ireland, D.S., R. Rodrigues, D.W. Funk, W.R. Koski, and D.E. Hannay. 2009. *Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–October 2008: 90-Day Report*. Document Number P1049-1. 277 p.

Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. 2011. *Computational Ocean Acoustics*. 2nd edition. AIP Series in Modern Acourics and Signal Processing. AIP Press - Springer, New York. 794 p. https://doi.org/10.1007/978-1-4419-8678-8.

Kujawa, S.G. and M.C. Liberman. 2006. Acceleration of age-related hearing loss by early noise exposure: Evidence of a misspent youth. *Journal of Neuroscience* 26(7): 2115-2123. https://doi.org/10.1523/JNEUROSCI.4985-05.2006.

Kujawa, S.G. and M.C. Liberman. 2009. Adding insult to injury: Cochlear nerve degeneration after 'temporary' noise induced hearing loss. *Journal of Neuroscience* 29(45): 14077-14086. https://doi.org/10.1523/JNEUROSCI.2845-09.2009.

Kujawa, S.G. and M.C. Liberman. 2015. Synaptopathy in the noise-exposed and aging cochlea: Primary neural degeneration in acquired sensorineural hearing loss. *Hearing Research* 330: 191-199. http://www.sciencedirect.com/science/article/pii/S037859551500057X.

Landrø, M. 1992. Modeling of GI gun signatures. *Geophysical Prospecting* 40(7): 721–747. https://doi.org/10.1111/j.1365-2478.1992.tb00549.x.

Laws, R.M., L. Hatton, and M. Haartsen. 1990. Computer modeling of clustered airguns. *First Break* 8(9): 331–338.

Lurton, X. 2002. *An Introduction to Underwater Acoustics: Principles and Applications*. Springer, Chichester, UK. 347 p.

MacGillivray, A.O. and N.R. Chapman. 2012. Modeling underwater sound propagation from an airgun array using the parabolic equation method. *Canadian Acoustics* 40(1): 19-25. https://jcaa.caa-aca.ca/index.php/jcaa/article/view/2502/2251.

MacGillivray, A.O. 2018. Underwater noise from pile driving of conductor casing at a deep-water oil platform. *Journal of the Acoustical Society of America* 143(1): 450-459. https://doi.org/10.1121/1.5021554.

Maison, S.F., H. Usubuchi, and M.C. Liberman. 2013. Efferent Feedback Minimizes Cochlear Neuropathy from Moderate Noise Exposure. *Journal of Neuroscience* 33(13): 5542-5552. https://www.jneurosci.org/content/jneuro/33/13/5542.full.pdf.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1984. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase II: January 1984 migration*. Report Number 5586. Report by Bolt, Beranek and Newman Inc. for the US Department of the Interior, Minerals Management Service, Cambridge, MA, USA. https://www.boem.gov/BOEM-Newsroom/Library/Publications/1983/rpt5586.aspx.

Martin, B., K. Bröker, M.-N.R. Matthews, J.T. MacDonnell, and L. Bailey. 2015. Comparison of measured and modeled air-gun array sound levels in Baffin Bay, West Greenland. *OceanNoise 2015*. 11-15 May 2015, Barcelona, Spain.

Martin, B., J.T. MacDonnell, and K. Bröker. 2017a. Cumulative sound exposure levels—Insights from seismic survey measurements. *Journal of the Acoustical Society of America* 141(5): 3603-3603. https://doi.org/10.1121/1.4987709.

Martin, S.B. and A.N. Popper. 2016. Short- and long-term monitoring of underwater sound levels in the Hudson River (New York, USA). *Journal of the Acoustical Society of America* 139(4): 1886-1897. https://doi.org/10.1121/1.4944876.

Martin, S.B., M.-N.R. Matthews, J.T. MacDonnell, and K. Bröker. 2017b. Characteristics of seismic survey pulses and the ambient soundscape in Baffin Bay and Melville Bay, West Greenland. *Journal of the Acoustical Society of America* 142(6): 3331-3346. https://doi.org/10.1121/1.5014049.

Matthews, M.-N.R. and A.O. MacGillivray. 2013. Comparing modeled and measured sound levels from a seismic survey in the Canadian Beaufort Sea. *Proceedings of Meetings on Acoustics* 19(1): 1-8. https://doi.org/10.1121/1.4800553

Mattsson, A. and M. Jenkerson. 2008. Single Airgun and Cluster Measurement Project. *Joint Industry Programme (JIP) on Exploration and Production Sound and Marine Life Proramme Review*. 28-30 Oct 2008. International Association of Oil and Gas Producers, Houston, TX, USA.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, et al. 2000a. Marine seismic surveys: A study of environmental implications. *Australian Petroleum Production Exploration Association (APPEA) Journal* 40(1): 692-708. https://doi.org/10.1071/AJ99048.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, et al. 2000b. *Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid*. Report Number R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Maine Science and Technology, Western Australia. 198 p. https://cmst.curtin.edu.au/wp-content/uploads/sites/4/2016/05/McCauley-et-al-Seismic-effects-2000.pdf.

McCrodan, A., C.R. McPherson, and D.E. Hannay. 2011. *Sound Source Characterization (SSC) Measurements for Apache's 2011 Cook Inlet 2D Technology Test*. Version 3.0. Technical report by JASCO Applied Sciences for Fairweather LLC and Apache Corporation. 51 p.

McPherson, C.R. and G.A. Warner. 2012. *Sound Sources Characterization for the 2012 Simpson Lagoon OBC Seismic Survey 90-Day Report*. Document Number 00443, Version 2.0. Technical report by JASCO Applied Sciences for BP Exploration (Alaska) Inc. http://www.nmfs.noaa.gov/pr/pdfs/permits/bp_openwater_90dayreport_appendices.pdf.

McPherson, C.R., K. Lucke, B.J. Gaudet, S.B. Martin, and C.J. Whitt. 2018. *Pelican 3-D Seismic Survey Sound Source Characterisation*. Document Number 001583. Version 1.0. Technical report by JASCO Applied Sciences for RPS Energy Services Pty Ltd.

McPherson, C.R. and B. Martin. 2018. *Characterisation of Polarcus 2380 in^3 Airgun Array*. Document Number 001599, Version 1.0. Technical report by JASCO Applied Sciences for Polarcus Asia Pacific Pte Ltd.

Nedwell, J.R. and A.W. Turnpenny. 1998. The use of a generic frequency weighting scale in estimating environmental effect. *Workshop on Seismics and Marine Mammals*. 23–25 Jun 1998, London, UK.

Nedwell, J.R., A.W. Turnpenny, J. Lovell, S.J. Parvin, R. Workman, J.A.L. Spinks, and D. Howell. 2007. *A validation of the dB_{ht} as a measure of the behavioural and auditory effects of underwater noise*. Document Number 534R1231 Report prepared by Subacoustech Ltd. for Chevron Ltd, TotalFinaElf Exploration UK PLC, Department of Business, Enterprise and Regulatory Reform, Shell UK Exploration and Production Ltd, The Industry Technology Facilitator, Joint Nature Conservation Committee, and The UK Ministry of Defence. 74 p. https://tethys.pnnl.gov/sites/default/files/publications/Nedwell-et-al-2007.pdf.

O'Neill, C., D. Leary, and A. McCrodan. 2010. Sound Source Verification. (Chapter 3) *In* Blees, M.K., K.G. Hartin, D.S. Ireland, and D.E. Hannay (eds.). *Marine mammal monitoring and mitigation during open water seismic exploration by Statoil USA E&P Inc. in the Chukchi Sea, August-October 2010: 90-day report*. LGL Report P1119. Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Applied Sciences Ltd. for Statoil USA E&P Inc., National Marine Fisheries Service (US), and US Fish and Wildlife Service. pp. 1-34.

Payne, J.F., C. Andrews, L. Fancey, D. White, and J. Christian. 2008. *Potential Effects of Seismic Energy on Fish and Shellfish: An Update since 2003*. Report Number 2008/060. Canadian Science Advisory Secretariat. 22 p.

Payne, R. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. *Annals of the New York Academy of Sciences* 188: 110-141. https://doi.org/10.1111/j.1749-6632.1971.tb13093.x.

Plomp, R. and M.A. Bouman. 1959. Relation between Hearing Threshold and Duration for Tone Pulses. *Journal of the Acoustical Society of America* 31(6): 749-758. https://doi.org/10.1121/1.1907781.

Popper, A.N., M.E. Smith, P.A. Cott, B.W. Hanna, A.O. MacGillivray, M.E. Austin, and D.A. Mann. 2005. Effects of exposure to seismic airgun use on hearing of three fish species. *Journal of the Acoustical Society of America* 117(6): 3958-3971. https://doi.org/10.1121/1.1904386

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, et al. 2014. *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. ASA S3/SC1.4 TR-2014. SpringerBriefs in Oceanography. ASA Press and Springer. https://doi.org/10.1007/978-3-319-06659-2.

Popper, A.N., T.J. Carlson, J.A. Gross, A.D. Hawkins, D.G. Zeddies, L. Powell, and J. Young. 2016. Effects of seismic air guns on pallid sturgeon and paddlefish. *In* Popper, A.N. and A.D.

Hawkins (eds.). *The Effects of Noise on Aquatic Life II*. Volume 875. Springer, New York. pp. 871-878. https://doi.org/10.1007/978-1-4939-2981-8_107.

Popper, A.N. 2018. *Potential for impact of cumulative sound exposure on fishes during a seismic survey*. Environmental BioAcoustics, LLC, Maryland, USA. https://www.nopsema.gov.au/assets/epdocuments/A601445-EP-Summary-redacted.pdf.

Porter, M.B. and Y.C. Liu. 1994. Finite-element ray tracing. *In*: Lee, D. and M.H. Schultz (eds.). *International Conference on Theoretical and Computational Acoustics*. Volume 2. World Scientific Publishing Co. pp. 947-956.

Racca, R.G., A.N. Rutenko, K. Bröker, and M.E. Austin. 2012a. A line in the water - design and enactment of a closed loop, model based sound level boundary estimation strategy for mitigation of behavioural impacts from a seismic survey. *11th European Conference on Underwater Acoustics*. Volume 34(3), Edinburgh, UK.

Racca, R.G., A.N. Rutenko, K. Bröker, and G. Gailey. 2012b. Model based sound level estimation and in-field adjustment for real-time mitigation of behavioural impacts from a seismic survey and post-event evaluation of sound exposure for individual whales. *In*: McMinn, T. (ed.). *Acoustics 2012*. Fremantle, Australia. http://www.acoustics.asn.au/conference_proceedings/AAS2012/papers/p92.pdf.

Racca, R.G., M.E. Austin, A.N. Rutenko, and K. Bröker. 2015. Monitoring the gray whale sound exposure mitigation zone and estimating acoustic transmission during a 4-D seismic survey, Sakhalin Island, Russia. *Endangered Species Research* 29(2): 131-146. https://doi.org/10.3354/esr00703.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4): 411-521.

Southall, B.L., D.P. Nowaceck, P.J.O. Miller, and P.L. Tyack. 2016. Experimental field studies to measure behavioral responses of cetaceans to sonar. *Endangered Species Research* 31: 293-315. https://doi.org/10.3354/esr00764.

Southall, B.L., J.J. Finneran, C.J. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2): 125-232. https://doi.org/10.1578/AM.45.2.2019.125.

Teague, W.J., M.J. Carron, and P.J. Hogan. 1990. A comparison between the Generalized Digital Environmental Model and Levitus climatologies. *Journal of Geophysical Research* 95(C5): 7167-7183. https://doi.org/10.1029/JC095iC05p07167.

Warner, G.A., C. Erbe, and D.E. Hannay. 2010. Underwater Sound Measurements. (Chapter 3) *In* Reiser, C.M., D. Funk, R. Rodrigues, and D.E. Hannay (eds.). *Marine Mammal Monitoring and Mitigation during Open Water Shallow Hazards and Site Clearance Surveys by Shell Offshore Inc. in the Alaskan Chukchi Sea, July-October 2009: 90-Day Report*. LGL Report P1112-1. Report by LGL Alaska Research Associates Inc. and JASCO Applied Sciences for Shell Offshore Inc., National Marine Fisheries Service (US), and Fish and Wildlife Service (US). pp. 1-54.

Warner, G.A., M.E. Austin, and A.O. MacGillivray. 2017. Hydroacoustic measurements and modeling of pile driving operations in Ketchikan, Alaska [Abstract]. *Journal of the Acoustical Society of America* 141(5): 3992. https://doi.org/10.1121/1.4989141.

Whiteway, T. 2009. *Australian Bathymetry and Topography Grid, June 2009*. GeoScience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/67703.

