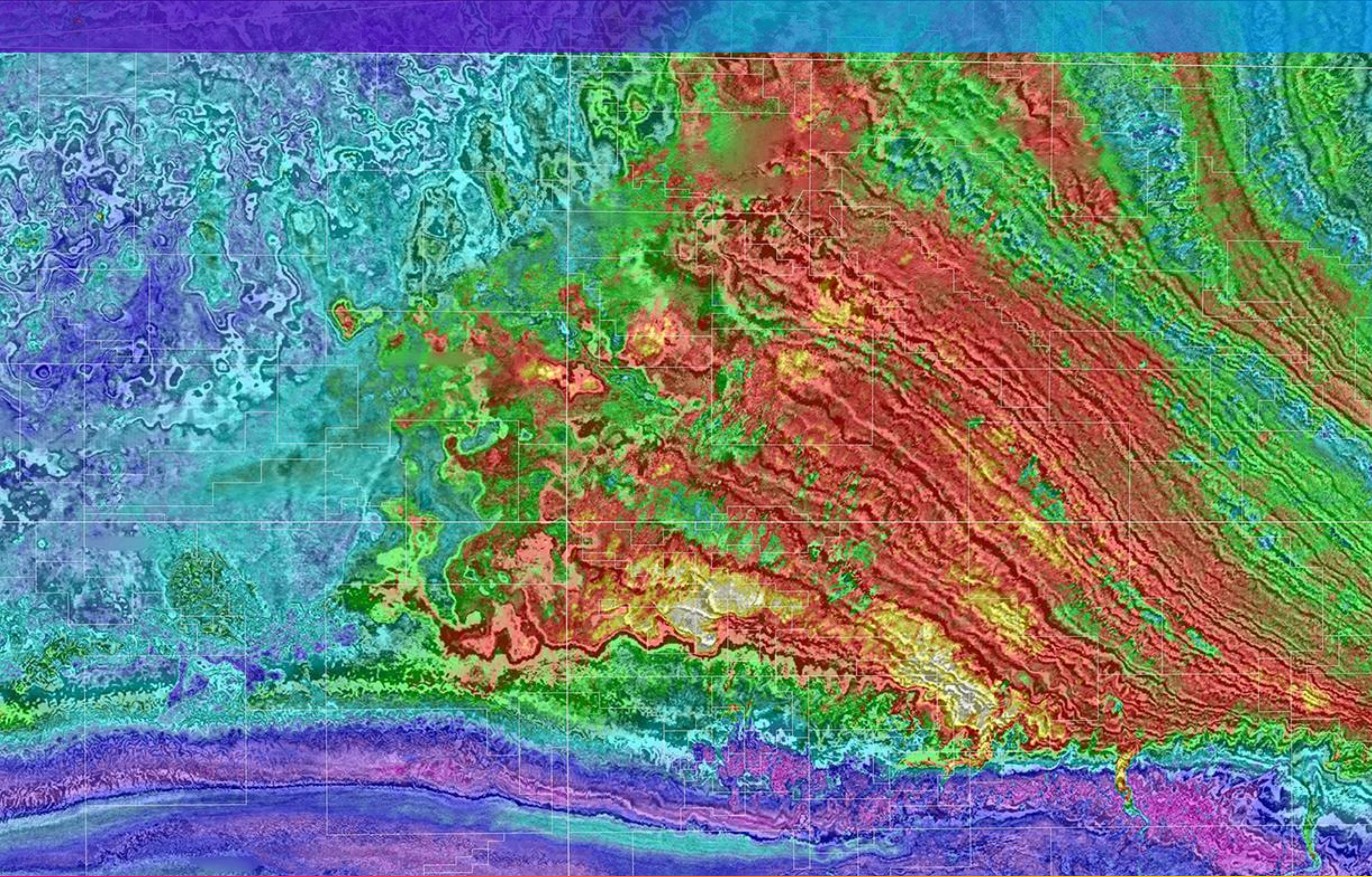


ENVIRONMENT PLAN

Sauropod 3D Marine Seismic Survey (WA-527-P)

cgg.com

SEE THINGS DIFFERENTLY

CGG

Document Status					
Version	*Purpose of document*	*Authored by*	*Reviewed by*	*Approved by*	*Review Date*
A	Draft for internal review	RPS	RPS	JF	30/07/2021
B	Draft for CGG review	RPS	CGG	PR	6/08/2021
0	Final for issue	RPS			
1	Update in response to public comment	RPS	CGG	PR	

PREPARED BY:

MAKING COMPLEX EASY

Level 2, 27-31 Troode Street
West Perth WA 6005

T +61 8 9211 1111
W rpsgroup.com

Table of contents

Appendix

Figures

Tables

Acronyms and Abbreviations

Name	Description
$	Dollars (Australian dollars unless specified otherwise)
%	Per cent
°	Degrees
°C	Degrees Celsius
‘	Minutes
“	Seconds
AGDD	Australian government department of defence
AFZ	Australian Fishing Zone
AHO	Australian Hydrographic Office
ALARP	As low as reasonably practicable
AMMC	Australian Marine Mammal Centre
AMOSC	Australian Marine Oil Spill Centre
AMP	Australian Marine Park
AMSA	Australian Marine Safety Authority
API	American Petroleum Institute gravity (A measure of how heavy or light a petroleum liquid in comparison to water)
ASBTIA	Australian Southern Bluefin Tuna Industry Association
BIA	Biologically important area
BoM	Bureau of Meteorology
BWMC	Ballast Water Management Certificate
BWMP	Ballast Water Management Plan
CCWA	Conservation council of Western Australia
CFA	Commonwealth Fisheries Association
COLREGS	International Regulations for Preventing Collisions at Sea 1972
cP	Centipoise (unit of viscosity)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Department of Agriculture, Water and the Environment (formerly Department of Agriculture and Water Resources)
DAWR	Department of Agriculture and Water Resources (superseded by Department of Agriculture, Water and the Environment)
dB	Decibel
DEC	Department of Environment and Conservation
DEH	Department of Environment and Heritage
DoEE	Department of the Environment and Energy (superseded by Department of Agriculture, Water and the Environment)
DoF	Department of Fisheries
DoT	Department of Transport
DPIRD	Department of Primary Industries and Regional Development
DPLH	Department of Planning, Lands and Heritage
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities

Name	Description
E	East
EEZ	Exclusive Economic Zone
EMBA	Environment that may be affected
ENVID	Environmental hazard identification
EP	Environment Plan
EPBC	Environment Protection and Biodiversity Conservation
EPO	Environmental performance outcome
EPS	Environmental performance standard
ERM	Environmental Resources Management
ESD	Ecologically sustainable development
FRMA	*Fish Resources Management Act 1994*
GHG	Greenhouse gas
g/m^2	Grams per square meter (unit of surface or area density)
GMEM	Gippsland Marine Environmental Monitoring
HF	High frequency
hrs	Hours
Hz	Hertz
IAGC	International Association of Geophysical Contractors
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMO	International Maritime Organisation
IMS	Invasive marine species
IOGP	International Association of Oil and Gas Producers
ISPP	International Sewage Pollution Prevention
IUCN	International Union for the Conservation of Nature
JASCO	JASCO Applied Sciences
KEF	Key Ecological Feature
KLC	Kimberley Land Council
km	Kilometre
km^2	Square kilometres
LF	Low frequency
m	Metre
m^2	Metres squared
m^3	Metres cubed
M	Million
m/s	Metres per second
MAMF	Marine Aquarium Managed Fishery
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978
MDO	Marine diesel oil
MEPC	Marine Environment Protection Committee
MF	Medium frequency

Name	Description
MFO	Marine fauna observer
MGO	Marine gas oil
MMF	Mackerel Managed Fishery
MOD	Maximum-over-depth
MPA	Marine Protected Area
MSS	Marine Seismic Survey
MUZ	Multiple Use Zone
N	North
NBPMF	Nickol Bay Prawn Managed Fishery
NDSMF	Northern Demersal Scalefish Managed Fishery
nm	Nautical mile
NMSC	National Marine Safety Committee
NNTT	National Native Title Tribunal
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NWMR	North-west Marine Region
NWS	North West Shelf
NWSTF	North West Slope Trawl Fishery
OBN	Ocean bottom nodes
OIW	Oil in Water
OPGGS	*Offshore Petroleum and Greenhouse Gas Storage Act 2006*
OPGGS(E) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
PFTIMF	Pilbara Fish Trawl Interim Managed Fishery
PK	Peak pressure levels
PLF	Pilbara Line Fishery
pm	Picometre
PMI	Potential mortality injury
PMST	Protected Matters Search Tool
POLREP	Oil Pollution Report
PPA	Pearl Producers Association
ppb	Parts per billion
PSU	Practical salinity unit
PTMF	Pilbara Trap Managed Fishery
PTS	Permanent threshold shift
RPS	RPS Group
RWDC	Restricted work day case
S	South
SBTF	Southern Bluefin Tuna Fishery
SEL	Sound exposure levels
SITREP	Situation Report

Name	Description
SOLAS	International Convention for the Safety of Life at Sea
SOPEP	Shipboard Oil Pollution Emergency Plan
SSMF	Specimen Shell Managed Fishery
TSSC	Threatened Species Scientific Committee
TSS	Temporary threshold shift
µg/l	Micrograms per litre
UNESCO	United Nations Educational, Scientific and Cultural Organization
µPa	Micropascals
UTM	Universal Transverse Mercator
UXO	Unexploded ordinance
VOC	Volatile organic compounds
W	West
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council
WAM	Western Australian Museum
WASF	Western Australian North Coast Shark Fishery
WDCS	Whale and Dolphin Conservation Society
WSTF	Western Skipjack and Tuna Fishery
WTBF	Western Tuna Billfish Fishery
WWF	World Wildlife Fund for Nature
CGG	CGG Services (Australia) Pty Ltd
3D	Three dimensional

EP Summary

This EP summary has been prepared from material provided in this EP. The summary consists of the following as required by regulation 11(4):

EP Summary material requirement	Relevant section of EP containing EP Summary material
The location of the activity	Section 3.1
A description of the receiving environment	Section 4
A description of the activity	Section 3.3
Details of the environmental impacts and risks	Sections 7 and 8
The control measures for the activity	Sections 7 and 8
The arrangements for ongoing monitoring of the titleholders environmental performance	Section 9
Response arrangements in the oil pollution emergency plan	Appendix G:
Consultation already undertaken and plans for ongoing consultation	Section 5 and Appendix C:
Details of the titleholders nominated liaison person for the activity	Section 1.2.1

1 Introduction

1.1 Scope of this Environment Plan

CGG Services (Australia) Pty Ltd (CGG) is proposing to undertake the Sauropod 3D marine seismic survey (hereafter referred to as the Sauropod 3D MSS) in exploration permit area WA-527-P, which is located on the North West Shelf in the Roebuck Basin. An Environment Plan (EP) was previously accepted by NOPSEMA for this activity on 13 July 2020. It was developed and submitted by 3D Oil Limited (3D Oil). CGG is now planning to conduct and manage the survey in WA-527-P under a revised and updated EP. The purpose of the Sauropod 3D MSS is to collect three-dimensional (3D) geophysical data about the underlying rock types to inform oil and gas exploration.

This EP has been prepared in accordance with the requirements of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and associated Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations). It has also been prepared with reference to the Environment Plan Content Requirements Guidance Note (2020) produced by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

1.2 Proponent

CGG is a fully integrated geoscience company providing leading geological, geophysical and reservoir capabilities to its broad base of customers, primarily from the global oil and gas industry. CGG offers a range of products to assist oil companies to find oil and gas reserves offshore worldwide, including seismic and electromagnetic services, data acquisition, processing, reservoir analysis/interpretation and multi-client library data. CGG was founded in 1931 and has a workforce of over 6,000 staff in 70 locations worldwide.

CGG has extensive experience of conducting seismic surveys internationally and in Australia. The company has a well-developed and systematic approach to environmental management, including an Environment Policy (Appendix A:) that is applied successfully to operations around the world. CGG is a specialised seismic operator with a proven record of environmentally responsible operations in Australian waters.

1.2.1 Titleholder and Nominated Liaison Person

Permit titleholder and titleholder nominated liaison person details for WA-527-P are provided in Table 1-1. 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, CGG will notify NOPSEMA and provide the updated details (as described in Section 9 of this EP).