Zhang, Z.Y. and C.T. Tindle. 1995. Improved equivalent fluid approximations for a low shear speed ocean bottom. *Journal of the Acoustical Society of America* 98(6): 3391-3396. https://doi.org/10.1121/1.413789.

Ziolkowski, A.M. 1970. A method for calculating the output pressure waveform from an air gun. *Geophysical Journal International* 21(2): 137-161. https://doi.org/10.1111/j.1365-246X.1970.tb01773.x.

Zykov, M.M. and J.T. MacDonnell. 2013. *Sound Source Characterizations for the Collaborative Baseline Survey Offshore Massachusetts Final Report: Side Scan Sonar, Sub-Bottom Profiler, and the R/V Small Research Vessel experimental*. Document Number 00413, Version 2.0. Technical report by JASCO Applied Sciences for Fugro GeoServices, Inc. and the (US) Bureau of Ocean Energy Management.

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, $p(t)$:

$$L_{p,\mathrm{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \quad \text{(A-1)}$$

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, $p(t)$:

$$L_{p,\mathrm{pk\text{-}pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \quad \text{(A-2)}$$

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:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt \Big/ p_0^2\right) \quad \text{(A-3)}$$

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):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \middle/ T_0 p_0^2\right) \tag{A-4}$$

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:

$$L_{\mathrm{eq}} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)\,dt \middle/ p_0^2\right) \tag{A-8}$$

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., $L_{E,\mathrm{LF24h}}$; see Appendix A.3.1) 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. 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.2.1. Auditory Impairment

There are two categories of auditory threshold shifts (also termed Noise Induced Threshold Shift, NITS): Permanent Threshold Shift (PTS), a physical injury to an animal's hearing system; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of physiological and mechanical processes in the inner ear. While PTS undoubtedly constitutes an injury, TTS (as a temporary effect) was not considered in the same way. However, recent research clearly indicates that already moderate levels (<12 dB) of TTS produced an accelerated hearing loss (PTS) resulting from progressive neural degeneration with age (Kujawa and Liberman 2006, 2009, Maison et al. 2013, Kujawa and Liberman 2015).

The most recent criteria for assessing possible effects of impulsive sounds (such as pile driving or seismic impulses) noise and non-impulsive sound (such as vessel noise) on marine mammals, Southall et al. (2019), was applied in this study.

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, which are numerically identical to those in Southall et al. (2019).

A.2.2. Behavioural response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.3. 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.3.1. 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:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-10)}$$

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
Sirenians (dugongs and manatees)	1.8	2	4,300	25,000	2.62

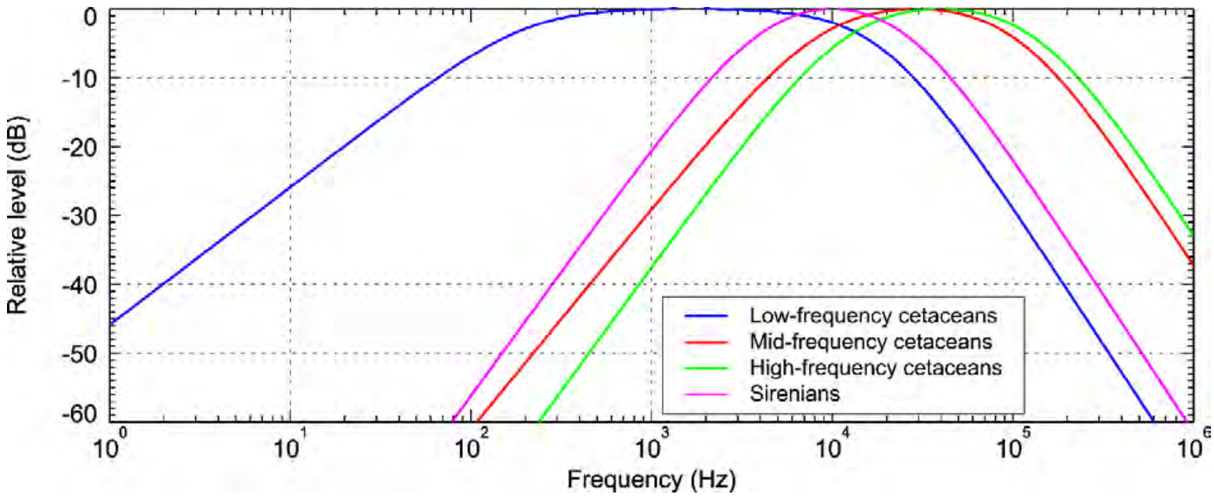


Figure A-1. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by NMFS (2018).

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 Landrø (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:

$$R_{\mathrm{nf}} < \frac{l^2}{4\lambda} \tag{B-1}$$

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 3480 in^3 array (Appendix D.4).

Horizontal 1/3-octave-band source levels are shown as a function of band centre frequency and azimuth (Figure B-2).

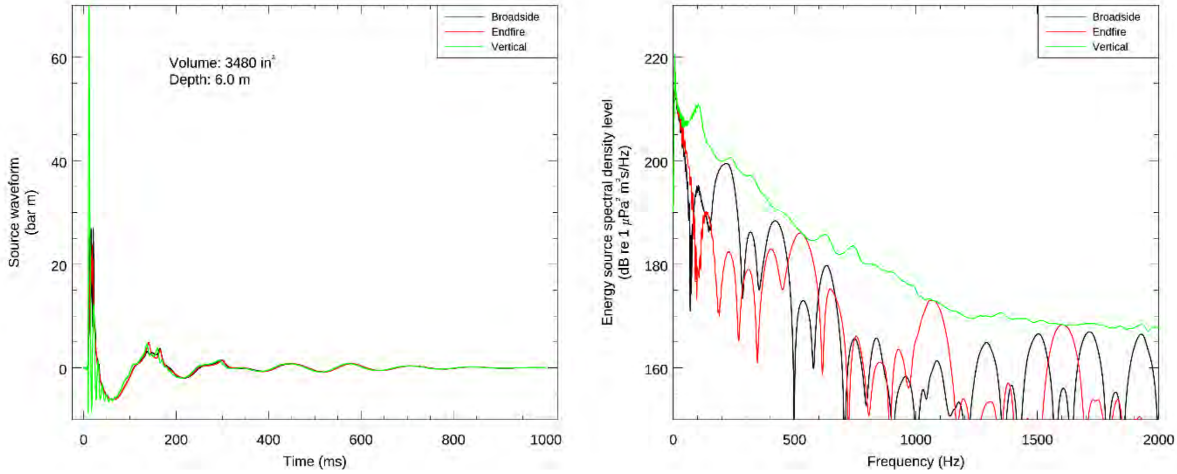


Figure B-1. Predicted source level details for the 3480 in^3 array at 6 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

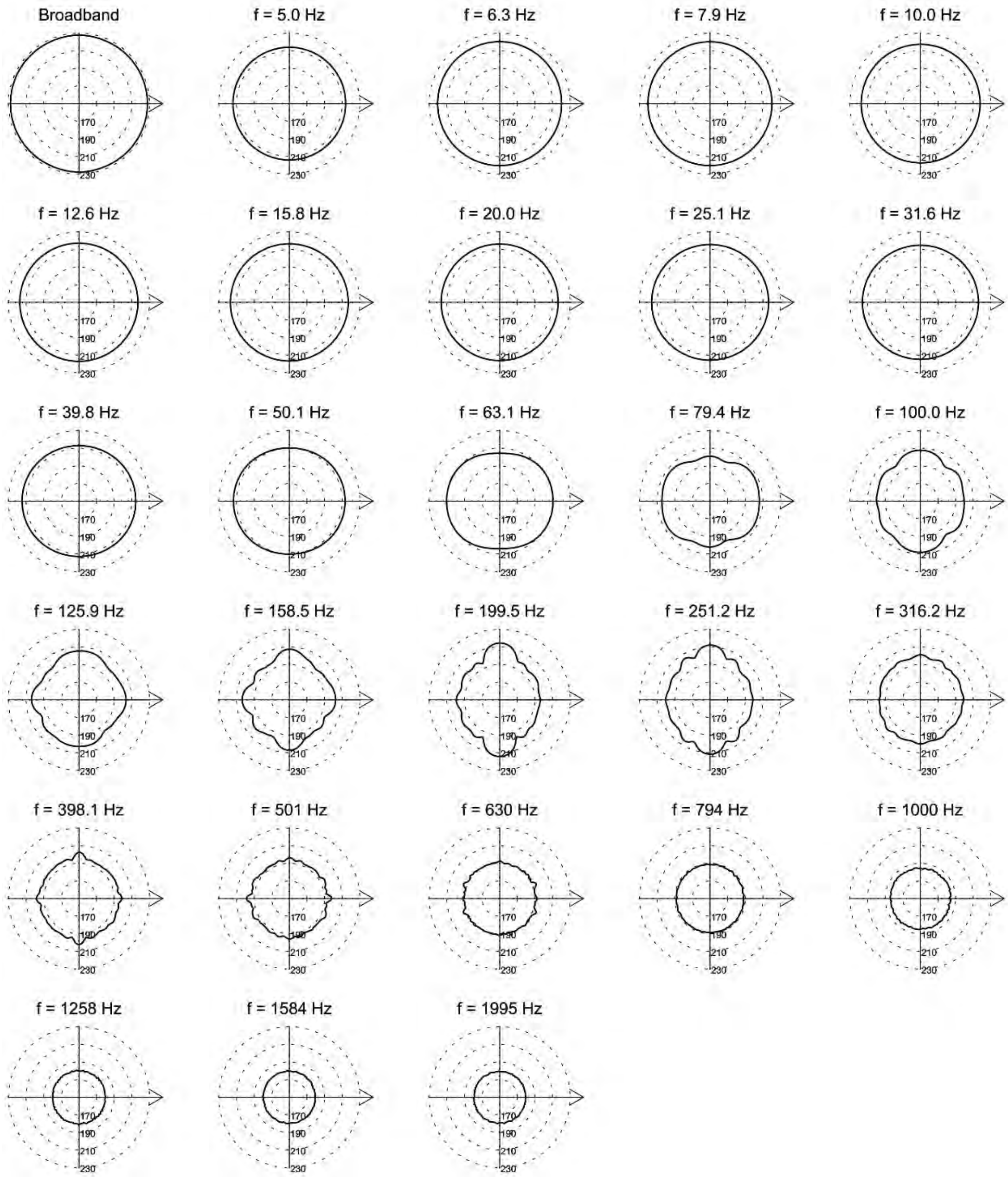


Figure B-2. Directionality of the predicted horizontal source levels for the 3480 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 µPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Tow depth is 6 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 5 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).

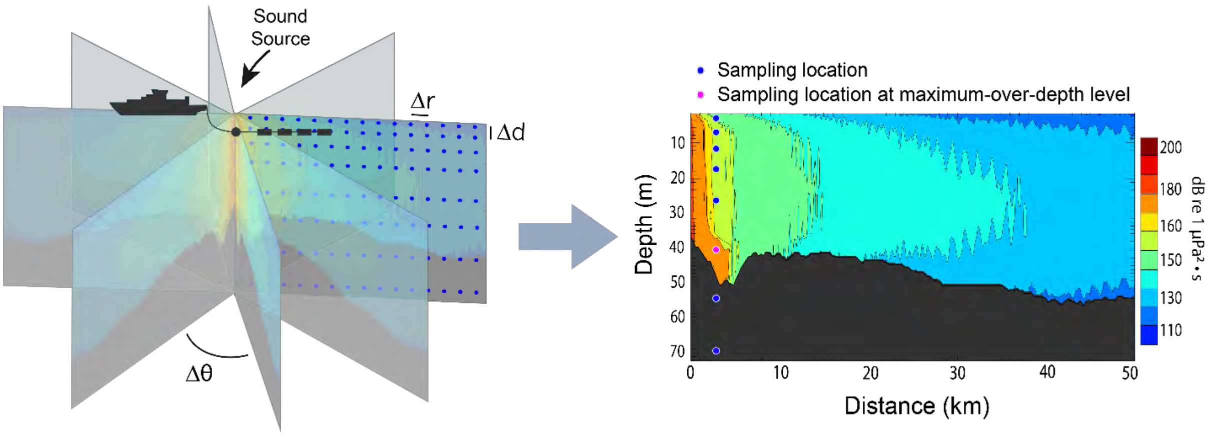


Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

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.

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.

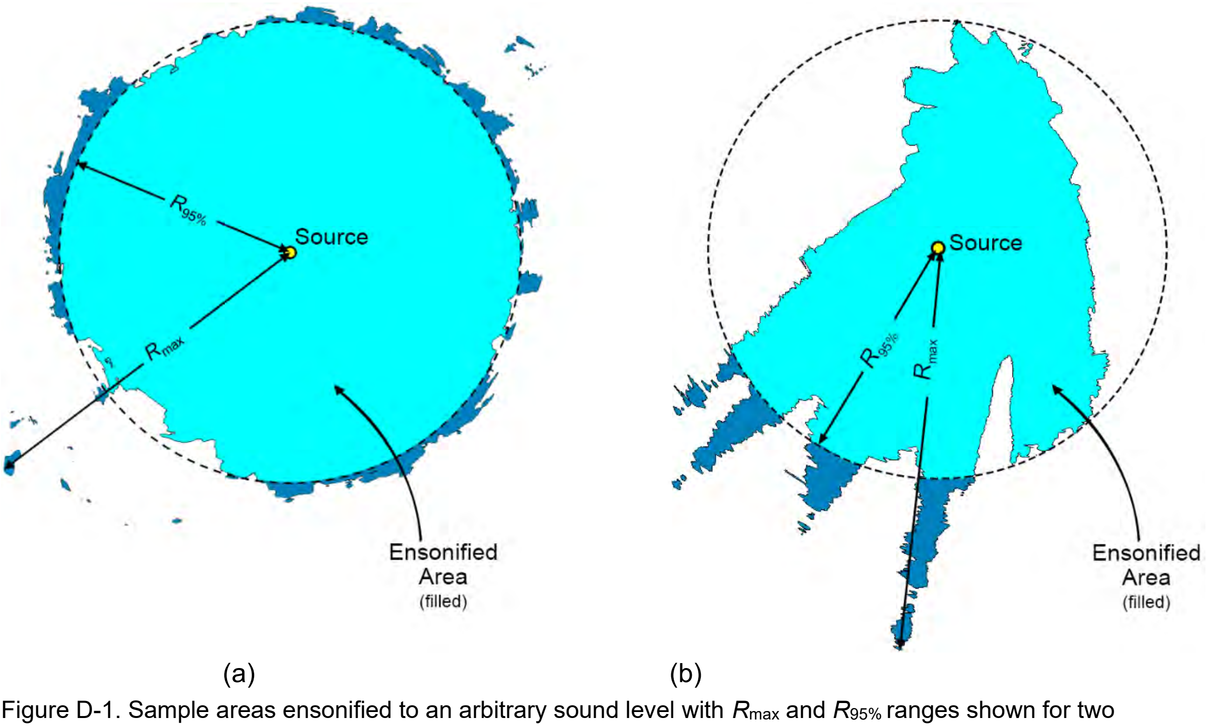


Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified 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 5–2048 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. Figures D-2 and D-3 show the conversion offsets for Sites 2 and 3; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source.

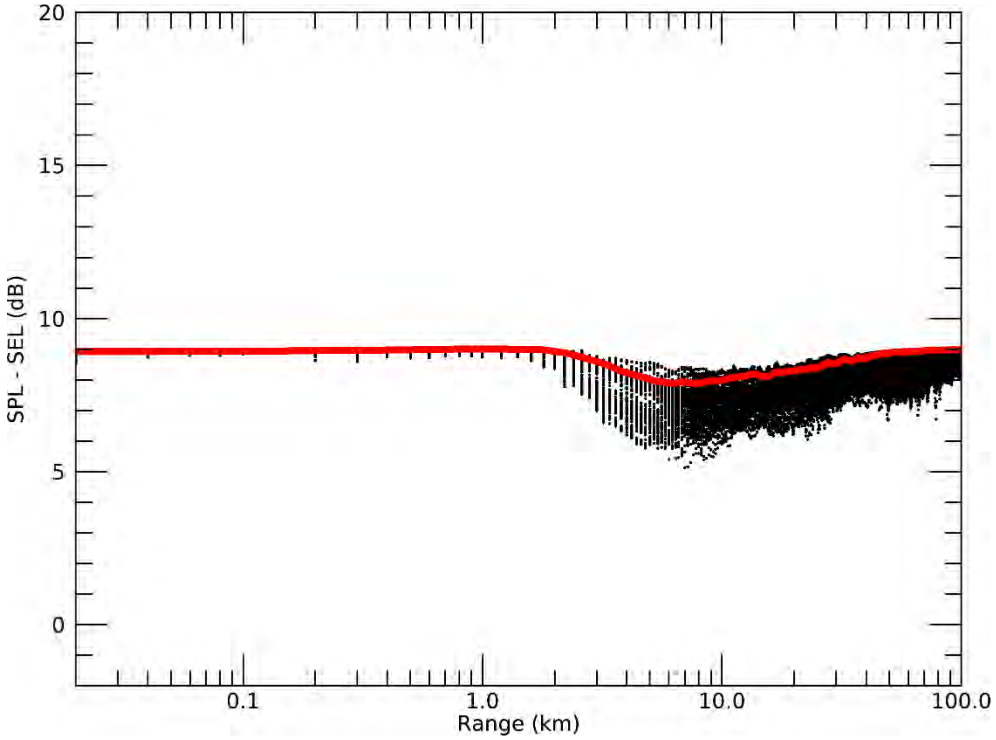


Figure D-2. *Site 2*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3480 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

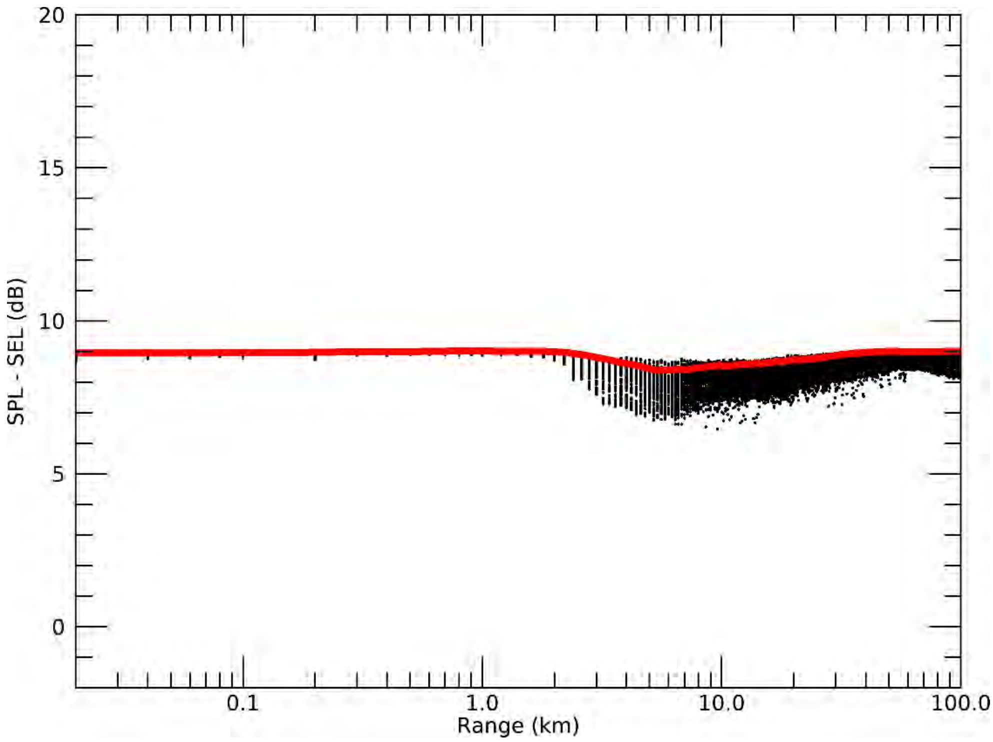


Figure D-3. *Site 3*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3480 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th 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 2. Bathymetry data were extracted and re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 52) with a regular grid spacing of 100 × 100 m to generate the bathymetry in Figure D-4.

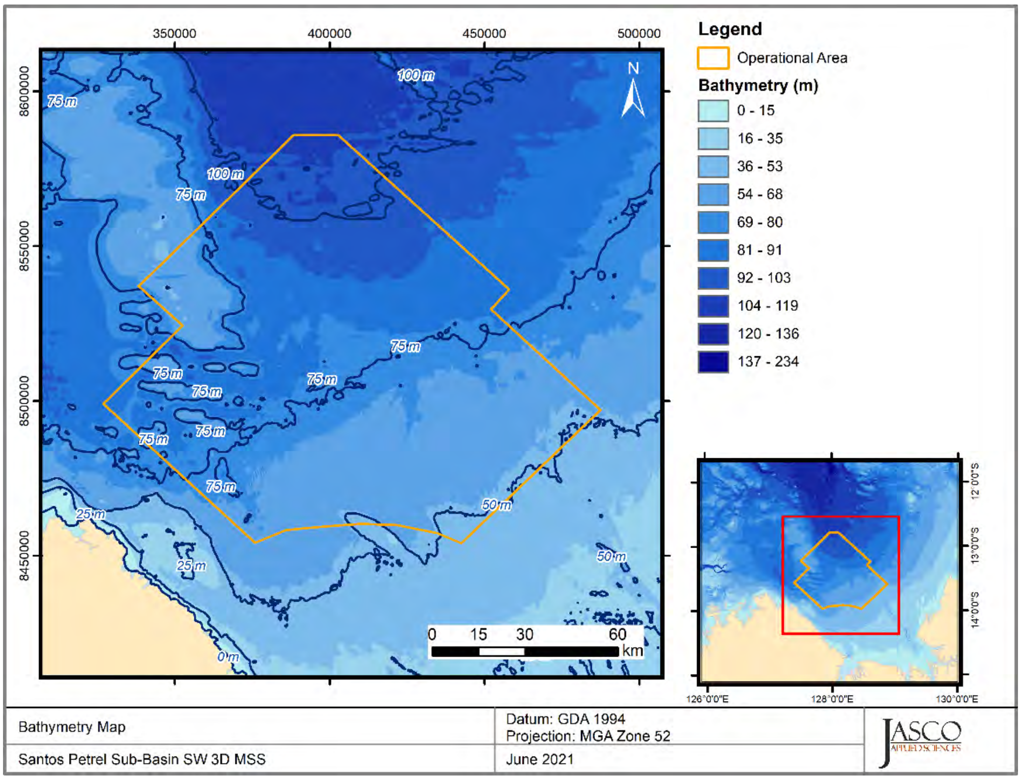


Figure D-4. Bathymetry map of the modelling area.

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 were derived from the GDEM profiles within a 100 km box radius encompassing all modelling sites. The June sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, June was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-5 shows the resulting profile used as input to the sound propagation modelling.

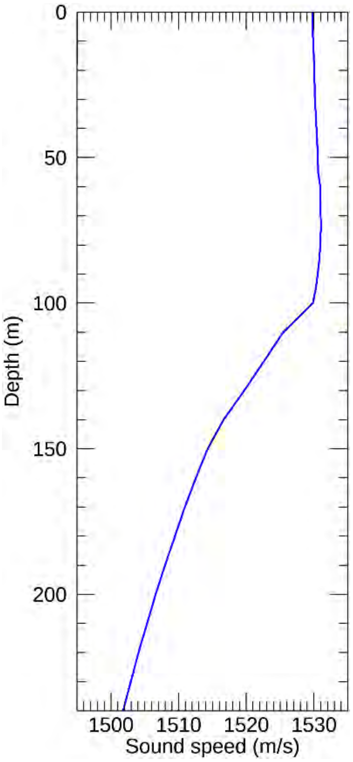


Figure D-5. The final sound speed profile (June) used for the modelling showing the entire water column. The profile was calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

D.3.3. Geoacoustics

Geoacoustic parameters used for modelling at Sites 1–4 are located within the North West Marine Region of Australia (Baker et al. 2008), more specifically the middle shelf region, which is dominated by calcareous sand; the sand content of the sites is 40–60%. Grain size distributions are spatially variable in the area. Overall sediment thicknesses are over 1 km (Whittaker et al. 2013). To provide precautionary estimates of underwater sound levels in the spatially heterogeneous environments, a simplified profile was constructed assuming increasingly consolidated sediment. The geoacoustic parameters for each site were estimated from the sediment model of Buckingham (2005), Table D-1 lists the parameters used for modelling.

Table D-1. Geoacoustic profile for the Sites 1–4. 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)
0–10	Unconsolidated muddy sand	1.88	1624–1724	0.34–0.71	262	3.65
10–20		1.88	1724–1777	0.71–0.88		
20–50		1.88–1.90	1777–1874	0.88–1.14		
50–100	Compact muddy sand	1.90–1.92	1874–1978	1.14–1.37		
100–200		1.92–1.96	1978–2118	1.37–1.62		
200–500	Consolidated muddy sand/sedimentary rock	1.96–2.06	2118–2392	1.62–1.93		
>500		2.06	2392	1.93		

D.4. Seismic Sources

The layout of the 3480 in³ and the 2495 in³ seismic sources used for modelling in this study and considered in Appendix B and Appendix E are provided in Figures D-6 and D-7. Details of the airgun parameters used for acoustic modelling are provided in Tables D-2 and D-3.