Table 1-1 – Details of WA-527-P Titleholder and Nominated Liaison Person

Titleholder Details	Liaison Person Details
CGG Services (Australia) Pty Ltd	Paul Rheinberg
Level 1, 1 Ord Street, West Perth WA 6005	Business Development Manager
T: +61 8 9214 6200	E: Paul.Rheinberg@CGG.com
ACN: 081 777 755	T: +61 8 9214 6200

2 Environmental Requirements

The OPGGS Act provides the regulatory framework for all offshore petroleum exploration, production and greenhouse gas (GHG) activities in Commonwealth waters. The related OPGGS (E) Regulations require titleholders to undertake their petroleum activity in accordance with an EP accepted by NOPSEMA. This EP has been prepared to meet the requirements of the OPGGS (E) Regulations. This section provides information on the requirements that apply to the activity. Requirements include relevant laws, codes, standards, agreements, treaties, conventions or practices (in whole or part) that apply to the jurisdiction in which the activity will take place.

The Sauropod 3D MSS will take place within Commonwealth waters. Relevant requirements associated with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), related policies, guidelines, plans of management, recovery plans, threat abatement plans, and other relevant advice issued by the Department of Agriculture, Water and the Environment (DAWE) (formerly Department of the Environment and Energy) are detailed in Section 4 in the applicable subsections, as part of the description of the existing environment.

Table 2-1 provides a summary of requirements that apply to the activity and are relevant to the activity's environmental management, while Table 2-2 summarises the international conventions and agreements of which Australia is a signatory that are relevant to the Sauropod 3D MSS.

Table 2-1 - Summary of Requirements Relevant to the Activity

Requirements	Scope (as Relevant to this EP)	Application to Sauropod 3D MSS	Administering Authority
Australian Maritime Safety Authority Act 1990	Facilitates international cooperation and mutual assistance in preparing and responding to major oil spill incidents and encourages countries to develop and maintain an adequate capability to deal with oil pollution emergencies.	Under this Act, any hydrocarbon spill to the marine environment, resulting from the survey must be reported. In Commonwealth waters the Australian Maritime Safety Authority (AMSA) is the Statutory Agency for vessels and must be notified of all incidents involving a vessel. Hydrocarbon spill risks are detailed in Section 8	AMSA
Biosecurity Act 2015 Biosecurity Regulations 2016	The objects of this Act are: (a) to provide for managing the following: (i) biosecurity risks (ii) the risk of contagion of a listed human disease (iii) the risk of listed human diseases entering Australian territory or a part of Australian territory, or emerging, establishing themselves or spreading in Australian territory or a part of Australian territory (iv) risks related to ballast water (v) biosecurity emergencies and human biosecurity emergencies (b) to give effect to Australia's international rights and obligations, including under the International Health Regulations, the SPS Agreement and the Biodiversity Convention.	The Biosecurity Act and regulations apply to 'Australian territory' which is the airspace over and the coastal seas out to 12 nm from the coastline. Biosecurity risks associated with the survey are detailed in Section 8.8.	Department of Agriculture, Water and the Environment (DAWE)
Biosecurity Act 2015	Australian Ballast Water Management Requirements (DAWR 2017)	Provides guidance on how vessel operators should manage ballast water when operating within Australian seas in order to comply with the Biosecurity Act. Section 8.8 details these requirements.	DAWE
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The EPBC Act aims to protect the environment, particularly matters of national environmental significance for which Australia has made international agreements. The EPBC Act streamlines national environmental assessment and approval processes and promotes ecologically sustainable development and conservation of biodiversity. It also provides for a cooperative approach to the management of natural, cultural, social and economic aspects of ecosystems, communities and resources. Section 3A of the Act defines the principles of ecological sustainable development. The following principles are principles of ecologically sustainable development: (a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations (b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation (c) the principle of inter-generational equity--that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations (d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making (e) improved valuation, pricing and incentive mechanisms should be promoted.	Petroleum activities are excluded from within the boundaries of a World Heritage Area (Sub regulation 10A(f)). Petroleum activities must be carried out in a manner consistent with the principles of ecological sustainable development set out in Section 3A of the EPBC Act. Determination of impact and risk Acceptability details that residual risks are ALARP, and the principles of ecologically sustainable development have been met (Section 6). Assessment of impacts and risks to Matters of National Environmental Significance (MNES) from the survey are described in Section 7 and 8.	DAWE
Environment Protection and Biodiversity Conservation Regulations 2000	Provides additional regulations regarding Matters of National Environmental Significance.	Part 8 of the Regulations details requirements for operating vessels and aircraft in relation to cetaceans. Section 7.3 details these requirements.	DAWE
EPBC Act Policy Statement 2.1 Interaction between offshore seismic exploration and whales	The aim of this Policy Statement is to: • provide practical standards to minimise the risk of acoustic injury to whales in the vicinity of seismic survey operations • provide a framework that minimises the risk of biological consequences from acoustic disturbance from seismic survey sources to whales in biologically important habitat areas or during critical behaviours • provide guidance to both proponents of seismic surveys and operators conducting seismic surveys about their legal responsibilities under the EPBC Act.	The policy statement provides guidance on undertaking seismic activities in Australian waters to limit potential impacts to whales. Section 7.1 and 7.2 details how the policy statement has been applied to this survey.	DAWE

Requirements	Scope (as Relevant to this EP)	Application to Sauropod 3D MSS	Administering Authority
Underwater Cultural Heritage (Consequential and Transitional Provisions) Act 2018	This Act protects historic wrecks (and associated relics) in Commonwealth waters that are more than 75 years old. Under this Act, historic shipwrecks are protected for their heritage values and maintained for recreational, scientific and educational purposes.	Anyone who finds the remains of a ship, or an article associated with a ship, needs to notify the relevant authorities, as soon as possible but ideally no later than after one week, and to give them information about what has been found and its location. Refer to Section 4.4.9 for information on historic shipwrecks in relation to the Sauropod 3D MSS.	DAWE
Navigation Act 2012	Regulates international ship and seafarer safety, shipping aspects of protecting the marine environment and the actions of seafarers in Australian waters. It gives effect to the relevant international conventions (MARPOL 73/78, COLREGS 1972) relating to maritime issues to which Australia is a signatory. The Act also has subordinate legislation contained in Regulations and Marine Orders.	Several Marine Orders are enacted under this Act relating to offshore petroleum activities, including: • Marine Order 21: Safety and emergency arrangements • Marine Order 27: Safety of navigation and radio equipment • Marine Order 30: Prevention of collisions • Marine Order 31: Vessel surveys and certification • Marine Order 58: Safe management of vessels. Section 7 and Section 8 detail where the applicable requirements apply to the survey.	AMSA
Offshore Petroleum and Greenhouse Gas Storage Act 2006 Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009	Addresses all licensing, health, safety, environmental and royalty issues for offshore petroleum exploration and development operations extending beyond the three nautical mile limit. Ensures that petroleum activities are undertaken in an ecologically sustainable manner and in accordance with an approved EP.	A titleholder must have an in-force EP prior to the commencement of any petroleum activity. This requirement is met by submission and acceptance of this EP. A significant modification, change or new stage of an existing activity that is not included in an in-force EP requires a revision of the EP to be submitted to NOPSEMA for acceptance. Titleholders are required to maintain financial assurance sufficient to give the titleholder carrying out the petroleum activity, the capacity to meet the costs, expenses and liabilities that may result in connection with carrying out the petroleum activity; doing any other thing for the purpose of the petroleum activity; or complying (or failing to comply) with a requirement under the OPGGS Act in relation to the petroleum activity. This requirement must be met by the titleholder before NOPSEMA can accept the EP.	NOPSEMA
Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Act 2003 Offshore Petroleum and Greenhouse Gas Storage (Regulatory Levies) Regulations 2004	An Act to impose levies relating to the regulation of offshore petroleum activities and greenhouse gas storage activities.	Requires that EP levies are imposed on EP submissions, including revisions, where the activities to which the EP relates are authorised by one or more Commonwealth titles. This requirement applies once the EP is accepted.	NOPSEMA
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	Regulates ship-related operational activities and invokes certain requirements of the MARPOL Convention relating to discharge of noxious liquid substances, sewage, garbage, air pollution etc.	Provides for discharges and emissions from ships as per MARPOL Annex I, II, III, IV, V and VI. Several Marine Orders are enacted under this Act relevant to the activity, including: • Marine Order 91: Marine pollution prevention – oil • Marine Order 93: Marine pollution prevention – noxious liquid substances • Marine Order 94: Marine pollution prevention – packaged harmful substances • Marine Order 95: Marine pollution prevention – garbage • Marine Order 96: Marine pollution prevention – sewage • Marine Order 97: Marine pollution prevention – air pollution • Marine Order 98: Marine pollution prevention – anti-fouling systems. • Provides exemptions for the discharge of materials in response to marine pollution incidents. • Requires ships ≥400 gross tonnes to have pollution emergency plans. Section 7 details where the applicable requirements apply to the survey.	AMSA
Protection of the Sea (Harmful Antifouling Systems) Act 2006	Is an offence to engage in negligent conduct that results in a harmful anti-fouling compound being applied to a ship. Australian ships must hold ‘anti-fouling certificates’, provided they meet certain criteria.	If required, a ship must have a current anti-fouling certificate and must not use harmful antifouling compounds. Marine Order 98: Marine Pollution Prevention – anti-fouling systems is enacted under this Act. Section 8 details where the applicable requirements apply to the survey.	AMSA
International Association of Geophysical Contractors (IAGC) Environment Manual for Worldwide Geophysical Operations (2013)	Provides the industry with useful information for conducting geophysical field operations in an environmentally sensitive manner.	Provide guidelines for best practice operations of seismic surveys to minimise environment impacts. Section 7 details applicable guidance.	IAGC
IAGC Mitigation Measures for Cetaceans during Geophysical Operations (February 2015)	Provides recommended mitigation measures for cetaceans during geophysical operations. IAGC recommends implementing the suggested controls (mentioned in the document) in the absence of regulations or guidelines.	Provide recommended mitigation measures for cetaceans during geophysical operations. Section 7 details applicable requirements.	IAGC

Requirements	Scope (as Relevant to this EP)	Application to Sauropod 3D MSS	Administering Authority
International Maritime Organisation (IMO) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) 2011	Provide a globally consistent approach to the management of biofouling. They were adopted by the Marine Environment Protection Committee (MEPC) in July 2011 and were the result of three years of consultation between IMO Member States	Specific requirements are that vessels have a biofouling management plan and biofouling record book. Section 8 details these requirements.	IMO
WA Department of Fisheries (DoF) Guidance Statement on Undertaking Seismic Surveys in WA Waters	Identifies potential issues of concern associated with seismic surveys on fish and fish habitats, as defined under the *Fish Resources Management Act 1994* (FRMA). It is aimed at giving proponents direction on general standards and protocols designed to avoid or mitigate the potential impacts of seismic surveys on fish. It is expected that proponents will incorporate these standards and protocols when planning and implementing seismic surveys.	Provides guidance and mitigation strategies to avoid or minimise potential impacts of seismic surveys on fish. Section 7.1 and 7.2 details applicable requirements.	WA Department of Primary Industries and Regional Development (DPIRD)
National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2016)	The overarching goal of the Strategy is to provide guidance on understanding and reducing the risk of vessel collisions and the impacts they may have on marine mega-fauna.	The strategy provides information and guidance on reducing vessel collisions with marine mega-fauna. Section 8.5 details applicable information and requirements.	DAWE
International Association of Oil and Gas Producers (IOGP) Recommended monitoring and mitigation measures for cetaceans during marine seismic survey geophysical operations (March 2017)	Provides recommendations on applying mitigation measures for cetaceans during geophysical operations. The measures outlined in this report are recommended for use during all marine seismic surveys that use compressed air source arrays, and are only intended for cetaceans (whales, dolphins and porpoises).	Provides recommended mitigation measures for cetaceans during a marine seismic survey, including exclusion zones, soft starts, seismic testing procedures, and recording Marine Fauna Observer (MFO) observations. Section 7.1 and 7.2 details applicable requirements.	IOGP

Table 2-2 - Summary of Relevant International Agreements

Agreement	Scope (as Relevant to this EP)	Relevance
1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972	Contributes to the international control and prevention of marine pollution by prohibiting the dumping of certain hazardous materials. Under the 1996 Protocol, dumping is prohibited, except for materials on an approved list.	No dumping of any wastes or other matter from survey activities with the exception of those listed in Annex 1 of the Protocol (which will be discharged in line with MARPOL requirements).
Convention on Oil Pollution Preparedness, Response and Cooperation 1990 (OPRC 90)	This Convention establishes measures for dealing with marine oil pollution incidents nationally and in cooperation with other countries.	All vessels ≥400 gross tonnes will have a SOPEP in place (Section 8.1).
International Convention for the Prevention of Pollution from Ships 1973/1978 (MARPOL 73/78)	This Convention covers prevention of pollution of the marine environment by ships from operational or accidental causes. It includes regulations aimed at preventing and minimising pollution from ships (accidental and routine).	Pollution from the survey activities will be managed in accordance with MARPOL requirements, as described in Sections 7 and 8.
International Regulations for Preventing Collisions at Sea, 1972 (COLREGS)	The COLREGS outline internationally agreed rules for safe navigation, including 'give way' rules between vessels and other requirements for safe conduct including the requirement to keep a look out, travel at a safe speed, and how to operate vessels in narrow channels.	The survey will adhere to the requirements of COLREGS as implemented in Commonwealth waters through the *Navigation Act 2012* (refer to Table 2-1).
International Convention for the Safety of Life at Sea, 1974 (SOLAS)	This convention outlines the minimum safety standards in the construction, equipment and operation of merchant ships.	The survey will adhere to the requirements of SOLAS as implemented in Commonwealth waters through the *Navigation Act 2012* (refer to Table 2-1).
International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001	The Convention prohibits the use of harmful organotins in anti-fouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems.	The survey will adhere to the requirements of the convention as implemented through the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*.