For each modelled array, the layouts are presented in a nominal cartesian coordinate system. In this coordinate system the direction of vessel travel determines the relative position of the array elements as plotted and tabulated. The layouts used for acoustic modelling (Figures D-6 and D-7) were produced transforming the coordinates of client supplied layouts such that the resultant layouts correspond to a vessel travel direction along the positive X-axis and the array is centred on the X-Y origin. When used with an acoustic model the positive X-axis in this nominal coordinate system aligns with the vessel tow direction or survey line azimuth.

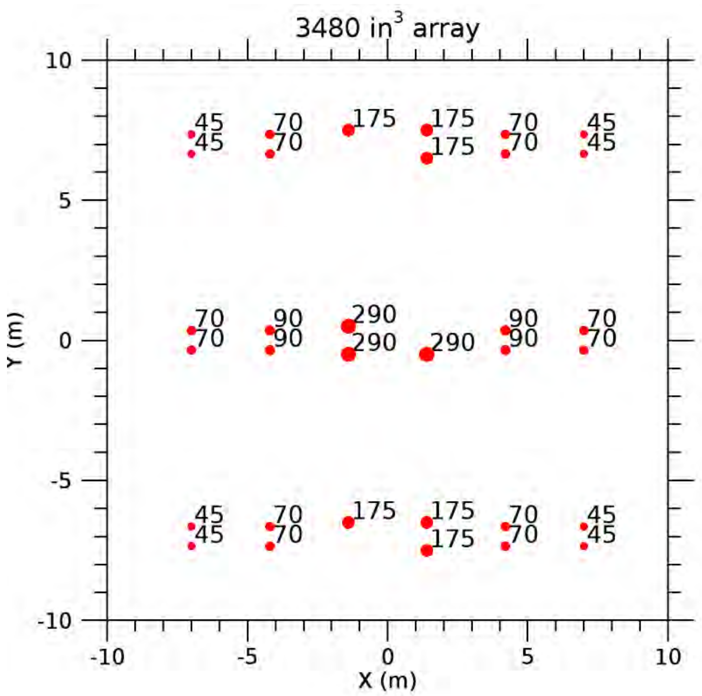


Figure D-6. Layout of the modelled 3480 in³ array where the plotted layout is such that the array is centred on the origin and vessel travel direction is in the positive x-direction. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-2.Table D-2. Layout of the modelled 3480 in³ array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure D-6 (right).

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in³)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in³)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in³)
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

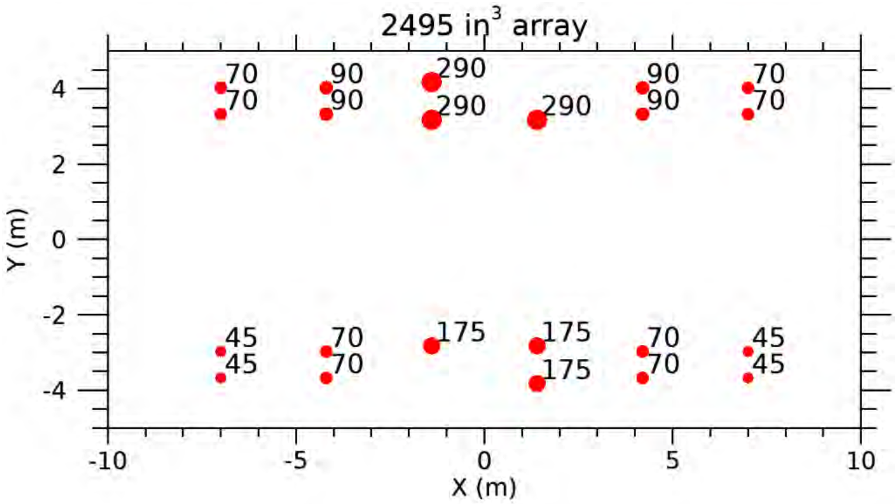


Figure D-7. Layout of the modelled 2495 in^3 array where the plotted layout is such that the array is centred on the origin and vessel travel direction is in the positive x-direction. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-3.

Table D-3. Layout of the modelled 2495 in^3 array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure D-7 (right).

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7	−3.675	6	45	13	−7	−2.975	6	45
2	7	−2.975	6	45	14	7	3.325	6	70
3	4.2	−3.675	6	70	15	7	4.025	6	70
4	4.2	−2.975	6	70	16	4.2	3.325	6	90
5	1.4	−3.825	6	175	17	4.2	4.025	6	90
6	1.4	−2.825	6	175	19	1.4	3.175	6	290
9	−1.4	−2.825	6	175	21	−1.4	3.175	6	290
10	−4.2	−3.675	6	70	22	−1.4	4.175	6	290
11	−4.2	−2.975	6	70	23	−4.2	3.325	6	90
12	−7	−3.675	6	45	24	−4.2	4.025	6	90

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

Two different seismic sources were considered for preliminary source analysis and selecting a worst-case seismic source, the total volumes were 2495 in^3 and 3480 in^3. The results from AASM for these sources are provided in Table E-1.

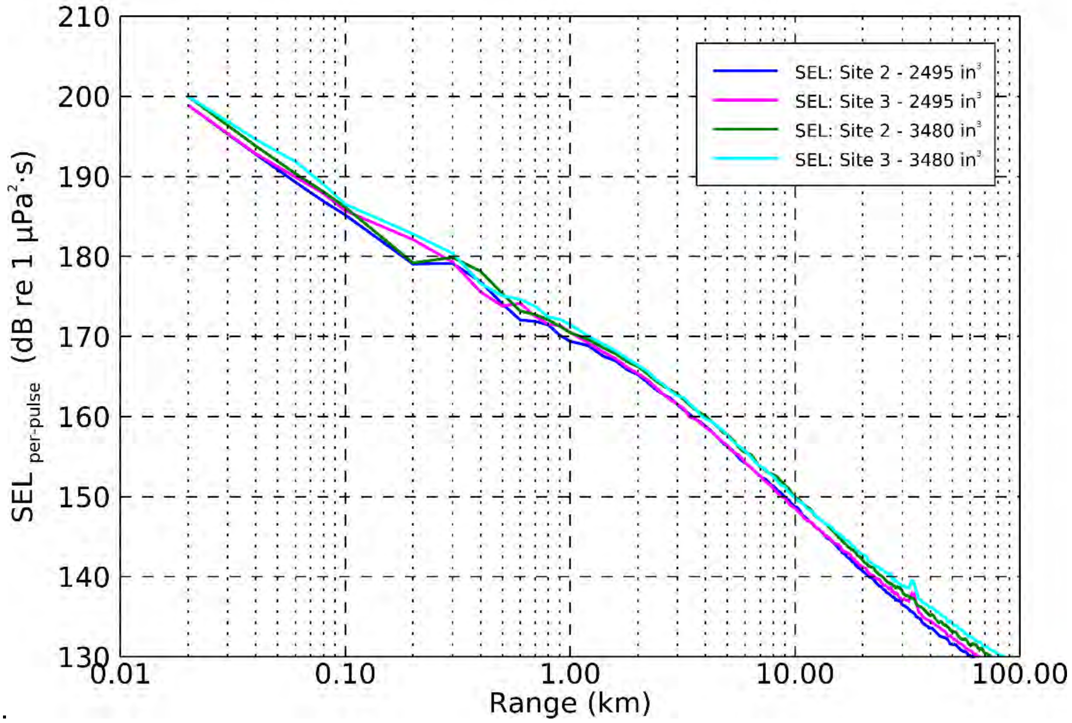
Table E-1. Far-field source level specifications for 2495 and 3480 in^3 seismic sources, for a 6 m tow depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

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 µPa**^{2}m^{2}s)
			10–25000 Hz
2495	Broadside	248.8	224.3
3480		248.6	225.3
2495	Endfire	244.8	222.4
3480		247.5	225.2
2495	Vertical	254.7	227.6
3480		258.1	230.9

E.2. Per-pulse sound field comparison

FWRAM was used to model synthetic seismic pulses over a frequency range of 5–2048 Hz at Site 2 and Site 3 considering a tow direction of 28 ° and 132° respectively. 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 allows for a comparison of the two sources in a representative environment. Modelling was performed along all broadside and endfire radials for the two the seismic sources considered above.

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 3480 in^3 array consistently produced the highest SEL and SPL. The difference in SEL and SPL between these two arrays will result in larger isopleths for energy based assessments (i.e., the SEL_{24h} assessment) and isopleths to behavioural disturbance for the 3480 in^3 array. The 3480 in^3 array was therefore selected as the worst-case source for modelling in this study.



.

Figure E-1. *SEL*: Maximum-over-depth predicted for the 3480 and 2495 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire and directions.

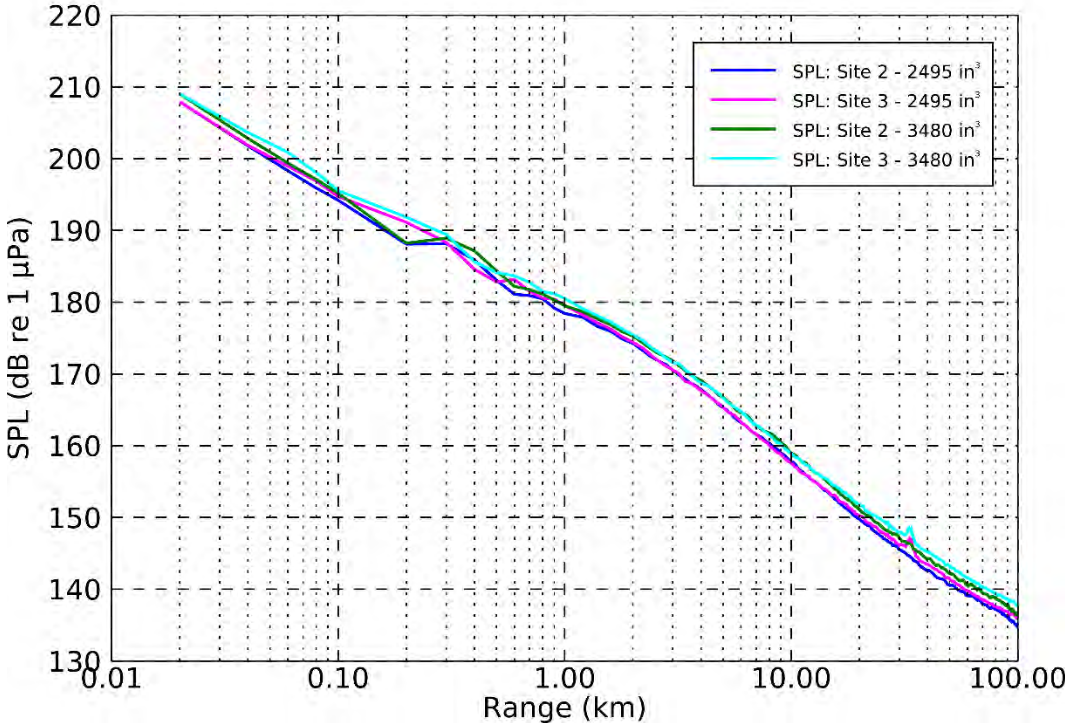


Figure E-2. *SPL*: Maximum-over-depth predicted for the 3480 and 2495 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire and directions.

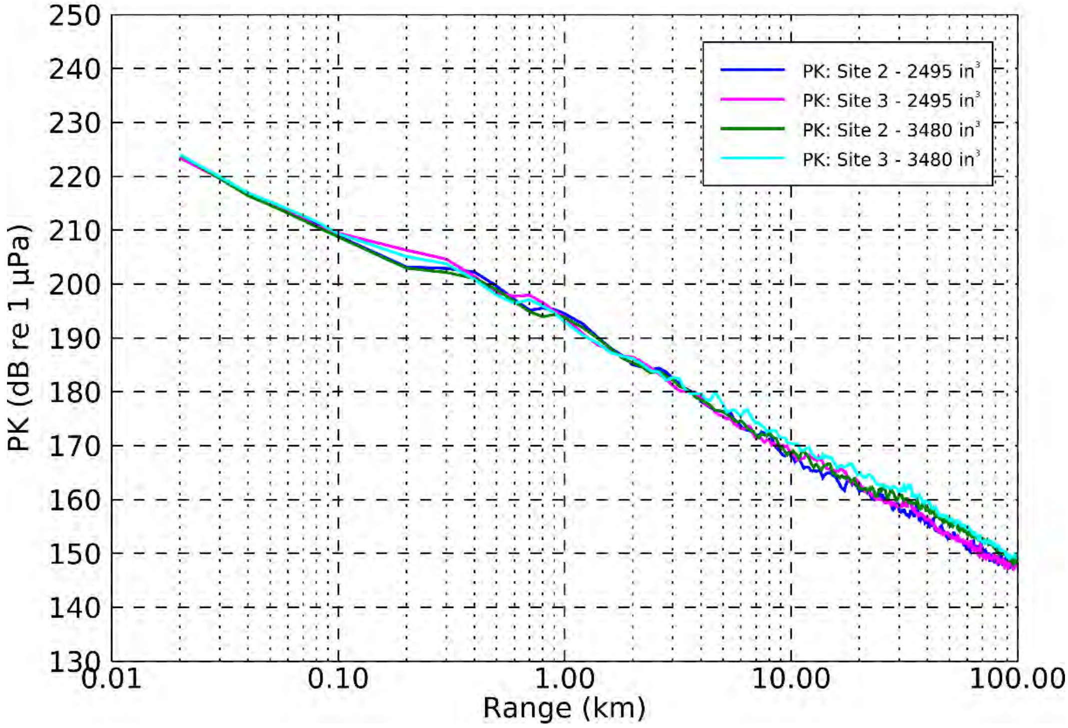


Figure E-3. *PK*: Maximum-over-depth predicted PK for the 3480 and 2495 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire and directions.