3 Description of the Activity

3.1 Survey Location

The Sauropod 3D MSS will take place within Commonwealth waters off the north-west Western Australian (WA) coast, within the Roebuck Basin in exploration permit area WA-527-P. The survey will be undertaken within an ‘Acquisition Area’, where seismic data acquisition will occur. The Acquisition Area will be located within a broader ‘Operational Area’, which includes additional space for vessel activities such as line turns, run-ins, run-outs, soft-start procedures and seismic source testing. The co-ordinates for the Operational and Acquisition area are provided in Table 3-1.

The Acquisition Area will be up to a maximum of approximately 3,500 km^2, with an Operational Area of approximately 6,000 km^2 (Figure 3-1). At its closest point, the Operational Area is approximately 120 km from the WA coast at Pardoo and 230 km from Broome. Water depths in the Operational and Acquisition Areas range from approximately 65 – 170 m and 75 – 165 m respectively.

The seismic source will be discharged at or below full capacity (power) within the Operational Area, for the purpose of run-outs, source testing and soft starts during run-ins. This discharge of the source will be sporadic, only occur for short periods of time, and will be limited to relatively short distances (e.g. 4–5 km) from the northern and southern boundaries of the Acquisition Area.

Table 3-1 - Operational and Acquisition Area co-ordinates (GDA 94)

Operational Area		Acquisition Area	
Latitude	Longitude	Latitude	Longitude
-17° 55’ 47.93”	120° 3’ 24.12”	-18° 1’ 49.19”	119° 59’ 24.25”
-18° 50’ 45.74”	120° 4’ 22.48”	-18° 44’ 52.37”	120° 0’ 8.93”
-18° 51’ 15.77”	119° 31’ 2.71”	-18° 45’ 14.87”	119° 35’ 4.56”
-17° 56’ 16.4”	119° 30’ 14.87”	-18° 2’ 10.75”	119° 34’ 26.08”

3.2 Schedule

The Sauropod 3D MSS will take a maximum of 60 days to acquire and will be undertaken within the acquisition window of January to May 2022.

The precise timing of the survey is subject to vessel availability, weather conditions and other operational considerations, and will take into account the seasonality of environmental sensitivities, where practicable. The exact start and end dates will be communicated to stakeholders (refer to Section 9.11).

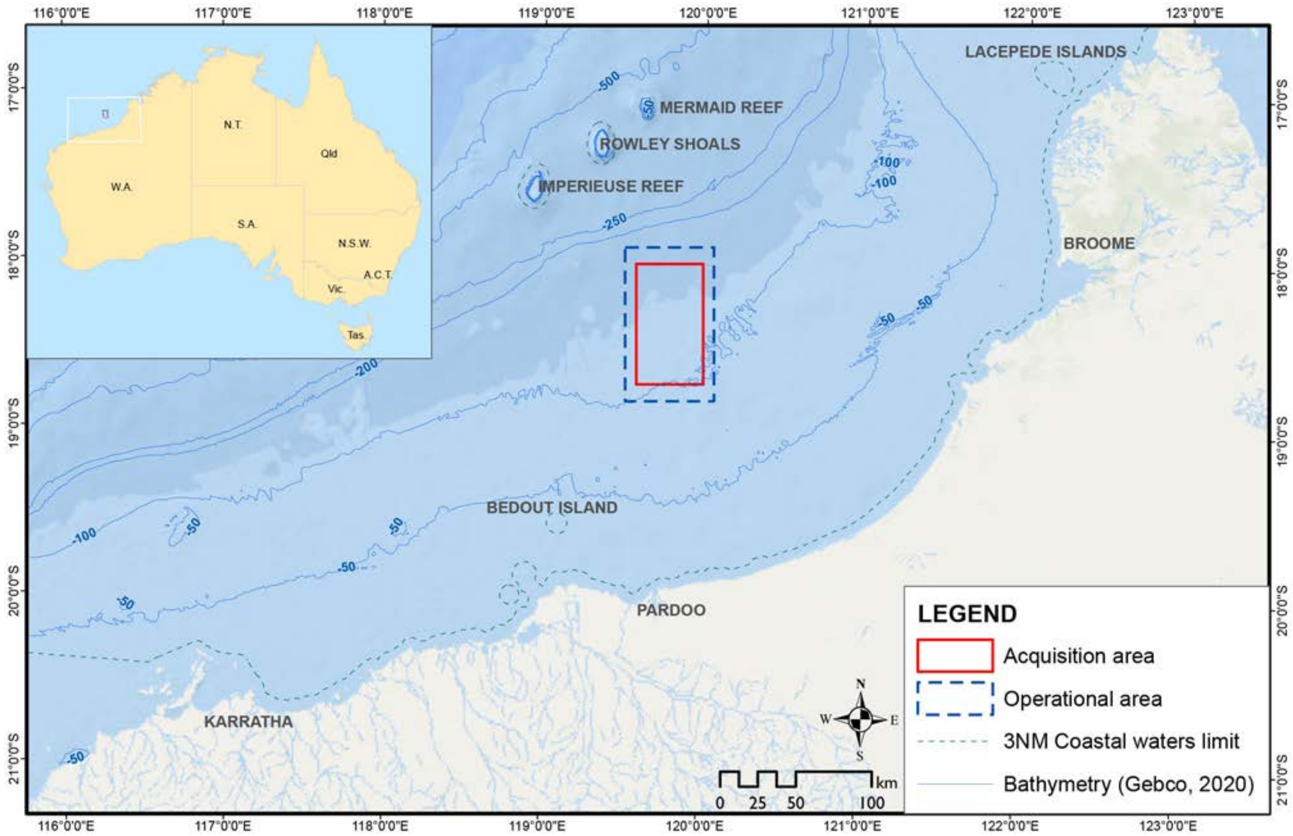


Figure 3-1 – Location of Sauropod 3D MSS

3.3 Activity Details

The core activity that forms the basis for this EP is the undertaking of the Sauropod 3D MSS. Associated activities in support of the survey are likely to include refuelling and resupply, use of support vessels as required, and crew changes within the Operational Area. Associated activities are described in this section as appropriate, with a focus on those considered relevant to the assessment of environmental impact and risk. Key details of the proposed seismic survey are summarised in Table 3-2 and described below.

The Sauropod 3D MSS will be undertaken by a seismic survey vessel towing an underwater seismic source and a series of up to 12 streamers behind it. The seismic source will consist of an array of airguns of varying volumes, distributed in three separate arrays that will be discharged alternately. The airguns emit high pressure pulses of sound, with the primary energy directed downwards into the subsurface (not horizontally away from the source). The streamers contain underwater microphones (known as hydrophones) which record the sound waves reflected off the seabed and underlying rock formations. These data are later processed to provide information about the structure and composition of geological formations below the seabed.

The survey vessel will tow the seismic source at 5–10 m beneath the sea surface, with a total discharge volume of up to 2,820 cubic inches (in^3). The total volume size of the airgun array has been chosen based on the range of water depths within the survey area and depth of the target within the subsurface to ensure adequate seismic imaging.

The hydrophone streamers will extend approximately 7.05 km behind the vessel and be spaced 112.5 m apart. The streamers will be towed at a depth of approximately 15 m below the surface. Tail buoys will be used to maintain position in the water and clearly indicate the streamer ends. As tail buoys are self-inflating, they will return to the surface if they go beyond a certain water depth. In addition, the tail buoys will be fitted with turtle guards, lights and radar reflectors. Depth monitoring and control devices positioned along the streamers will be used to maintain the preferred tow depth.

Table 3-2 – Key Details for the Sauropod 3D MSS

Parameter	Sauropod 3D MSS
Survey Area	
Permit area	WA-527-P
Acquisition area	Approximately 3,500 km^2
Operational area	Approximately 6,000 km^2
Seismic Activity	
Survey earliest commencement date	January 2022
Survey latest completion date	May 2022
Duration of survey	60 days
Length of sail lines	83 km
Time to traverse a sail line	~10 hours
Orientation of sail lines	North–south
Distance between sail lines	675 m – 716 m
Seismic vessel sail line speed	~4.5 knots
Seismic source discharge interval	Approximately every 12.5 m (approximately every 5.4 seconds) along survey lines
Seismic Source	
Type	Airgun / three arrays, which will be discharged alternately
Size	Max 2,820 in^3
Pressure	2,000 psi
Source levels (at 0–2,000 Hz)	223.0-228.2 dB re 1 μPa2m^{2}s (SEL) 244.8-255.0 dB re 1 μPa m (PK)
Sound source tow depth	5–10 m
Streamers	
Number	12
Streamer length	7,050 m
Distance from seismic vessel bow to tail buoy	7,800 m
Distance between streamers	112.5 m
Streamer tow depth	15 m
Vessels	
Seismic vessel	One vessel - specific vessel yet to be determined
Support vessels	Two support vessels (one supply and one chase) – specific vessels yet to be determined
Refuelling	Refuelling at sea will occur approximately every 2–4 weeks (depending on the specific vessel and contractor)
Crew changes	Via helicopter or support vessel every 4–6 weeks.

3.3.1 Seismic Source Operation

When acquiring data, the vessel will travel along a series of pre-determined lines within the Acquisition Area at approximately 4.5 knots (8 km/hour), discharging the seismic source at 12.5 m intervals (approximately every 5.4 seconds).

The Sauropod 3D MSS is a typical 3D survey using methods and procedures similar to others conducted in Australian waters. No unique or unusual equipment or operations are proposed. The survey will be conducted 24 hours a day. Survey and equipment parameters are provided in Table 3-2.

The seismic survey vessel will typically acquire the data along a series of adjacent and parallel lines in a “racetrack”-like pattern. At the end of the first line in a racetrack sequence, the vessel will turn in a wide arc to position for another parallel line in the opposite direction, offset several kilometres from the previous line. The vessel will then turn again to position to return in the opposite direction along the third parallel line in the sequence, offset approximately 675 – 716 m from the first line. This pattern is repeated across the Acquisition Area until the required coverage is completed. The vessel will sail lines that are typically in a north–south orientation. Each sail line is approximately 83 km long and will take approximately ten hours to acquire. The time required to complete each sail line is dependent on vessel speed and currents.

Full-fold seismic data acquisition involving operation of the seismic source at full volume will occur within the Acquisition Area, although the seismic source will also be operated outside of the Acquisition Area during line run-outs, source testing, soft starts during run-ins, maintenance and testing.

During line run-outs, the seismic source will typically be operated at full volume for the equivalent of half a streamer length (approximately 4 km) before the source is shut down and the survey vessel commences the next line turn. Following completion of the line turn, the vessel will complete a run-in towards the Acquisition Area, which involves sailing in a straight line to allow the streamers to straighten prior to commencing acquisition. During these run-ins, soft-start procedures occur for a minimum of 30 minutes (approximately 4 km), which begins with the operation of the single smallest source element in the array and gradual ramp-up to include additional source elements until the seismic source is operated at full volume for the commencement of the acquisition line at the Acquisition Area boundary.

The seismic source may also be operated for short durations in a controlled manner elsewhere in the Operational Area, for the purpose of source maintenance and testing. These activities are infrequent and typically involve short intermittent controlled discharges of individual source elements (i.e. single gun/cluster or single source array) for durations in the order of a short number of testing shots. Since this testing only involves a single gun or a small cluster of guns, the noise propagated from the source during this activity must logically be less than the whole array. Therefore, any impacts from noise emissions will not be greater than that predicted in the impact assessment.

Operation of the seismic source in all cases will be in accordance with control measures and performance standards specified in this EP.

3.3.2 Infill

When acquiring 3D marine seismic data, surface currents may shift the streamers away from their nominal positions. This shift, called feathering, can lead to holes in the data coverage. Holes in data coverage can also occur when the airgun array is turned off due to technical or logistical reasons (e.g. technical problems or marine fauna interactions). These holes are typically filled in by steering the vessel closer to the previous sail-line or by acquiring additional sail-lines along the coverage holes. These extra sail-lines are commonly known as infill. Infill can be a large part of the time and cost for a marine seismic survey. Without infill activity, seismic surveys would be incomplete, the data compromised, and contract requirements not fulfilled.

It is not possible to estimate what the amount of feather (and resulting coverage) will be. Typically, pre-plot sail lines will be completed and the infills are left to the end of a survey once the seismic data have been partially processed and all infill locations identified.

With proper infill management, unnecessary infill lines may be reduced or avoided. The on-board navigator steers the seismic vessel for coverage to minimise the amount of infill. Additionally, steerable streamers and fan-mode techniques for the streamer spread are used to minimise infill requirements.

3.3.3 Vessels

3.3.3.1 Seismic Vessel

A purpose-built survey vessel will be used for the Sauropod 3D MSS and will carry up to approximately 70 people. The specific vessel for the survey has yet to be determined.

3.3.3.2 Support Vessels

Two support vessels will be engaged for the Sauropod 3D MSS. These comprise:

- One chase vessel accompanying the seismic vessel to assist with managing potential interactions with other marine users
- One supply vessel responsible for resupply, refuelling, and other support functions.

Refuelling and resupply at sea by a supply vessel is expected to occur approximately every 2–4 weeks during the survey (depending on the specific vessel and contractor). At-sea refuelling of the seismic vessel will only take place during daylight hours and within strict weather limit guidelines. Refer to Section 8.3 for details of control measures to be implemented during refuelling.

Crew changes are expected to be undertaken by a supply vessel or helicopter approximately every 4–6 weeks.

4 Description of the Existing Environment

4.1 Overview

This section describes the environmental and socio-economic values and sensitivities within the existing environment of the Operational Area and wider environment that may be affected (EMBA) by the proposed activity (see Figure 4-1). The EMBA is a conservative approximation of the furthest extent that could be affected in any credible impact scenario. In this case, the EMBA represents an unplanned release of marine diesel oil (MDO). The EMBA was derived from oil spill modelling for an instantaneous release of 280 m^3 at the north-west corner of the Operational Area. It is important to note that the EMBA covers a much larger area than the area that is likely to be affected during any one single spill event. The modelling was run for a variety of weather and metocean conditions (300 simulations in total), and the resulting EMBA for the north-west corner of the Operational Area was extrapolated to the three other corners. Other nearby sensitivities that were considered potentially relevant to the EP are also described in this section. The information contained in this section has been used to inform the assessment of impacts and risks in Section 7 and Section 8. For further detail on the modelling refer to Section 8.1.

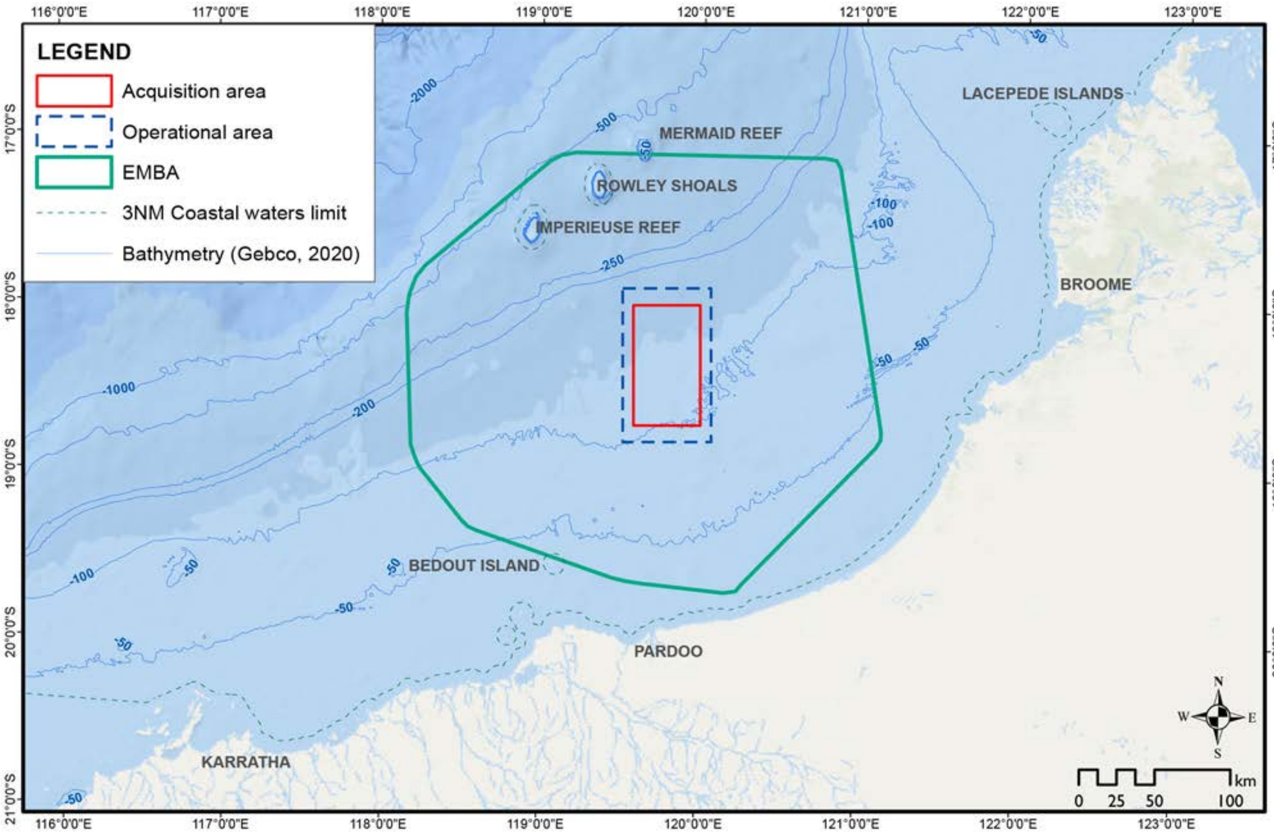


Figure 4-1 – Operational Area and EMBA for the Sauropod 3D MSS

4.1.1 Regional Context – the North-west Marine Region

The Operational Area is located in the centre of the North West Shelf (NWS), an area of significant environmental, economic and cultural value. 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 bioregions (Figure 4-2). 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 Operational Area is located within the North-west Marine Region (NWMR).

The NWMR comprises Commonwealth waters from the Western Australia–Northern Territory border to Kalbarri, south of Shark Bay. The NWMR is characterised by the following aspects (DEWHA 2008a):

- Containing a large portion of continental shelf and continental slope

- Highly variable tidal regions and very high cyclone incidence
- Shallow-water tropical marine ecosystems, which are home to globally significant populations of internationally threatened species
- Containing threatened and migratory species listed under the EPBC Act, including cetaceans, Dugong, marine reptiles, seabirds and migratory shorebirds, seahorses and pipefish, sharks and sawfishes
- Containing biologically important areas (BIAs), where protected species display biologically important behaviour such as breeding, foraging, resting or migration.

Within the NWMR, marine habitats are further categorised into eight provincial bioregions. The Operational Area is located within the North West Shelf Province, and the EMBA overlaps with part of the North-west Transition (Figure 4-3). These two provincial bioregions are described below.

4.1.1.1 North West Shelf Province

The Operational Area is located within the North West Shelf Province, a bioregion that covers 238,759 km^2 of waters on the continental shelf in depths of up to 200 m. The North West Shelf Province is described as a dynamic oceanographic environment, influenced by strong tides, cyclonic storms, long-period swells and internal tides (DEWHA 2008a). Waters are generally warm, and currents are primarily driven by the Indonesian Throughflow (ITF). Diverse pelagic and demersal fish communities occupy the bioregion and are thought to be closely associated with depth ranges. The region facilitates seasonal migrations of iconic megafauna such as the blue whale, Humpback whale and whale shark. Coastal areas provide important breeding sites for a variety of seabirds, including Eighty Mile Beach and the Lacepede Islands. The region is commercially important to both the petroleum industry and commercial fishing industry.

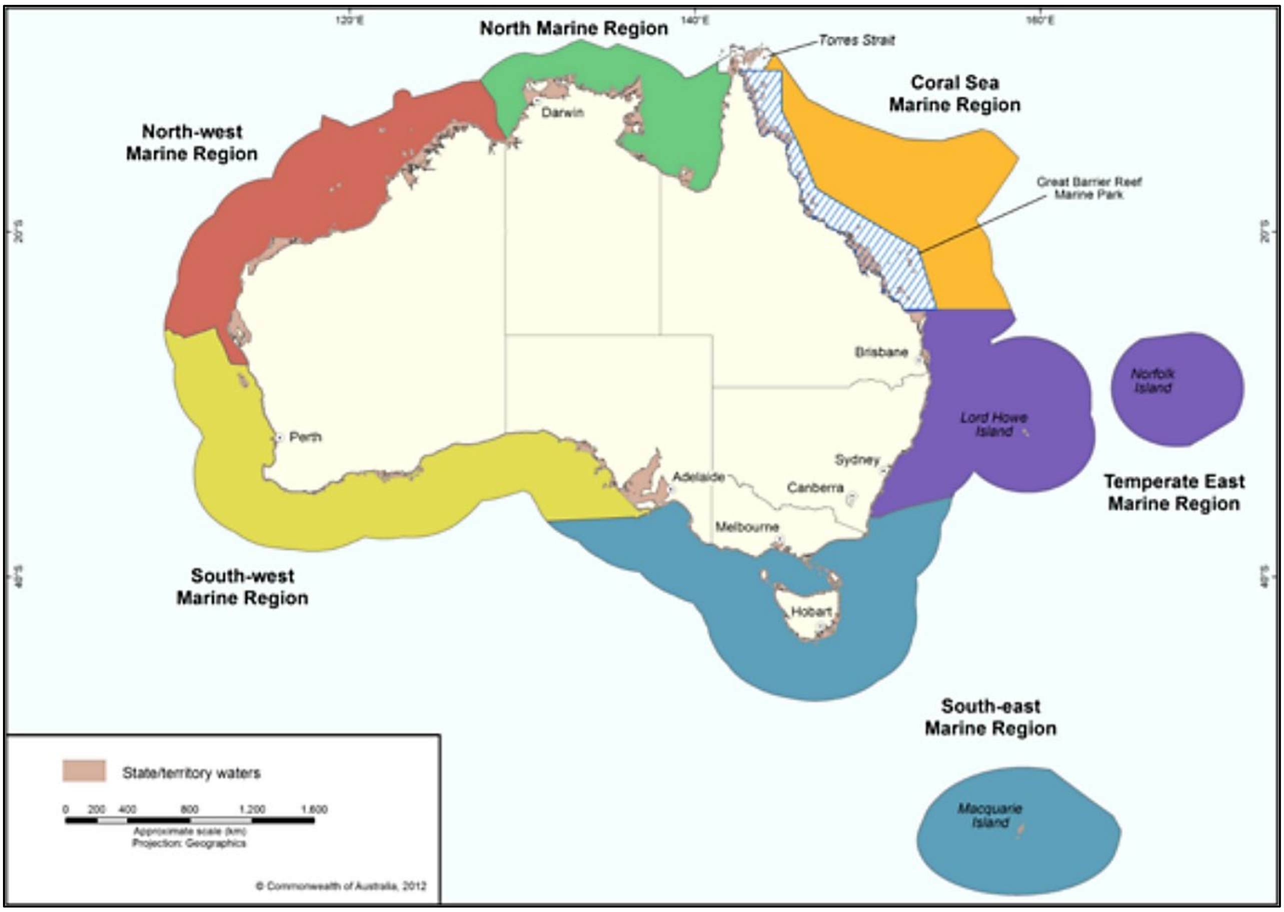


Figure 4-2 – Marine Bioregions of Australia (Source: DSEWPaC 2012a)