Appendix F. Additional Results

Figures F 1–F 5 show maps of the estimated sound field isopleths of interest for the per-pulse SEL sound fields at all modelled sites.

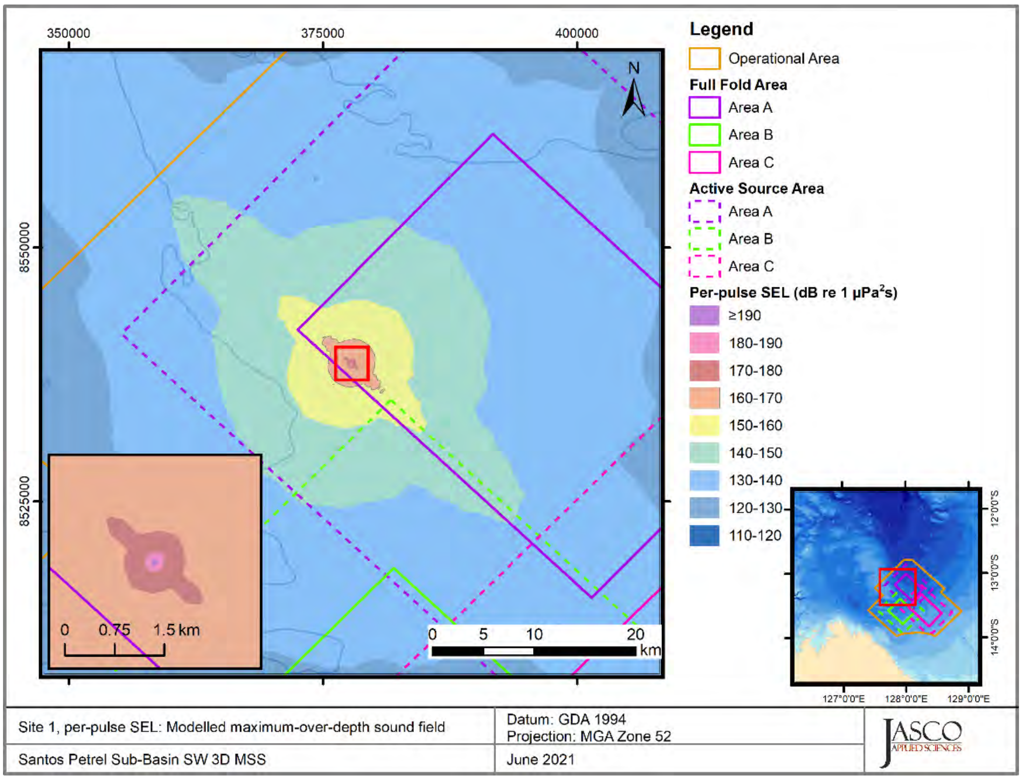


Figure F-1. *Site 1, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

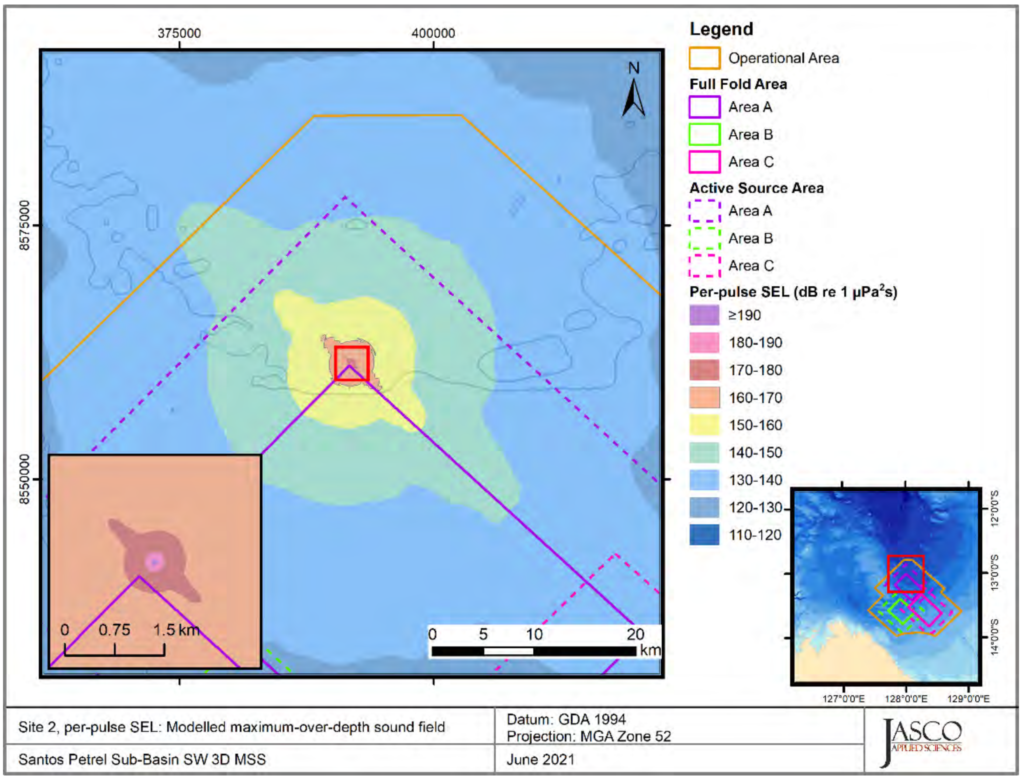


Figure F-2. *Site 2, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

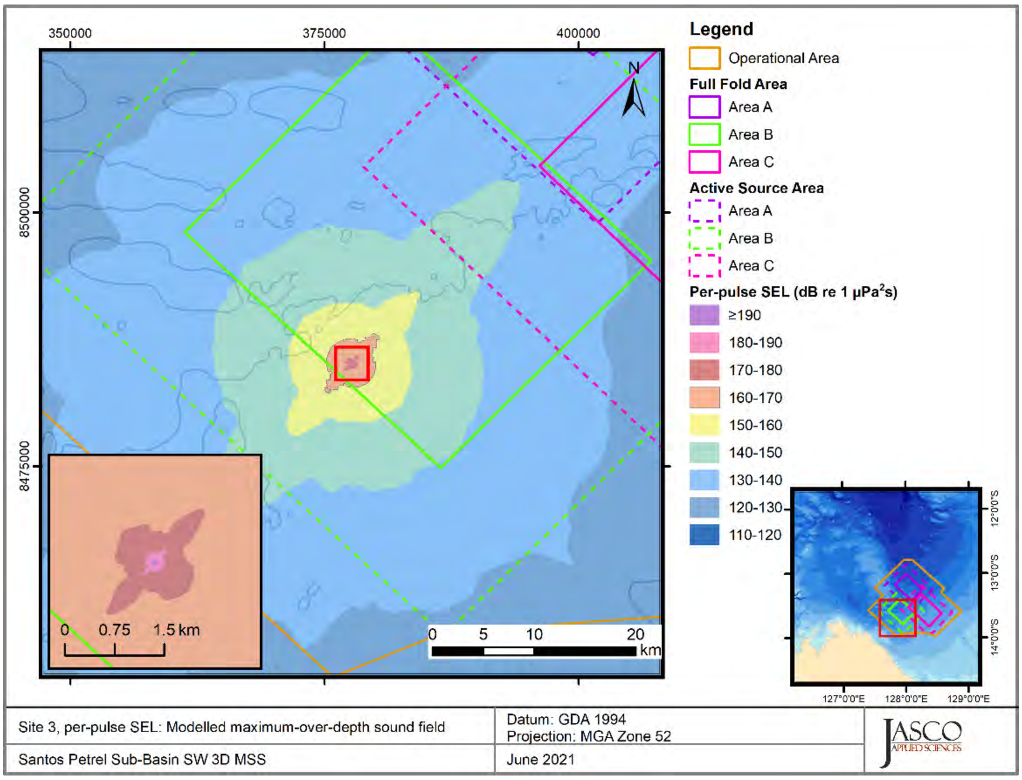


Figure F-3. *Site 3, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

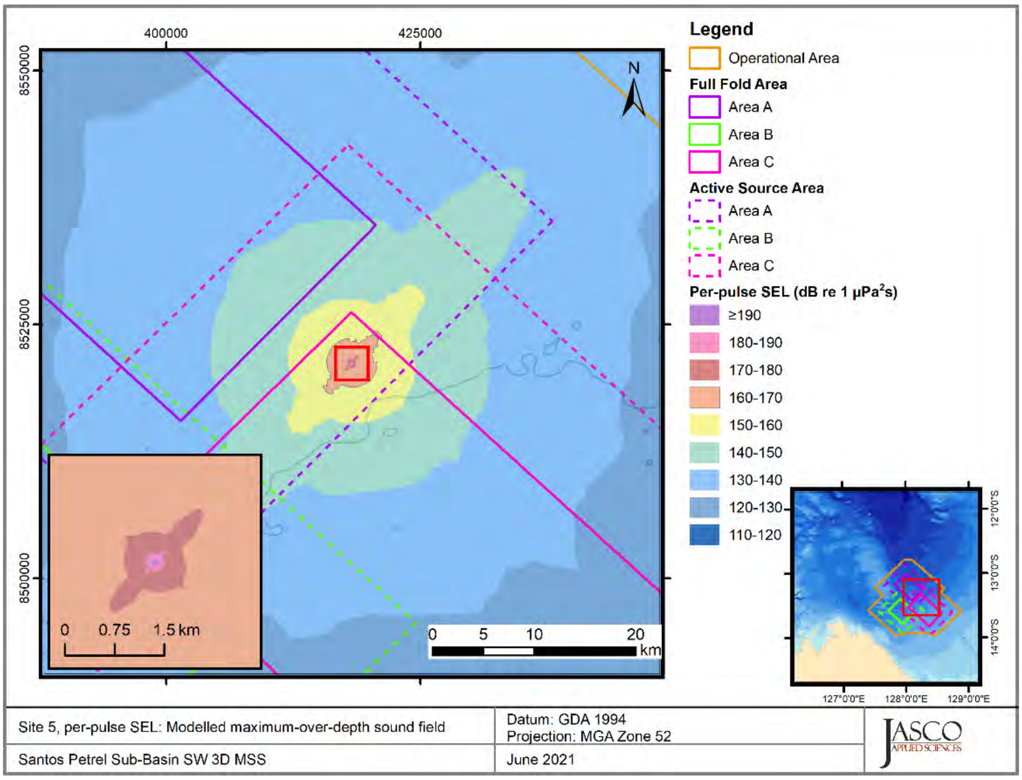


Figure F-4. *Site 5, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

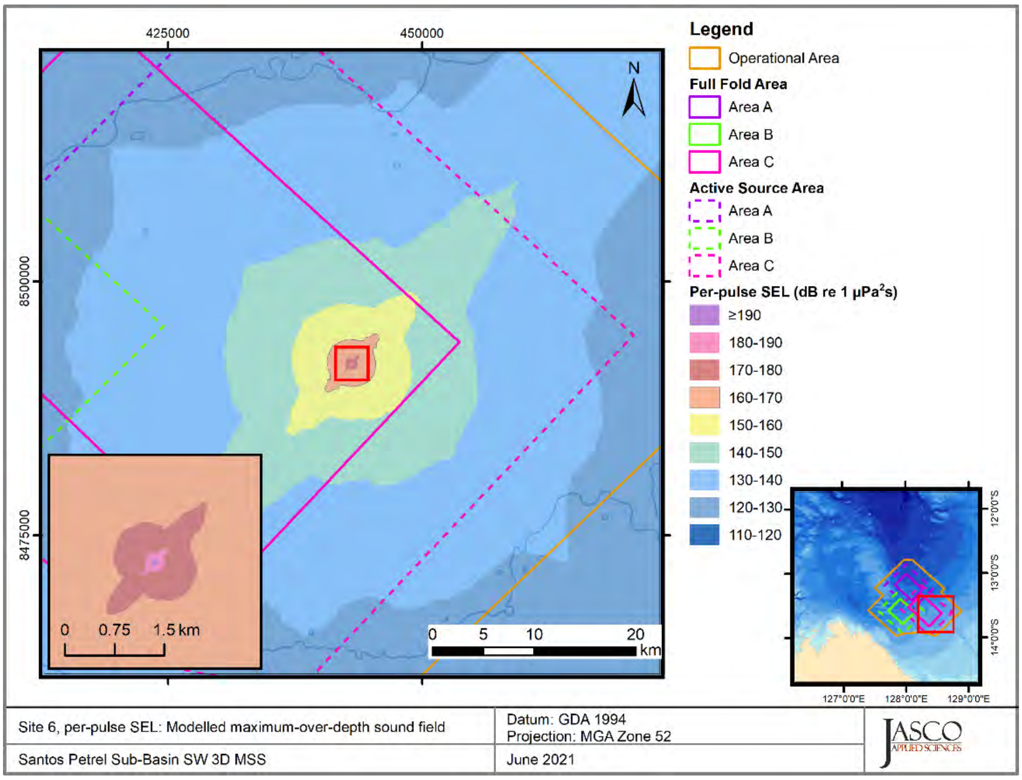


Figure F-5. *Site 6, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

Appendix G: Noise Impact Technical Appendix

Technical Appendix: Noise Impacts on Marine Fauna

PROJECT / FACILITY	Santos Keraudren Extension 3D MSS
REVIEW INTERVAL (MONTHS)	No Review Required
CONTROLLED DOCUMENT	NO

Santos

Rev	Rev Date	Author / Editor	Amendment
A	12.10.2018	Klaus Lucke	
B	20.11.2018	S Mavrick	
0	07.12.2018	S Mavrick	
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

Contents

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

Santos

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

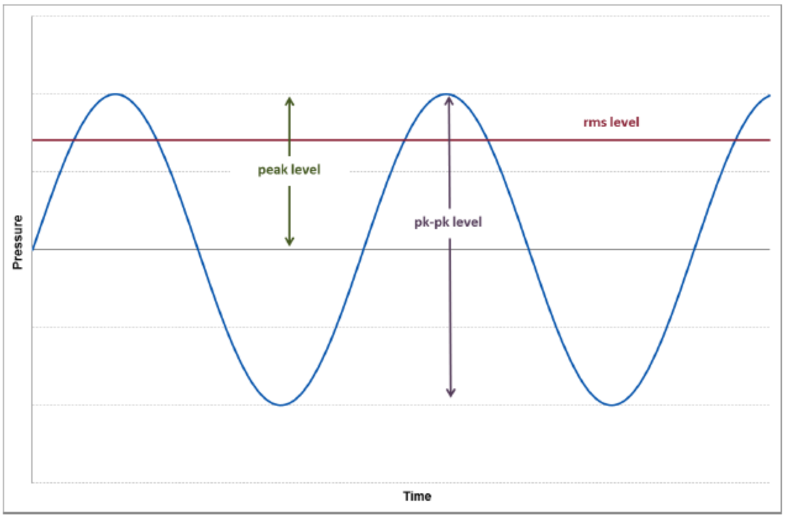
Metric	Commonly used (before 2017)	ISO (2017) / NMFS (2018)	
		Main text	Tables/equations
Sound Pressure Level	SPL_{rms}, SPL_{RMS}	SPL	SPL (L_p)
Peak Pressure	SPL_{pk}	PK	PK (L_{pk})
Sound Exposure Level	SEL_{cum}	SEL_{24h}	SEL_{24h} ($L_{E,24h}$)

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 Seismic Survey Environment Plan, QE-91-RI-10012.03*. 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 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 other studies, 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 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 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 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 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 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. Similarly, 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 μPa^2·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 μPa^2·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 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.

Santos

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.

7 References

[Caltrans] California Department of Transportation. 2001. *San Francisco–Oakland Bay Bridge East Span Seismic Safety Project, Pile Installation Demonstration Project*. Marine Mammal Impact Assessment Report Number PIDP EA 012081, PIDP 04-ALA-80-0.0/0.5, Caltrans Contract 04A0148, Task Order 205.10.90. California Department of Transportation.

[DMAC] Diving Medical Advisory Committee. 2019. *Safe Diving Distance from Seismic Surveying Operations*. DMAC 12 Rev. 2, London, UK. 2 pp. http://www.dmac-diving.org/guidance/DMAC12.pdf.

[DoN] Department of the Navy (U.S.). 2008. *Northwest training range complex draft environmental impact statement/overseas environmental impact statement*. Volume 1. United States Department of the Navy, Washington, D.C.

[HESS] High Energy Seismic Survey. 1999. *High Energy Seismic Survey Review Process and Interim Operational Guidelines for Marine Surveys Offshore Southern California*. Prepared for the California State Lands Commission and the United States Minerals Management Service Pacific Outer Continental Shelf Region by the High Energy Seismic Survey Team, Camarillo, CA. 98 pp. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2001100103.xhtml.

[ISO] International Organization for Standardization. 2017. *ISO/DIS 18405.2:2017. Underwater acoustics—Terminology*. Geneva. https://www.iso.org/standard/62406.html.

[NIOSH] National Institute for Occupational Safety and Health. 1998. *Criteria for a recommended standard: Occupational noise exposure. Revised Criteria*. Document Number 98-126. U.S. Department of Health and Human Services, NIOSH, Cincinnati, OH, USA. 122 pp. https://www.cdc.gov/niosh/docs/98-126/pdfs/98-126.pdf.

[NMFS] National Marine Fisheries Service (U.S.). 2018. *2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Department of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-59. 167 pp. https://www.fisheries.noaa.gov/webdam/download/75962998.

Aguilar de Soto, N., N. Delorme, J. Atkins, S. Howard, J. Williams, and M. Johnson. 2013. Anthropogenic noise causes body malformations and delays development in marine larvae. *Scientific Reports* 3(2831): 5. https://doi.org/10.1038/srep02831.

André, M., M. Solé, M. Lenoir, M. Durfort, C. Quero, A. Mas, A. Lombarte, M. van der Schaar, M. López-Bejar, et al. 2011. Low-frequency sounds induce acoustic trauma in cephalopods. *Frontiers in Ecology and the Environment* 9(9): 489-493. https://doi.org/10.1890/100124.

Andrew, R.K., B.M. Howe, J.A. Mercer, and M.A. Dzieciuch. 2002. Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California coast. *Acoustics Research Letters Online* 3(2): 65.