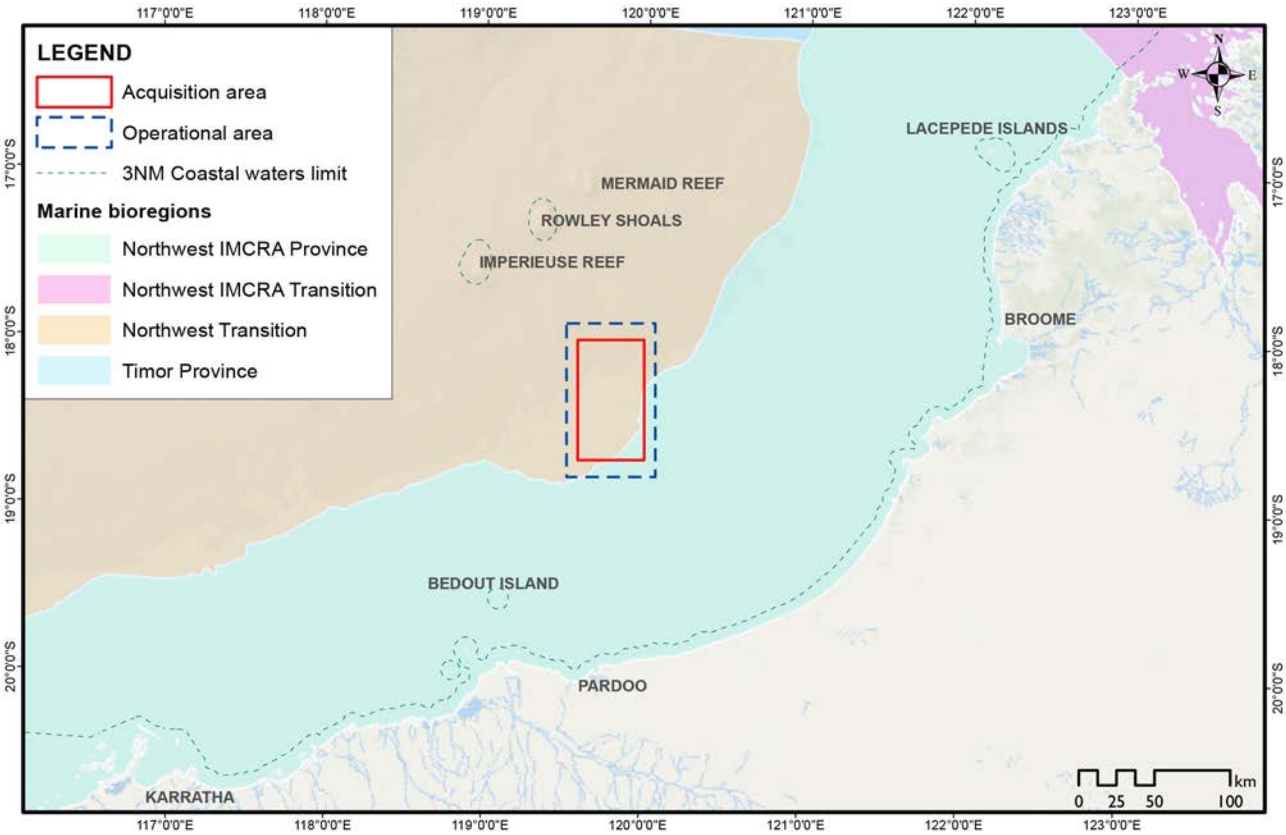


Figure 4-3 – Provincial Bioregions (IMCRA v4.0)

4.1.1.2 North-west Transition

The EMBA overlaps with part of the North-west Transition, a bioregion that covers 184,424 km^2 and includes shelf break and continental slope and the majority of the Argo Abyssal Plain, covering depths up to 5,980 m. The Rowley Shoals are a key topographic feature of the bioregion (see Sections 4.3.2.1 and 4.4.2.1). The continental slope portion of the bioregion is thought to support fish communities with high levels of species diversity and endemism; however, little is known about the benthic biological communities in the deeper parts of the bioregion (DEWHA 2008a). A range of pelagic migratory species including billfish, sharks, tuna and cetaceans occur within the bioregion, particularly in association with the Rowley Shoals.

4.2 Physical Environment

4.2.1 Climate

4.2.1.1 Seasonal Patterns

The climate of the NWMR is dry tropical, exhibiting a hot summer season from October to April and a milder winter season between May and September (BoM 2021a). There are often distinct transition periods between the summer and winter regimes, which are characterised by periods of relatively low winds (Pearce *et al.* 2003).

4.2.1.2 Air Temperature and Rainfall

Air temperatures in the region, as measured at the Rowley Shoals platform (approximately 107 km from the Operational Area), indicate maximum average temperatures during summer of 30.4 °C and minimum temperatures of 23.6 °C in winter (BoM 2021b).

The region experiences a tropical monsoon climate, with distinct wet (October to April) and dry (May to September) seasons (Pearce *et al.* 2003). Rainfall in the region (measured at Wallal Downs Station) typically occurs during the wet season (summer), with highest falls observed during late summer (BoM 2021c), and often associated with the passage of tropical low-pressure systems and cyclones (Pearce *et al.* 2003). Rainfall outside this period is typically low.

4.2.1.3 Wind

Winds vary seasonally, with a tendency for winds from the south-west quadrant during summer and the south-east quadrant in winter. The summer south-westerly winds are driven by high pressure cells that pass from west to east over the Australian continent. During winter months, the relative position of the high-pressure cells moves further north, leading to prevailing south-easterly winds blowing from the mainland (Pearce *et al.* 2003). Winds typically weaken and are more variable during the transitional period between the summer and winter regimes, generally between April and August (Table 4-1).

Table 4-1 – Predicted Monthly Average and Maximum Winds within the Operational Area (RPS 2019, Derived from CFSR Hindcast Model)

Month	Average Wind (knots)	Maximum Wind (knots)	General Direction (from)
January	11	35	W
February	11	47	W
March	9	58	Variable
April	8	27	Variable
May	13	32	ESE
June	13	30	ESE
July	13	29	ESE
August	11	29	ESE
September	11	31	Variable
October	10	25	WSW
November	10	27	WSW
December	11	36	W
Minimum	8	25	-
Maximum	13	58	-

4.2.1.4 Tropical Cyclones

Tropical cyclones are a relatively frequent event for the region, with the Pilbara coast experiencing more cyclonic activity than any other region of the Australian mainland coast (BoM 2021d). Tropical cyclone activity can occur between November and April and is most frequent in the region during January to March, with an annual average of approximately one storm per month. Cyclones are less frequent in the months of November, December and April but historically the worst storms have occurred in April.

4.2.2 Oceanography

4.2.2.1 Tides

Tides in the region of the NWS are semi-diurnal and have a pronounced spring-neap cycle, with tidal currents flooding towards the south-east and ebbing towards then north-west (Pearce *et al.* 2003). Within the North West Shelf Province, tidal activity is considered a significant factor for the oceanography. Tides in this part of the bioregion are large and tend to increase in magnitude from south to north (from an amplitude of one metre at Exmouth to over three metres at Broome). In shallower waters, the tides contribute to the vertical mixing of the surface water layer and sediments. It should be noted that in the shallower coastal waters there is a high evaporation rate, which results in slower offshore movement of denser, more saline waters across the North West Shelf. This dense, more saline water is typically found as a bottom layer of coastal water out as far as the 200 m depth contour.

4.2.2.2 Waves

Internal tides are typically generated around the shelf break and appear to contribute to the biological productivity of the region. When the internal waves break, it causes mixing of more nutrient-rich water with the photic zone, and therefore enhancing biological productivity.

Furthermore, the region is known to have seasonal cyclonic events, which are key drivers in the bioregion. Tropical cyclone activity can occur between November and April and is most frequent in the region during January to March, with an annual average of approximately one storm per month. Cyclones are less frequent in the months of November, December and April but historically the worst storms have occurred in April. During cyclone season, wave action in the bioregion is increased.

4.2.2.3 Temperature

The offshore oceanic sea water characteristics of the NWS exhibit seasonal and water depth variation in temperature and salinity, being greatly influenced by major currents in the region. Surface waters are relatively warm year-round due to the tropical water supplied by the Indonesian Throughflow and the Leeuwin Current, with temperatures reaching 30 °C in summer and dropping to 22 °C in winter (Pearce *et al.* 2003). This is reflected in data available from NOAA, where the average annual surface temperature water in the EMBA and Operational Area is approximately 27 °C (NOAA 2021a).

4.2.2.4 Currents

The oceanography of this bioregion is generated by the movement of surface currents from the waters of the Indonesian Throughflow (Figure 4-4). The Throughflow waters are circulated from the North-west Marine region through the South Equatorial and Eastern Gyral currents. Within the North West Shelf Province water circulation is highly seasonal. During winter, the Throughflow's southern flow is at its strongest and tends to dominate the water column. On the other hand, during summer, the Throughflow is weaker and strong winds from the south-west cause intermittent reversal of the currents, which generates upwellings of colder and deeper water. Typical ocean current circulation patterns during summer months (the main proposed timing of the Sauropod 3D MSS) are shown in Figure 4-5.

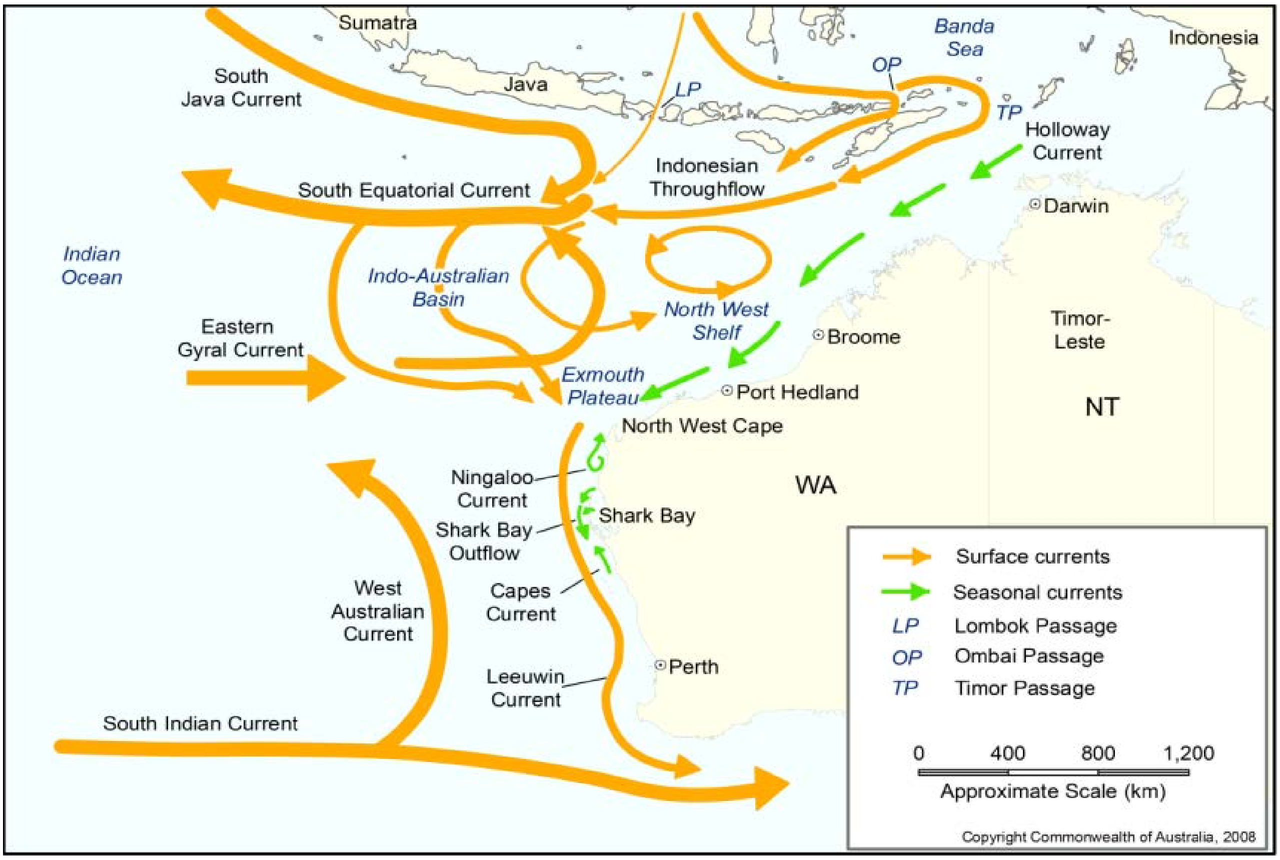


Figure 4-4 – Surface Currents in Western Australian Waters. Source: DEWHA (2008a)

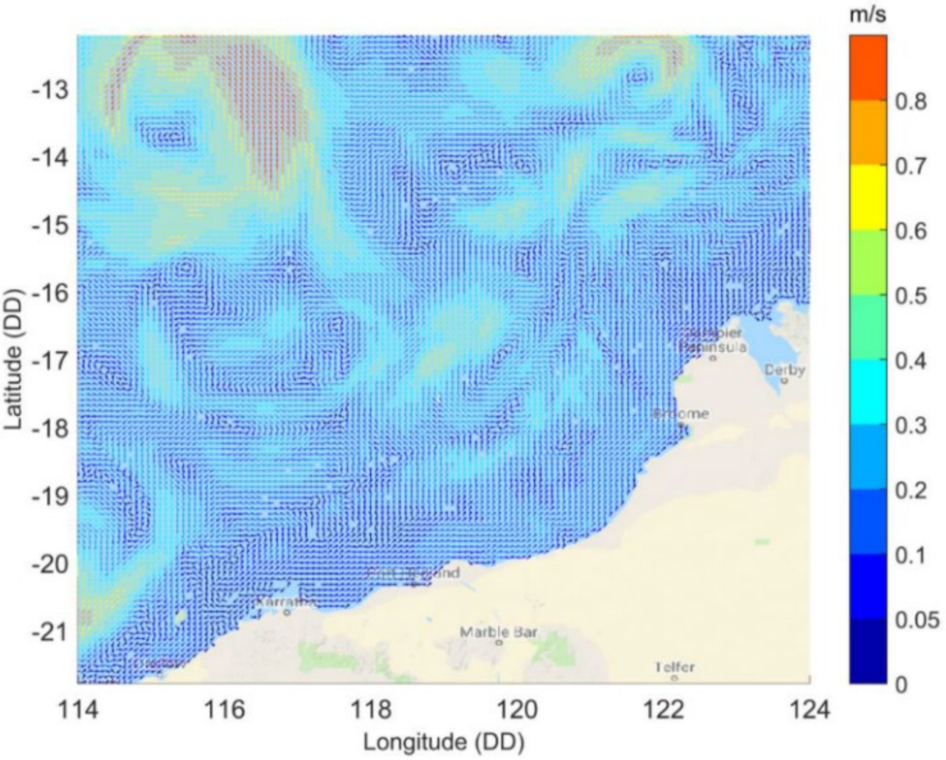


Figure 4-5 – Typical Ocean Current Circulation Pattern during Summer Months. Source: RPS (2019)

4.2.2.5 Salinity

Variation in surface salinity along the NWS throughout the year is minimal (between 35.2 and 35.7 PSU), with slight increases occurring during the summer months due to intense coastal evaporation (Pearce *et al.* 2003; James *et al.* 2004). This small increase in salinity during summer is then countered by the arrival of the lower salinity waters of the Leeuwin Current and Indonesian Throughflow in autumn and winter (James *et al.* 2004). This is also reflected in more recent publicly available data from the NOAA (2021b), where annual surface salinity levels are ~35 PSU.

4.2.2.6 Water Quality

Water quality in the NWMR is regulated by the ITF, a low-salinity water mass that plays a key role in initiating the Leeuwin Current (DSEWPaC 2012a). It brings warm, low-nutrient, low-salinity water from the western Pacific Ocean through the Indonesian archipelago to the Indian Ocean. It is the primary driver of the oceanographic and ecological processes in the region (DEWHA 2008a). South of the NWMR, the Leeuwin Current continues to bring warm, low-nutrient, low-salinity water further south. Eddies formed by the Leeuwin Current transport nutrients and plankton communities offshore (DEWHA 2008a). During summer, the Leeuwin Current typically weakens, and the Ningaloo Current develops, facilitating upwellings of cold, nutrient-rich waters up onto the NWS (DSEWPaC 2012a). Other areas of localised upwelling in the NWMR include the Wallaby Saddle and Exmouth Plateau, where these seabed topographical features force the surrounding deeper, cooler, nutrient-rich waters up into the photic zone (DSEWPaC 2012a).

Turbidity is primarily influenced by sediment transport by oceanic swells and primary productivity (Semeniuk *et al.* 1982; Pearce *et al.* 2003). Upwelling of nutrient-rich waters may increase phytoplankton productivity in the photic zone, which may increase local turbidity (Semeniuk *et al.* 1982; Wilson *et al.*, 2003). In nearshore areas, turbidity is highly variable due to storm run-off, wind generated waves and large tidal ranges (Pearce *et al.* 2003). Periodic events, such as major sediment transport associated with tropical cyclones, may influence turbidity on a regional scale (Brewer *et al.* 2007).

4.2.3 Bathymetry and Geomorphology

The Operational Area is located in waters approximately 65-170 m deep on the continental shelf. The bathymetry within the Operational Area is predominately characterised by relatively flat seabed. The water depth is approximately 65 m in the south-eastern corner of the Operational Area and increases to 150 m in the north-west corner of the Operational Area (Figure 4-6).

In the wider EMBA, the North West Shelf (NWS) Province encompasses more than 60% of the continental shelf in the NWMR (Baker *et al.* 2008), gradually sloping from the coastline to the shelf break at the edge of the region and includes water depths of 0–200 m. Approximately half the province is in water depths of 50–100 m (DEWHA 2008a). The NWS Province includes a number of sea floor features such as submerged banks and shoals, and valley features that are thought to be morphologically distinct from other features of these types in different regions of the NWMR (DEWHA 2008a) (Figure 4-7).

Several steps and terraces caused by Holocene sea level changes are present in the NWMR with the most prominent of these features occurring as an escarpment along the North West Shelf and Sahul Shelf at a depth of 125 m. This escarpment is related to an ancient sub-aerially exposed land surface and coastline (beach and dune deposits), known as the ancient coastline. The ancient coastline at the 125 m depth contour is designated as a Key Ecological Feature (KEF) and overlaps at the middle portion of the Operational Area (Section 4.4.3, Figure 4-16).

Previous movements in sea level have had a significant influence on the geology of the region of the Operational Area. Between 21,000 and 19,000 years ago the sea level was approximately 120 to 125 m lower than present day (Lewis *et al.* 2013). Therefore, the processes responsible for the formations present in the region include sub-aerial exposure of sediment and processes associated with land and coastal environments. Across the NWS region, the occurrence of an undulating cemented surface, expressed at the seabed as a series of ridges interspersed with sediment ponds infilling hollows and troughs, is related to an ancient sub-aerially exposed land surface and coastline (beach and dune deposits). Other coastal features including sand bars and river outlets are also present in this region, complicating the geology and geological sequence adjacent (seaward) to the area of ridges. A complex geological feature in close proximity to the Operational Area and located within the EMBA is the Rowley Shoals, which contains the Mermaid Reef KEF (Section 4.4.3, Figure 4-7).

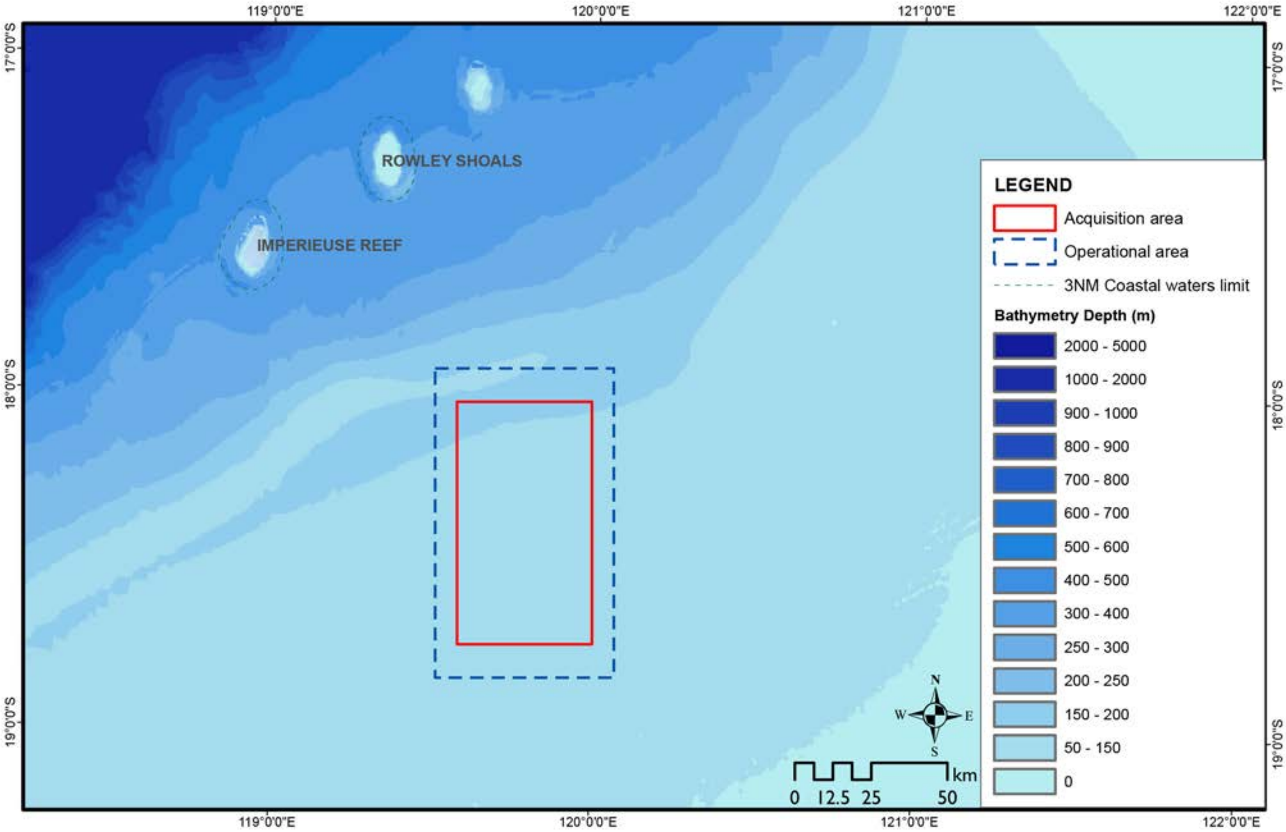


Figure 4-6 – Bathymetry within the Operational Area and Surrounds

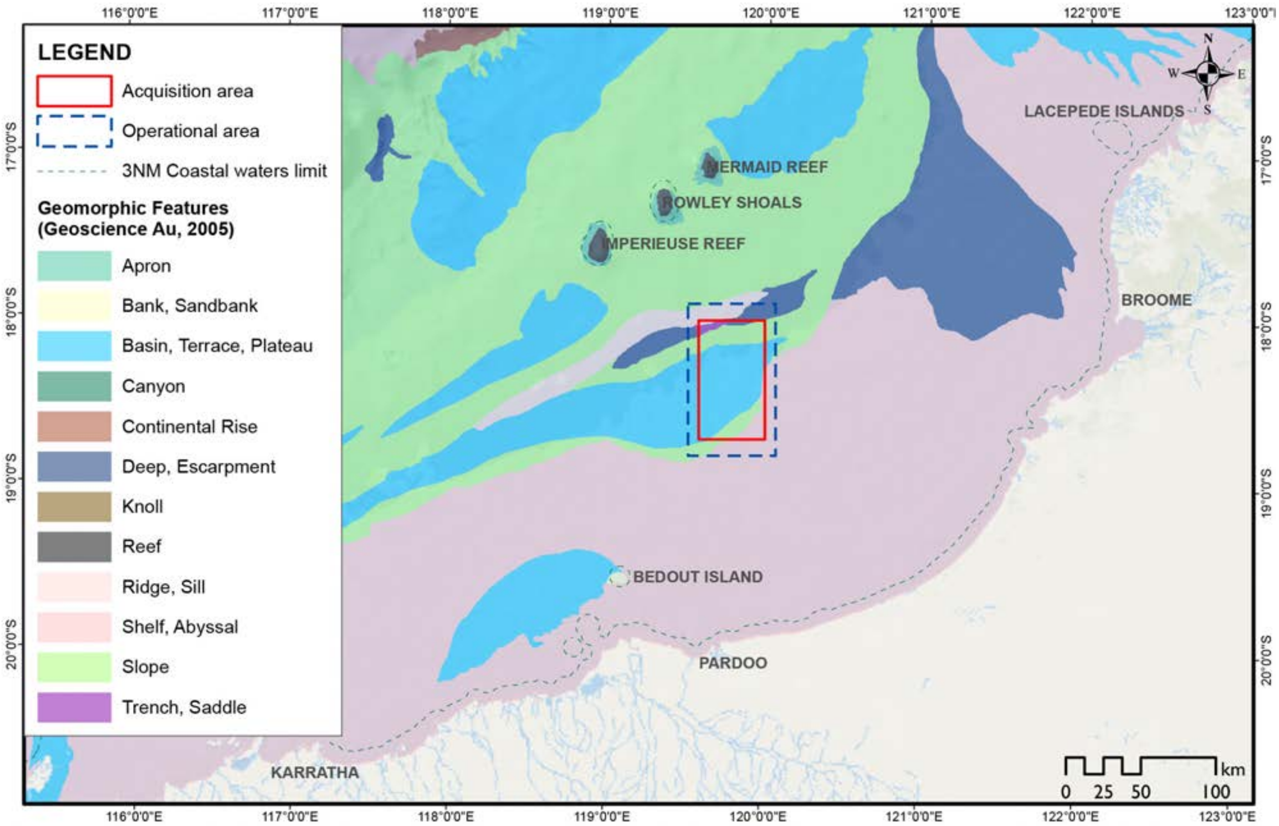


Figure 4-7 – Geomorphic Features of the North West Shelf

4.2.4 Sedimentology

Sediment differentiation in the North West Shelf Province occurs on a north–south gradient and is thought to differ from the rest of the NWMR (DEWHA 2008a). Sediment in the region is broadly characterised by calcareous gravel, sand and silt (CSIRO 2015). South of Broome, sediment is relatively homogenous and dominated by sand, typically only containing a small amount of gravel. Sediment becomes highly variable north of Broome, with sand being dominant in some areas and gravel dominant in others (DEWHA 2008a). Within 100 km of the coast and 100 km of the shelf break, there is the slight presence of mud in the sediment. Sediments within the Operational Area are expected to be relatively homogenous and dominated by calcareous gravel, sand and silt (DEWHA 2008a; CSIRO 2015).