Andrew, R.K., B.M. Howe, and J.A. Mercer. 2011. Long-time trends in ship traffic noise for four sites off the North American West Coast. *Journal of the Acoustical Society of America* 129(2): 642-651. https://doi.org/10.1121/1.3518770.

Au, W.L.W. and M.C. Hastings. 2008. Hearing in Marine Animals. 337-400.

Bartol, S.M., J.A. Musick, and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). *Copeia* 3: 836-840.

Bartol, S.M. and D.R. Ketten. 2006. *Turtle and tuna hearing*. *In*: Swimmer, Y. and R. Brill. Volume December 2006. NOAA Technical Memorandum NMFS-PIFSC-7. 98-103 pp. http://www.sefsc.noaa.gov/turtles/TM_NMFS_PIFSC_7_Swimmer_Brill.pdf#page=108.

Bertrand, A. and E. Josse. 2000. Tuna target-strength related to fish length and swimbladder volume. *ICES Journal of Marine Science* 57: 1143-1146.

Braun, C. and T. Grande. 2008. Evolution of peripheral mechanisms for the enhancement of sound reception. *In* Webb JF, P.A., Fay RR (ed.). *Fish bioacoustics*. Springer, New York, NY. pp 99-144.

Budelmann, B.U. 1992a. Hearing in Nonarthropod Invertebrates. (Chapter 10) *In* Webster, D.B., A.N. Popper, and R.R. Fay (eds.). *The Evolutionary Biology of Hearing*. Springer, New York. pp 141-155. https://doi.org/10.1007/978-1-4612-2784-7_10.

Budelmann, B.U. 1992b. Hearing in crustacea. *In* Webster, D.B., R.R. Fay, and A.N. Popper (eds.). *The Evolutionary Biology of Hearing*. Springer-Verlag, NY, USA. pp 131-139.

Caiger, P.E., J.C. Montgomery, and C.A. Radford. 2012. Chronic low- intensity noise exposure affects the hearing thresholds of juvenile snapper. *Marine Ecology Progress Series* 466: 225–232.

Carlson, T. and G. Johnson. 2009. *Compliance Monitoring of Underwater Blasting for Rock Removal at Warrior Point, Columbia River Channel Improvement Project, 2009/2010*. *In*: USACE Portland District, P., Oregon (ed.) Report Number PNNL-20388. Pacific Northwest National Laboratory, Richland, WA. 69 pp + App. pp.

Carroll, A.G., R. Przeslawski, A. Duncan, M. Gunning, and B. Bruce. 2017. A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. *Marine Pollution Bulletin* 114: 9-24. https://doi.org/10.1016/j.marpolbul.2016.11.038.

Casper, B.M., A.N. Popper, F. Matthews, T.J. Carlson, and M.B. Halvorsen. 2012. Recovery of barotrauma injuries in Chinook salmon, *Oncorhynchus tshawytscha* from exposure to pile driving sound. *PLOS ONE* 7(6): e39593. https://doi.org/10.1371/journal.pone.0039593.

Casper, B.M., M.E. Smith, M.B. Halvorsen, H. Sun, T.J. Carlson, and A.N. Popper. 2013. Effects of exposure to pile driving sounds on fish inner ear tissues. *Comparative Biochemistry and Physiology Part A* 166(2): 352-360. https://doi.org/10.1016/j.cbpa.2013.07.008.

Chapman, R.N. and A. Price. 2011. Low frequency deep ocean ambient noise trend in the Northeast Pacific Ocean. *Journal of the Acoustical Society of America* 129(5): EL161-EL165. https://doi.org/10.1121/1.3567084.

Christensen-Dalsgaard, J., C. Brandt, K.L. Willis, C.B. Christensen, D.R. Ketten, P. Edds-Walton, R.R. Fay, P.T. Madsen, and C.E. Carr. 2012. Specialization for underwater hearing by the tympanic middle ear of the turtle, *Trachemys scripta elegans*. *Proceedings of the Royal Society of London Series B* 279(1739): 2816-2824. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3367789/pdf/rspb20120290.pdf.

Clark, C.W., W.T. Ellison, B.L. Southall, L.T. Hatch, S.M. Van Parijs, A.S. Frankel, and D.W. Ponirakis. 2009. Acoustic masking in marine ecosystems: Intuitions, analysis, and implication. *Marine Ecology Progress Series* 395: 201-222. https://doi.org/10.3354/meps08402.

Cohen, M.J., Y. Katsuki, and T.H. Bullock. 1953. Oscillographic analysis of equilibrium receptors in Crustacea. *Experientia* 9(11): 434-435. https://doi.org/10.1007/BF02175537.

Cohen, M.J. 1955. The function of receptors in the statocyst of the lobster *Homarus americanus*. *Journal of Physiology* 130(1): 9-34. https://doi.org/10.1113/jphysiol.1955.sp005389.

Cranford, T.W. and P. Krysl. 2015. Fin whale sound reception mechanisms: Skull vibration enables low-frequency hearing. *PLOS ONE* 10(1): e0116222. https://doi.org/10.1371/journal.pone.0116222.

Dahlheim, M.E. and D.K. Ljungblad. 1990. Preliminary hearing study on gray whales (*Eschrichtius robustus*) in the field. *In* Thomas, J. and R.A. Kastelein (eds.). *Sensory abilities of cetaceans*. Volume 196. Springer US. pp 335-346.

Dale, J.J., M.D. Gray, A.N. Popper, P.H. Rogers, and B.A. Block. 2015. Hearing thresholds of swimming Pacific bluefin tuna *Thunnus orientalis*. *Journal of Comparative Physiology A* 201(5): 441-454. https://doi.org/10.1007/s00359-015-0991-x.

Day, R., D., R.D. McCauley, Q.P. Fitzgibbon, K. Hartmann, J.M. Semmens, and Institute for Marine and Antarctic Studies. 2016. *Assessing the Impact of Marine Seismic Surveys on Southeast Australian Scallop and Lobster Fisheries*. Impacts of Marine Seismic Surveys on Scallop and Lobster Fisheries. Fisheries Ressearch & Development Corporation. FRDC Project No 2012/008, University of Tasmania, Hobart. 159 pp.