4.3 Biological Environment

4.3.1 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 being 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.

Spatial distribution of phytoplankton and zooplankton is irregular, both vertically and horizontally and temporally. Sporadic/short-lived and potentially localised episodes of nutrient upwelling can occur as a result of internal waves (the rising and sinking of sea water layers of different densities) at the shelf break, wind-driven currents, or cyclonic activity, which influence higher plankton concentrations.

Plankton within the Operational Area are expected to reflect the conditions of the wider upper continental slope. Surface waters of the NWS have low nutrient availability, with phytoplankton occurring in higher concentrations near areas where upwelling of deeper, nutrient-rich water occurs (Thomson 2015). The most common plankton in the offshore waters of the NWS are diatoms, single-cell algae with cell walls made of silica. Recent sampling by the UWA Oceans Institute (Thomson 2015) across the NWMR found that large summer blooms of diatoms occur in Pilbara offshore waters west of Broome. These blooms occur at the junction of stratified cool and warm water mass at depths of at least 45 m. High concentration of diatoms (Chlorophyll concentration of 1.39–2.10 µg/l) were recorded to occur in an area between 40 and 120 km east of the Operational Area.

4.3.2 Benthic Habitats and Communities

The distribution of benthic communities in the NWMR depends on the water depth, the substrate and sediment characteristics and availability of food. The sediments within the Operational Area are expected to be broadly characterised by calcareous gravel, sand and silt. This type of substrate is known to support relatively little seabed structure or sessile epibenthos.

The Operational Area is expected to be sparsely covered by sessile filter-feeding organisms (e.g. gorgonians, sponges, ascidians and bryozoans) and mobile invertebrates such as echinoderms, prawns and detritus-feeding crabs (Brewer *et al.* 2007; DEWHA 2008a). Heyward *et al.* (1997) also noted that benthic macro-invertebrate infauna and epifauna such as worms, crustaceans, molluscs, gastropods, sea urchins, starfish, sea cucumbers, etc. typically occur in low numbers in water depths greater than 50 m in the NWMR. Macro-invertebrates that are present in these habitats comprise mainly polychaete worms, small crustaceans, amphipods and isopods such as shrimps and lice. Other invertebrates that may occur in these habitats include occasional sea cucumbers, sea urchins, molluscs, hydroids and sponges, and other worm species.

In the Keraudren MSS Operational Area the study collected 17 transects of towed video footage covering a total length of 21.9 km of seabed over a three-day period. The key findings of the study as presented within the Santos Keraudren Seismic Survey EP Summary, were as follows:

- Thirteen main habitat types were defined, representing flat and gently sloping seabeds comprising mainly sand/gravel and rock with sediment veneer.
- No 'potato habitat' (ascidians and sponges on hard substrate) was identified in the 17 transects.
- Variants of potential 'garden habitat' (containing hydroids, sponges, octocorals, soft corals, ascidians and crinoids) comprised approximately 50% of the area surveyed and the habitat where the two pearl oysters were found, comprised 16.4% of the area surveyed.

The epibenthos recorded in this depth range is summarised as follows:

- Common epibiota included sponges, hydroids, whip corals, soft corals, crinoids, echinoderms (starfish, basket stars and sea cucumbers), gorgonians and ascidians.
- Densities and growth forms of epibiota (e.g. hydroids and sponges) were often a characteristic of specific habitat types. For example, habitats characterised by low abundance, short, turf-like forms were often characterised by mobile sand habitats with patches/troughs of more consolidated gravel/rock prone indicating periodic inundation by sand waves.
- Most transects comprised several different habitat types with high abundance, diverse assemblages in patches interspersed by lower abundance/diversity sand or sandy gravel habitats.
- Most common substrate type was consolidated sandy gravel with shell fragments, which was stabilised by patchy, very low-lying hydroid/bryozoan turf (40–75% cover). Large epibiota was generally evenly distributed as shorter forms at relatively low abundance (5% cover) or occurred as denser patches of larger growth forms on consolidated gravel in depressions or troughs (up to 24% cover).
- Another common habitat observed was large sand waves (with gently sloping relief) and very low abundance of epibiota (1%) or no conspicuous epibiota.
- Of particular note was a mesophytic gorgonian forest with high densities of large epibiota on relatively flat emergent bedrock with sand/gravel veneer. Gorgonians were estimated at between 1 to 1.8 m high, with shorter colonies also present.

It is expected that the Sauropod 3D MSS Operational Area and wider EMBA would support similar epibenthos as those found in the Santos study due to shared bioregions and comparable benthic habitat, sediments, and geomorphic features. As there are no known banks, shoals or shallow areas within the Operational Area, the Operational Area is unlikely to support diverse benthic assemblages, such as hard and soft corals, gorgonians, encrusting sponges, seagrass and macroalgae.

There are a number of banks and shoals located within the EMBA that may support diverse benthic assemblages. These banks and shoals are discussed further below.

4.3.2.1 Rowley Shoals

The Rowley Shoals are located within the EMBA for the Sauropod 3D MSS and comprise three reef systems distanced 30–40 km apart. These are Clerke Reef, Imperieuse Reef and Mermaid Reef, located approximately 65, 60 and 80 km from the

Operational Area respectively. The marine reef fauna of the Rowley Shoals is considered to be exceptionally rich and diverse, including species typical of the oceanic coral reef communities of the Indo-West Pacific (DEC 2007).

The major habitats of the Rowley Shoals include intertidal and subtidal reefs that support a diverse range of benthic communities. Surveys carried out by the Western Australian Museum (WAM), identified 184 species of corals (primarily Indo-West Pacific species), 264 species of molluscs, 82 species of echinoderms and 389 species of finfish were also identified (DEC 2007).

Over 200 species of hermatypic (hard) corals have been recorded at the shoals over a range of depths (Veron 1986; Veron 1993; McKinney 2009). Sparse seagrass is found within the subtidal coral reef communities and although they are not a major habitat type, they are still an important component of these habitats (Berry 1986; Walker and Prince 1987). Invertebrate species (excluding corals) at the Rowley Shoals include sponges, cnidarians (jellyfish, anemones), worms, bryozoans (sea mosses), crustaceans (crabs, lobsters, etc.), molluscs (cuttlefish, baler shells, giant clams, etc.), echinoderms (starfish, sea urchins) and sea squirts (Veron 1986).

4.3.2.2 Ancient coastline at 125 m Depth Contour

The ancient coastline at 125 m depth contour is a series of several steps and terraces that form an escarpment along the NWS. The ancient coastline at 125 m depth contour is defined as a KEF as it is a unique sea floor feature with ecological properties of regional significance. The hard substrate may contribute to higher diversity and enhanced species richness relative to the soft sediment habitat, and may include sponges, crinoids, molluscs, echinoderms and other benthic invertebrates (DSEWPaC 2012). The topographic complexity of these escarpments may also provide a relatively nutrient-rich environment for sessile communities (DSEWPaC 2012). The ancient coastline at 125 m depth contour KEF is further described in Section 4.3.3 and Section 4.4.3.1.

4.3.3 Fish Assemblages

Fish communities in this region are diverse and are closely related to different depth ranges (DEWHA, 2008a). Fish species of the inner shelf include lizardfish, goatfish, trevally, angelfish and tuskfish. In waters with a depth between 100 m–200 m, goatfish, deep lizardfish, ponyfish, deep threadfin bream, adult trevally, billfish and tuna are usually present (DEWHA 2008a).

The Protected Matters Database search (Appendix B:) identified 31 pipefish species, six seahorse species, and three pipehorse species that may occur in the EMBA. Pipefish are a listed marine species, however, are not listed as threatened or migratory under the EPBC Act. The Species Group Report Card – bony fishes (DSEWPAC 2012b), which supplements and supports the NWMR bioregional plan, 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. The water depths of the Operational Area range from 65 m–170 m. Only seven species of the 40 syngnathids species identified as potentially occurring within the EMBA have been recorded in water depths greater than 65 m (DoEE 2019a; Bray and Thompson 2019; Austin and Pollom 2019; Froese and Pauly 2019). Therefore, the majority of the identified species are not expected to occur across the flat, soft substrates that predominate the Operational Area and EMBA.

4.3.3.1 Ancient coastline at the 125 m Depth Contour

The ancient coastline at the 125 m depth contour KEF is thought to provide areas of hard substrate that may contribute to higher biological diversity. Little published information is currently available, but the hard substrate may provide suitable habitat for a variety of demersal fish species, which may exhibit some level of site fidelity. The Operational Area partially overlaps with approximately 9% of the KEF.

Santos WA commissioned a study in 2018, to describe the fishes associated with the ancient coastline KEF within and adjacent to the Acquisition Area of the Keraudren Seismic Survey. The Keraudren Seismic Survey Acquisition Area is located approximately 20 km from the Sauropod Operational Area and shares similar environmental characteristics. The SBRUVS technique (stereo baited remote underwater video system) was utilised for the survey. The key findings of the study as presented within the Santos Keraudren Seismic Survey EP Summary, were as follows:

- A total of 638 fish from 48 species and 18 families
- A number of commercially important species were observed including red emperor (one individual), goldband snapper (35 individuals), and saddletail snapper (one individual)

- Four most ubiquitous species were threadfin bream (observed in 97% deployments), lunartail puffer (observed in 95% deployments), longnose trevally (observed in 76% deployments) and giant trevally (observed in 60% deployments)
- Four most abundant species were longnose trevally (153 individuals), threadfin bream (103 individuals), lunartail puffer (78 individuals) and goldband snapper (35 individuals)
- No consistent structurally complex seabed feature was evident that 'site-attached' fish would normally be associated with.

It is expected that the Sauropod Operational Area would support similar fish assemblages as those identified in the Santos study due to shared bioregions and comparable benthic habitat, sediments, and geomorphic features.

4.3.4 Commercially Targeted Fish Stocks

The NWMR provides fishing grounds for several commercial fisheries, which target a variety of demersal and pelagic fish species. The Department of Primary Industries and Regional Development (DPIRD) provided information on the spawning and distribution of fish species that are used to provide an indication of fish stocks targeted by fisheries relevant to the Operational Area. These species are known as key 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.

The three demersal indicator species for the Pilbara region are red emperor (*Lutjanus sebae*), rankin cod (*Epinephelus multinotatus*), and bluespotted emperor (*Lethrinus punctulatus*). The status of ruby snapper (*Etelis* sp) is also used as an indicator species for the offshore demersal scalefish resources targeted by the Pilbara Line Fishery (Newman *et al.* 2019). Goldband snapper (*Pristipomoides multidens*) is an indicator species for the Kimberley region (which has limited overlap with the Sauropod 3D MSS Operational Area) although the species also occurs throughout the Pilbara region and comprises a significant proportion of the commercial catch, therefore, it is considered in this EP. Spanish mackerel (*Scomberomorus commerson*) is the principal target species and single indicator species for the Mackerel Managed Fishery.

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 in both directions along the North West Shelf, 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.* 2009, 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).

Note that fish stocks may also be considered in terms of smaller, more discrete 'management units', which are adopted by fisheries management authorities for the purposes of fisheries management. The management units consider the genetic stock 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. This 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 (Figure 4-8), which also inform the FRDC (2019) stock assessments. The fishery management unit boundaries are the same as the Pilbara and Kimberley region fisheries. The location of the boundary for the two management units, which determines the break in spatial extent of the fisheries stock assessments, is an artificial construct, which reflects both a practical spatial division of the genetic stock and the historical development of the fisheries in the Pilbara and Kimberley regions (Gaughan *et al.* 2018). All WA-managed commercial fisheries in the North

Coast Fisheries Bioregion (Pilbara and Kimberley management units) are assessed as having sustainable stock levels (Gaughan *et al.* 2019).

Table 4-2 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. Figure 4-9 presents the principal spawning ranges of the key indicator fish species based on Pilbara fisheries management units and the principal water depths provided by DPIRD (2019c). Both the biological stock ranges and the fishery management units are discussed in the impact and risk assessments in Section 7.