Edmonds, N.J., C.J. Firmin, D. Goldsmith, R.C. Faulkner, and D.T. Wood. 2016. A review of crustacean sensitivity to high amplitude underwater noise: Data needs for effective risk assessment in relation to UK commercial species. *Marine Pollution Bulletin* 108(1–2): 5-11. https://doi.org/10.1016/j.marpolbul.2016.05.006.

Ellers, O. 1995. Discrimination among wave-generated sounds by a swash-riding clam. *Biological Bulletin* 189(2): 128-137.

Ellison, W.T., B.L. Southall, C.W. Clark, and A.S. Frankel. 2012. A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds. *Conservation Biology* 26(1): 21-28. https://doi.org/10.1111/j.1523-1739.2011.01803.x.

Engineering-Environmental Management, I. 2008. *United States Coast Guard and Maritime Administration draft environmental impact statement for Port Dolphin LLC Deepwater Port licence application*. USCG Deepwater Ports Standards Division, Washington, DC.

Erbe, C. and D.M. Farmer. 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. *Deep Sea Research Part II* 45(7): 1373-1388. https://doi.org/10.1016/S0967-0645(98)00027-7.

Erbe, C. 2008. Critical ratios of beluga whales (*Delphinapterus leucas*) and masked signal duration. *Journal of the Acoustical Society of America* 124(4): 2216-2223. https://doi.org/10.1121/1.2970094.

Erbe, C., C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling. 2016. Communication masking in marine mammals: A review and research strategy. *Marine Pollution Bulletin* 103(1): 15-38. https://doi.org/10.1016/j.marpolbul.2015.12.007.

Etter, P.C. 1996. *Underwater Acoustic Modeling - Principles, Techniques, and Applications*. Second edition. E & FN Spon, London, UK. 344 pp.

Fields, D.M., N.O. Handegard, J. Dalen, C. Eichner, K. Malde, Ø. Karlsen, A.B. Skiftesvik, C.M.F. Durif, and H.I. Browman. 2019. Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod Calanus finmarchicus. *ICES Journal of Marine Science*.

Finneran, J.J. 2015. Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. *Journal of the Acoustical Society of America* 138(3): 1702-1726. https://doi.org/10.1121/1.4927418.

Finneran, J.J. 2016. *Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise*. Technical Report for Space and Naval Warfare Systems Center Pacific, San Diego, CA, USA. 49 pp. http://www.dtic.mil/dtic/tr/fulltext/u2/1026445.pdf.

Finneran, J.J., E. Henderson, D.S. Houser, K. Jenkins, S. Kotecki, and J. Mulsow. 2017. *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*. Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 pp. https://apps.dtic.mil/dtic/tr/fulltext/u2/a561707.pdf.

François, R.E. and G.R. Garrison. 1982a. Sound absorption based on ocean measurements: Part II: Boric acid contribution and equation for total absorption. *Journal of the Acoustical Society of America* 72(6): 1879-1890. https://doi.org/10.1121/1.388673.

François, R.E. and G.R. Garrison. 1982b. Sound absorption based on ocean measurements: Part I: Pure water and magnesium sulfate contributions. *Journal of the Acoustical Society of America* 72(3): 896-907. https://doi.org/10.1121/1.388170.

Frisk, G.V. 2012. Noiseonomics: the relationship between ambient noise levels in the sea and global economic trends. *Sci Rep* 2: 437. http://www.ncbi.nlm.nih.gov/pubmed/22666540.

Halvorsen, M., B. Casper, F. Matthews, T. Carlson, and A. Popper. 2012a. Effects of exposure to pile driving sound on the lake sturgeon, Nile tilapia and hogchocker. *Proceedings of the Royal Society B*.

Halvorsen, M.B., B.M. Casper, C.M. Woodley, T.J. Carlson, and A.N. Popper. 2011. Predicting and mitigating hydroacoustic impacts on fish from pile installations. Project 25–28. *National Cooperative Highway Research Program Research Results Digest* 363: 2011. https://dx.doi.org/10.17226/14596.

Halvorsen, M.B., B.M. Casper, C.M. Woodley, T.J. Carlson, and A.N. Popper. 2012b. Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. *PLOS ONE* 7(6): e38968. https://doi.org/10.1371/journal.pone.0038968.

Hatch, L.T., C.W. Clark, S.M. Van Parijs, A.S. Frankel, and D.W. Ponirakis. 2012. Quantifying loss of acoustic communication space for right whales in and around a U.S. National Marine Sanctuary. *Conservation Biology* 26(6): 983-994. https://doi.org/10.1111/j.1523-1739.2012.01908.x.

Hawkins, A.D. and A.N. Popper. 2017. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. *ICES Journal of Marine Science* 74(3): 635-651. https://doi.org/10.1093/icesjms/fsw205.

Higgs, D.M., Z. Lu, and D.A. Mann. 2006. Hearing and mechanoreception. *In* Evans, D.H. and J.B. Claiborne (eds.). *The physiology of fishes*. Taylor & Francis Group, Florida, USA. pp 391-429.

Houser, D.S., D.A. Helweg, and P.W.B. Moore. 2001. A bandpass filter-bank model of auditory sensitivity in the humpback whale. *Aquatic Mammals* 27(2): 82-91. https://www.aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/2001/AquaticMammals_27-02/27-02_Houser.PDF.

Houser, D.S., W. Yost, R. Burkard, J.J. Finneran, C. Reichmuth, and J. Mulsow. 2017. A review of the history, development and application of auditory weighting functions in humans and marine mammals. *Journal of the Acoustical Society of America* 141(3): 1371-1413. https://doi.org/10.1121/1.4976086.

Kastelein, R.A., S. van der Heul, W.C. Verboom, N. Jennings, J. van der Veen, and D. deHaan. 2008. Startle response of captive North Sea fish species to underwater tones between 0.1 and 64 kHz. *Marine Environmental Research* 65: 369-377.

Ketten, D., J. Lien, and S. Todd. 1993. Blast injury in humpback whale ears: Evidence and implications. *Journal of the Acoustical Society of America*. Volume 94(3/2). pp 1849-1850.

Ketten, D.R. and S.M. Bartol. 2005. *Functional measures of sea turtle hearing*. ONR project final report. Document Number ONR Award Number N00014-02-1-0510. Office of Naval Research (U.S.).

Kight, C.R. and J.P. Swaddle. 2011. How and why environmental noise impacts animals: An integrative, mechanistic review. *Ecology Letters* 14(10): 1052-1061. https://doi.org/10.1111/j.1461-0248.2011.01664.x

Koessler, M.W. and C.R. McPherson. 2019. Keraudren Extension 3-D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures. Document 01937, Version 1.0. Technical report by JASCO Applied Sciences for Santos WA Energy Limited.

Ladich, F. and A.N. Popper. 2004. Parallel evolution in fish hearing organs. *In* Manley, G.A., A.N. Popper, and R.R. Fay (eds.). *Evolution of the Vertebrate Auditory System* Springer-Verlag, NY, USA. pp 98-127.

Ladich, F. and R.R. Fay. 2013. Auditory evoked potential audiometry in fish. *Reviews in Fish Biology and Fisheries* 23(3): 317-364. https://doi.org/10.1007/s11160-012-9297-z.

Lavender, A.L., S.M. Bartol, and I.K. Bartol. 2012. Hearing capabilities of loggerhead sea turtles (*Caretta caretta*) throughout ontogeny. *In* Popper, A.N. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life*. Springer. pp 89-92. http://www.soundandmarinelife.org/research-categories/physical-and-physiological-effects-and-hearing/modelling-mysticete-baleen-whale-hearing.aspx.

Lavender, A.L., S.M. Bartol, and I.K. Bartol. 2014. Ontogenetic investigation of underwater hearing capabilities in loggerhead sea turtles (*Caretta caretta*) using a dual testing approach. *Journal of Experimental Biology* 217(14): 2580-2589. https://jeb.biologists.org/content/217/14/2580.

Lenhardt, M.L., R.C. Klinger, and J.A. Musick. 1985. Marine turtle middle-ear anatomy. *Journal of Auditory Research* 25(1): 66-72. http://europepmc.org/abstract/MED/3836997.

Lenhardt, M.L. 1994. Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (*Caretta caretta*). *In*: Bjorndal, K.A., A.B. Bolten, D.A. Johnson, and P.J. Eliazar (eds.). *14th Annual Symposium on Sea Turtle Biology and Conservation*. Springfield, VA, USA.

Mackenzie, S. and D. Raible. 2012. Proliferative regeneration of zebrafish lateral line hair cells after different ototoxic insults. *PLoS One* 7: e47257.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyak, and J.E. Bird. 1983. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior*. Report Number 5366. http://www.boem.gov/BOEM-Newsroom/Library/Publications/1983/rpt5366.aspx.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1984. *Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior. Phase II: January 1984 migration*. Report Number 5586. Report prepared by Bolt, Beranek and Newman Inc. for the U.S. Department of the Interior, Minerals Management Service, Cambridge, MA, USA. 357 pp. https://www.boem.gov/BOEM-Newsroom/Library/Publications/1983/rpt5586.aspx.

Martin, B., D.G. Zeddies, B.J. Gaudet, and J. Richard. 2016. Evaluation of Three Sensor Types for Particle Motion Measurement. *In* Popper, A.N. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life II*. Springer, NY, USA. pp 679-686. https://doi.org/10.1007/978-1-4939-2981-8_82.

Martin, K.J., S.C. Alessi, J.C. Gaspard, A.D. Tucker, G.B. Bauer, and D.A. Mann. 2012. Underwater hearing in the loggerhead turtle (*Caretta caretta*): A comparison of behavioral and auditory evoked potential audiograms. *Journal of Experimental Biology* 215(17): 3001-3009. https://jeb.biologists.org/content/215/17/3001.

Mccauley, R.D. 1994. *The Environmental Implications of Offshore Oil and Gas Development in Australia - Seismic Surveys*. *In*: Neff, J.M. and P.C. Young (eds.). Environmental Implications of Offshore Oil and Gas Develpment in Australia - The Findings of an Independent Scientific Review Swan. Australian Petroleum Exploration Association, Sydney. 19-122 pp.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, et al. 2000. *Marine seismic surveys: Analysis and propagation of air-gun* *signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid*. Report Number R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Maine Science and Technology, Western Australia. 198 pp. https://cmst.curtin.edu.au/wp-content/uploads/sites/4/2016/05/McCauley-et-al-Seismic-effects-2000.pdf.

McCauley, R.D., J. Fewtrell, and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears. *Journal of the Acoustical Society of America* 113: 638-642.

McCauley, R.D. and C.S. Kent. 2012. A Lack of Correlation Between Air Gun Signal Pressure Waveforms and Fish Hearing Damage. *In* Popper, A.N. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life*. Springer, New York. pp 245-250.

McCauley, R.D., R.D. Day, K.M. Swadling, Q.P. Fitzgibbon, R.A. Watson, and J.M. Semmens. 2017. Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature Ecology & Evolution* 1(7): 1-8. https://doi.org/10.1038/s41559-017-0195.

McDonald, M.A., J.A. Hildebrand, and S.M. Wiggins. 2006. Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California. *Journal of the Acoustical Society of America* 120(2): 711-718. https://doi.org/10.1121/1.2216565.

McKinstry, C., T. Carlson, and R. Brown. 2007. *Derivation of a mortal injury metric for studies of rapid decompression of depth-acclimated physostomous fish*. Document Number PNNL-17080. Pacific Northwest National Laboratory, Richland, WA. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17080.pdf.

Miksis-Olds, J.L. and S.M. Nichols. 2016. Is low frequency ocean sound increasing globally? *Journal of the Acoustical Society of America* 139(1): 501-511. https://doi.org/10.1121/1.4938237.

Miller, P. 2012. The Severity of Behavioral Changes Observed During Experimental Exposures of Killer (Orcinus orca), Long-Finned Pilot (Globicephala melas), and Sperm (Physeter macrocephalus) Whales to Naval Sonar. *Aquatic Mammals* 38(4): 362-401.

Moein, S.E., J.A. Musick, J.A. Keinath, D.E. Barnard, M.L. Lenhardt, and R. George. 1995. *Evaluation of Seismic Sources for Repelling Sea Turtles from Hopper Dredges, in Sea Turtle Research Program: Summary Report*. *In*: Hales, L.Z. (ed.). Report from U.S. Army Engineer Division, South Atlantic, Atlanta GA, and U.S. Naval Submarine Base, Kings Bay GA. Technical Report CERC-95. 90 pp.

Mooney, T.A., R.T. Hanlon, J. Christensen-Dalsgaard, P.T. Madsen, D.R. Ketten, and P.E. Nachtigall. 2010. Sound detection by the longfin squid (*Loligo pealeii*) studied with auditory evoked potentials: sensitivity to low-frequency particle motion and not pressure. *Journal of Experimental Biology* 213(21): 3748-3759. https://jeb.biologists.org/content/213/21/3748.

Morley, E.L., G. Jones, and A.N. Radford. 2014. The importance of invertebrates when considering the impacts of anthropogenic noise. *Proceedings of the Royal Society of London Series B* 281(1776). https://doi.org/10.1098/rspb.2013.2683.

Mosher, J. 1972. The responses of Macoma balthica (bivalvia) to vibrations. *Proceedings of the Malacological Society of London* 40.

Nedwell, J.R. and A.W. Turnpenny. 1998. The use of a generic frequency weighting scale in estimating environmental effect. *Workshop on Seismics and Marine Mammals*. 23–25 Jun 1998, London, UK.

Nedwell, J.R., B. Edwards, A.W.H. Turnpenny, and J. Gordon. 2004. *Fish and marine mammal audiograms: A summary of available information*. Report Number 534R014. Subacoustech. 278 pp.

Nedwell, J.R., A.W. Turnpenny, J. Lovell, S.J. Parvin, R. Workman, and J.A.L. Spinks. 2007. *A validation of the* dB_{ht} *as a measure of the behavioural and auditory effects of underwater noise*. Document Number 534R1231 Report prepared by Subacoustech Ltd. for the UK Department of Business, Enterprise and Regulatory Reform under Project No. RDCZ/011/0004. http://www.subacoustech.com/wp-content/uploads/534R1231.pdf.

Nieukirk, S.L., D.K. Mellinger, S.E. Moore, K. Klinck, R.P. Dziak, and J. Goslin. 2012. Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009. *Journal of the Acoustical Society of America* 131(2): 1102-1112. https://doi.org/10.1121/1.3672648.

Normandeau Associates Inc. 2012. *Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities*. A Workshop Report for the U.S. Dept. of the Interior, Bureau of Ocean Energy Management. Contract # M11PC00031. 361 pp. https://www.cbd.int/doc/meetings/mar/mcbem-2014-01/other/mcbem-2014-01-submission-boem-04-en.pdf.

O'Hara, J. and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, *Caretta caretta*, to low frequency sound. *Copeia* 2: 564-567.

Packard, A., H.E. Karlsen, and O. Sand. 1990. Low frequency hearing in cephalopods. *Journal of Comparative Physiology A* 166(4): 501-505. https://doi.org/10.1007/BF00192020.

Parks, S.E., D.R. Ketten, J.T. O'Malley, and J. Arruda. 2007. Anatomical predictions of hearing in the North Atlantic right whale. *The Anatomical Record* 290(6): 734-744. https://doi.org/10.1002/ar.20527.

Parry, G., S. Heislers, G. Werner, M. Asplin, and A. Gason. 2002. *Assessment of Environmental Effects of Seismic Testing on Scallop Fisheries in Bass Strait*. Document Number 50. Marine and Freshwater Resources Institute.

Pine, M., A. Jeffs, and C. Radford. 2012. Turbine Sound May Influence the Metamorphosis Behaviour of Estuarine Crab Megalopae. *PLoS One* 7(12): e51790.

Piniak, W.E., D.A. Mann, S.A. Eckert, and C.A. Harms. 2011. Amphibious hearing in sea turtles. *In*: Hawkins, T. and A.N. Popper (eds.). *2nd International Conference on the Effects of Noise on Aquatic Life*. August 15-20, 2010. Springer-Verlag.

Piniak, W.E.D., D.A. Mann, C.A. Harms, T.T. Jones, and S.A. Eckert. 2016. Hearing in the juvenile green sea turtle (*Chelonia mydas*): A comparison of underwater and aerial hearing using auditory evoked potentials. *PLOS ONE* 11(10). https://doi.org/10.1371/journal.pone.0159711.

Popper, A.N. and M.C. Hastings. 2009. The effects of anthropogenic sources of sound on fishes. *Journal of Fish Biology* 75(3): 455-489. https://doi.org/10.1111/j.1095-8649.2009.02319.x.

Popper, A.N. and R.R. Fay. 2011. Rethinking sound detection by fishes. *Hearing Research* 273(1): 25-36. https://doi.org/10.1016/j.heares.2009.12.023.

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S. Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, et al. 2014. Sound Exposure Guidelines. (Chapter 7) *In Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. ASA S3/SC1.4 TR-2014. SpringerBriefs in Oceanography. ASA Press and Springer. pp 33-51.

Popper, A.N. and A.D. Hawkins. 2018. The importance of particle motion to fishes and invertebrates Physical aspects of swimbladder function. *Journal of the Acoustical Society of America* 143(1): 470-488. https://doi.org/10.1121/1.5021594.

Popper, A.N. and A.D. Hawkins. 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes (Review Paper). *Journal of Fish Biology*: 1-22. https://doi.org/10.1111/jfb.13948.

Popper, A.N., A.D. Hawkins, and M.B. Halvorsen. 2019. *Anthropogenic Sound and Fishes*. Report Number WA-RD 891.1. Report by ICF for Washington State Department of Transportation, Research Office. 170 pp.

Przeslawski, R., L. Hurt, A. Forrest, A. Carroll, and Geoscience Australia. 2016. *Potential short-term impacts of marine seismic surveys on scallops in the Gippsland Basin*. Report Number 2014-041. CC BY 3.0, Canberra. http://frdc.com.au/research/Final_Reports/2014-041-DLD.pdf.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. *Marine Mammals and Noise*. Academic Press, San Diego, CA, USA. 576 pp.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin, and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. *Proceedings of the National Academy of Sciences* 64(3): 884-890. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC223317/pdf/pnas00113-0080.pdf.

Roberts, L., S. Cheesman, T. Breithaupt, and M. Elliott. 2015. Sensitivity of the mussel *Mytilus edulis* to substrate-borne vibration in relation to anthropogenically generated noise. *Marine Ecology Progress Series* 538: 185-195. http://www.int-res.com/abstracts/meps/v538/p185-195/.

Roberts, L., S. Cheesman, M. Elliott, and T. Breithaupt. 2016. Sensitivity of *Pagurus bernhardus* (L.) to substrate-borne vibration and anthropogenic noise. *Journal of Experimental Marine Biology and Ecology* 474: 185-194. https://doi.org/10.1016/j.jembe.2015.09.014.

Roberts, L. and M. Elliott. 2017. Good or bad vibrations? Impacts of anthropogenic vibration on the marine epibenthos. *Science of The Total Environment* 595: 255-268. https://doi.org/10.1016/j.scitotenv.2017.03.117.

Ross, D. 2005. Ship sources of ambient noise. *IEEE Journal of Oceanic Engineering* 30(2): 257-261. https://doi.org/10.1109/JOE.2005.850879.

Samuel, Y., S.J. Morreale, C.W. Clark, C.H. Greene, and M.E. Richmond. 2005. Underwater, low-frequency noise in a coastal sea turtle habitat. *Journal of the Acoustical Society of America* 117(3): 1465-1472. https://doi.org/10.1121/1.1847993.

Santulli, A., A. Modica, C. Messina, L. Ceffa, A. Curatolo, G. Rivas, G. Fabi, and V. D'Amelio. 1999. Biochemical responses of European sea bass (*Dicentrarchus labrax* L.) to the stress induced by off shore experimental seismic prospecting. *Marine Pollution Bulletin* 38(12): 1105-1114. https://doi.org/10.1016/S0025-326X(99)00136-8.

Scholik, A. and H. Yan. 2001. Effects of underwater noise on auditory sensitivity of a cyprinid fish. *Hear Res* 152: 17-24.

Sierra-Flores, R., T. Atack, H. Migaud, and A. Davie. 2015. Stress response to anthropogenic noise in Atlantic cod Gadus morhua L. *Aquacultural Engineering* 67: 67-76.

Sivle, L.D., P.H. Kvadsheim, C. Curé, S. Isojunno, P.J. Wensveen, F.-P.A. Lam, F. Visser, L. Kleivane, P.L. Tyack, et al. 2015. Severity of Expert-Identified Behavioural Responses of Humpback Whale, Minke Whale, and Northern Bottlenose Whale to Naval Sonar *Aquatic Mammals* 41(4): 469-502.

Slabbekoorn, H., N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A.N. Popper. 2010. A noisy spring: The impact of globally rising underwater sound levels on fish. *Trends in Ecology & Evolution* 25(7): 419-427. https://doi.org/10.1016/j.tree.2010.04.005.

Smith, M. and J. Monroe. 2016. Causes and Consequences of Sensory Hair Cell Damage and Recovery in Fishes. *Adv Exp Med Biol* 877: 393-417.

Solé, M., M. Lenoir, M. Durfort, M. López-Bejar, A. Lombarte, M. van der Schaar, and M. André. 2013. Does exposure to noise from human activities compromise sensory information from cephalopod statocysts? *Deep Sea Research Part II* 95: 160-181. https://doi.org/10.1016/j.dsr2.2012.10.006.

Solé, M., P. Sigray, M. Lenoir, M. van der Schaar, E. Lalander, and M. Andre. 2017. Offshore exposure experiments on cuttlefish indicate received sound pressure and particle motion levels associated with acoustic trauma. *Sci Rep* 7: 45899.

Song, J., A. Mathieu, R.F. Soper, and A.N. Popper. 2006. Structure of the inner ear of bluefin tuna Thunnus thynnus. *Journal of Fish Biology* 68(6): 1767–1781.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, et al. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *Aquatic Mammals* 33(4): 411-521. https://doi.org/10.1080/09524622.2008.9753846.

Southall, B.L., J.J. Finneran, C. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2): 125-232. https://doi.org/10.1578/AM.45.2.2019.125.

Stephenson, J., A. Gingerich, R. Brown, B. Pflugrath, Z. Deng, T. Carlson, M. Langeslay, M. Ahmann, R. Johnson, et al. 2010. Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory. *Fisheries Research* 106: 271-278.

Tavolga, W.N. and J. Wodinsky. 1963. Auditory capacities in fishes: pure tone thresholds in nine species of marine teleosts. *Bulletin of the American Museum of Natural History* 126: 177-240.

Tougaard, J., A.J. Wright, and P.T. Madsen. 2015. Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises. *Marine Pollution Bulletin* 90(1-2): 196-208. https://doi.org/10.1016/j.marpolbul.2014.10.051.

Tubelli, A., A. Zosuls, D.R. Ketten, and D.C. Mountain. 2012. Prediction of a mysticete audiogram via finite element analysis of the middle ear. *In*: Popper, A.N. and A.D. Hawkins (eds.). *The effects of noise on aquatic life*.

Urick, R.J. 1983. *Principles of Underwater Sound*. 3rd edition. McGraw-Hill, New York, London. 423 pp.

Videsen, S.K.A., L. Bejder, M. Johnson, and P.T. Madsen. 2017. High suckling rates and acoustic crypsis of humpback whale neonates maximise potential for mother–calf energy transfer. *Functional Ecology* 31(8): 1561-1573. https://doi.org/10.1111/1365-2435.12871.

Wartzok, D. and D.R. Ketten. 1999. Marine Mammal Sensory Systems. *In* Reynolds, J. and S. Rommel (eds.). *Biology of Marine Mammals*. Smithsonian Institution Press, Washington, DC. pp 117-175.

Wever, E.G. 1978. *The Reptile Ear: Its Structure and Function*. Princeton University Press, Princeton, NJ.

Willis, K.L. 2016. Underwater Hearing in Turtles. *In* Popper, N.A. and A.D. Hawkins (eds.). *The Effects of Noise on Aquatic Life II*. Springer, New York. pp 1229-1235. https://doi.org/10.1007/978-1-4939-2981-8_154.

Wood, J., B.L. Southall, and D.J. Tollit. 2012. *PG&E offshore 3-D Seismic Survey Project Environmental Impact Report–Marine Mammal Technical Draft Report*. SMRU Ltd. 121 pp. https://www.coastal.ca.gov/energy/seismic/mm-technical-report-EIR.pdf.

Yudhana, A., J.D. Sunardi, S. Abdullah, and R.B.R. Hassan. 2010. Turtle hearing capability based on ABR signal assessment. *Telkomnika* 8: 187-194.

Appendix H: 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

<u>Exposure Pathways</u>

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

Santos

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.

Exposure Values - Entrained

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 a 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).

Exposure Values – Dissolved (Instantaneous)

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.

Exposure Values – Dissolved (Time-Averaged)

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

Exposure Pathways

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.