Whilst the WA Pearl Oyster Fishery does not fish within the Operational Area (refer Section 4.4.4), habitat similar to that described for the target species silver-lipped pearl oyster (*Pinctada maxima)* broodstock may occur within the Operational Area and EMBA (DoF, 2016). Whilst aggregations of the silver-lipped pearl oyster are generally found in water depths of less than 40 m, two pearl oysters were found in a benthic study for the Santos Keraudren Seismic Survey in water depths of 40-60 m which is expected to be the limit of their depth range. The study area overlaps the extreme eastern portion of Sauropod Operational Area. Both individuals were observed growing vertically attached to consolidated rock substrates, with a relatively thick veneer of shelly/gravelly sand. Although it is expected that the Sauropod 3D MSS Operational Area and wider EMBA would support similar epibenthos as those found in the Santos study due to shared bioregions and comparable benthic habitat, sediments, and geomorphic features, a sparse distribution of silver-lipped pearl oyster broodstock is expected to occur within the area due to the water depths.

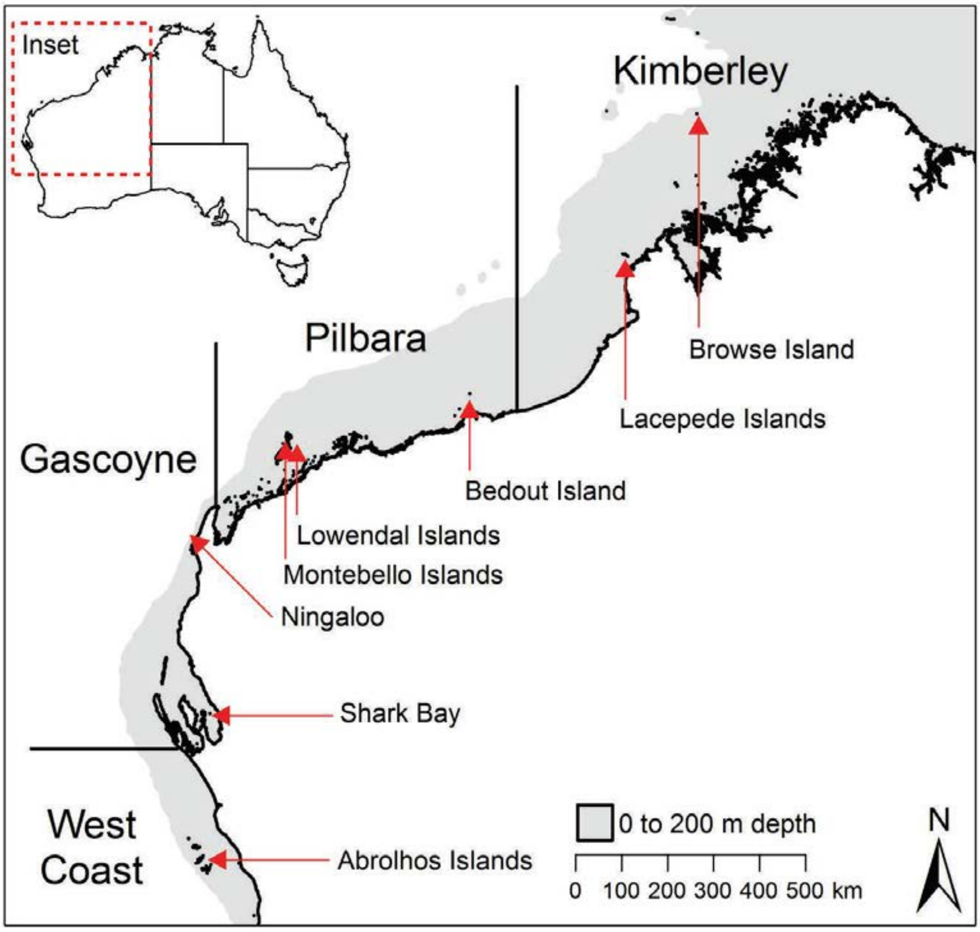


Figure 4-8 – Management units for the scalefish resources in northern WA (Gaughan *et al.* 2018). The North Coast Fisheries Bioregion comprises the Pilbara and Kimberley management units.

Table 4-2 – Key Indicator Fish Species of Commercial Fisheries Relevant to the Sauropod 3D MSS

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Spawning Season	Relevance to EP
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).	50-200 m (DPIRD 2019c).	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 2019c). 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). Stock status: Sustainable (Newman *et al.* 2019).	October – May (extended peak spawning period) (DPIRD 2019c).	Given the known distribution and habitat depths, Goldband snapper are likely to occur and may spawn within the Operational Area. The proposed acquisition window overlaps with five months of the Goldband snapper's eight month spawning period.
Rankin cod (*Epinephelus multinotatus*)	Rankin cod are a demersal species distributed in continental shelf waters throughout tropical and sub-tropical northern Australia, from Shark Bay in WA to the NT (Newman *et al.* 2018). They are generally found in warm coastal waters in association with drop-offs and deep rocky reefs. Juveniles are generally found in inshore coral reefs (Newman *et al.* 2008).	There is low genetic variation and extensive connectivity among populations over large distances (at least 1,400 km) (Gaughan *et al.* 2018). There is no evidence of discrete breeding populations of Rankin cod in Western Australia, indicating that there is a single biological stock between Shark Bay and the Kimberley (Gaughan *et al.* 2018; Newman *et al.* 2018)	10-150 m (DPIRD 2019c).	Rankin cod are highly fecund, serial, broadcast spawners that release eggs over a protracted spawning period (8-10 months of the year) and appear to spawn across much of the continental shelf of the Pilbara region (Gaughan *et al.* 2018). They spawn throughout their range (DPIRD 2019c). Juveniles generally occur inshore from the adults in deeper waters, indicating there may be some movement of juveniles offshore with increasing age (Newman *et al.* 2008). Fish are estimated to reach maturity after approximately 2 years (Newman *et al.* 2018). Stock status: Sustainable (Newman *et al.* 2019).	The species spawns for 8-10 months of the year in the Pilbara region (Gaughan *et al.* 2018). DPIRD (2019c) advise that the main spawning season is June – December and March (peaks August – October).	Given the known distribution and habitat depths, Rankin cod are likely to occur and may spawn within the Operational Area. The proposed acquisition window avoids the three month peak spawning period from August – October.
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).	10-180 m (DPIRD 2019c).	Red emperor are highly fecund, serial, broadcast spawners. Females release many batches of eggs over an extended spawning period. (Newman *et al.* 2008; Gaughan *et al.*2018). They spawn throughout their range (DPIRD 2019c). 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). Stock status: Sustainable (Newman *et al.* 2019).	The species spawns for 10-12 months of the year on the north coast of WA (Gaughan *et al.* 2018). DPIRD (2019c) advises 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. The proposed acquisition window overlaps with four months of the Red emperor's main 10 month spawning period, including one of the bimodal peaks.
Blue-spotted emperor (*Lethrinus punctulatus*)	The blue-spotted emperor are distributed primarily from around Geraldton and the Abrolhos Islands in WA to Darwin in the NT (Newman *et al.* 2018). Greatest abundances are noted in the western Pilbara region (Newman *et al.* 2018; Gaughan *et al.* 2018). The species is often found in association with shallow reef, sand and mud areas (Newman *et al.* 2008).	There is extensive connectivity among populations of Blue-spotted emperor over large distances, and there is considered to be a single biological stock in WA and potentially as far as the Northern Territory (Newman *et al.* 2018).	5-110 m (DPIRD 2019c).	Blue-spotted emperor are highly fecund, serial, broadcast spawners that release eggs over a protracted spawning period (11 months of the year) (Gaughan *et al.* 2018). They spawn throughout their range (DPIRD 2019c). Fish are estimated to reach maturity after approximately 18 months (Newman *et al.* 2018; Gaughan *et al.* 2018). Stock status: Sustainable (Newman *et al.* 2019).	The species spawns for 11 months of the year (Gaughan *et al.* 2018). DPIRD (2019c) advises that the main spawning season is July – March (extended peak spawning period).	Given the known distribution and habitat depths, Blue-spotted emperor are likely to occur and may spawn within the Operational Area. However, the water depths at which the species occurs is largely outside the water depths of the Operational Area and so overlap is limited (refer to Figure 4-9). The proposed acquisition window overlaps with three months of the Blue-spotted emperor's nine month spawning period.

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Spawning Season	Relevance to EP
Giant ruby snapper (*Etelis* carbunculus)	Ruby snapper occur across the Indo-West pacific region. In Australia, ruby snapper are recorded from Geraldton, WA to north-eastern Queensland (Australian Museum 2019; Bray 2020).	The extent of the biological stock of Ruby snapper is uncertain.	150 -480 m (DPIRD 2019c).	Ruby snapper spawn throughout their range (DPIRD 2019c). Like other snappers, they are understood to be highly fecund, serial, broadcast spawners (Newman *et al.* 2008). Stock status: Sustainable (Newman *et al.* 2019).	December-April (peak spawning period January-March) (DPIRD 2019c).	Ruby snapper are likely to occur and may spawn within the Operational Area. However, the water depths at which the species occurs are largely outside the water depths of the Operational Area and so overlap is limited (refer to Figure 4-9). The proposed acquisition window overlaps with the Ruby snapper's spawning period.
Other demersal species (non-indicator species)	Variable (DPIRD 2019c).	Variable (DPIRD 2019c).	Variable (DPIRD 2019c).	Spawn throughout their range (DPIRD 2019c). Stock status: Sustainable (Newman *et al.* 2019). The proposed acquisition window overlaps with the likely spawning periods of these species.	Most likely to exhibit a peak spawning period from October-May (DPIRD 2019c).	Other demersal fish species may spawn in the Operational Area.
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 up to 100 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).	1 – 50 m (DPIRD 2019c).	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 approximately 2 years (Langstreth *et al.* 2018). Stock status: Sustainable (Lewis and Brand-Gardner 2019).	September – December (peak spawning) (DPIRD 2019c).	Given the known distribution and habitat depths, the species may occur in the Operational Area but is highly unlikely to spawn in the Operational Area (refer to Figure 4-9). The proposed acquisition window does not overlap with the Spanish mackerel's four month spawning period.
Silver-lipped pearl oyster (*Pinctada maxima*)	Pearl oysters are a benthic species that are widely distributed throughout the Indo-West Pacific Region. In Western Australia they are found northward from Shark Bay, however the majority of the population occurs in the North-West Cape adjacent to Eighty Mile Beach (DoF 2016).	Pearl oysters in Western Australia are fished in four distinct zones from Exmouth to Kununurra.	Generally pearl oysters occur in water depths of 8-40 m (DoF 2016), however there is evidence to suggest they can occur in depths up to 60 m (Santos Keraudren Extension 3D MSS 2020 report).	Males mature at 3-4 years of age at 100-120 mm, and about half have changed to female by the time they reach 170 mm. Females are highly fecund, producing millions of eggs, however less than 1% of those fertilised survive the free-living larval stages (DoF, 2016). Stock status: Sustainable (FRDC 2020)	Synchronous spawning generally occurs from September to May each year, however the primary spawning period occurs in October-December (DoF 2016).	Pearl oysters are likely to occur within the Operational Area, however in depths greater than 40 m they are likely to occur in very low abundance. The proposed acquisition window overlaps five months of the pearl oysters nine month extended spawning period.

Figure 4-9 – Principal Spawning Ranges for Key Indicator Fish Species

4.3.5 Threatened and Migratory Species

The EPBC Act Protected Matters Search Tool (PMST) was used to identify listed species under the EPBC Act that may occur within the Operational Area and EMBA (report in Appendix B:). The results of the search inform the assessment of planned events in Section 7 as well as unplanned events in Section 8. 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.

A total of 34 EPBC Act listed species were identified as potentially occurring within the Operational Area. Of those listed, 16 are considered threatened marine species and all 34 are migratory species under the EPBC Act (Table 4-3).

An additional 11 EPBC Act listed species were identified as potentially occurring within the wider EMBA. Of those 11 additional species, three are considered threatened marine species and eight are migratory species under the EPBC Act (Table 4-3).

Three migratory terrestrial species were identified in the EPBC search as occurring within the EMBA, including the barn swallow (*Hirundo rustica*), grey wagtail (*Motacilla cinerea*) and yellow wagtail (*M. flava*). These have been excluded from further assessment due to lack of a credible impact scenario.

The full list of species identified from the PMST is provided in the EPBC Act PMST report (Appendix B:).

Table 4-3 – Threatened and Migratory Marine Species Listed Potentially Occurring within the Operational Area and EMBA

Scientific Name	Common Name	Threatened	Migratory	Relevance to EP	
				Operational Area	EMBA
Marine Mammals					
Balaenoptera borealis	Sei whale	Vulnerable	✓	✓	X
Balaenoptera musculus	Blue whale	Endangered	✓	✓	X
Balaenoptera physalus	Fin whale	Vulnerable	✓	✓	X
Megaptera novaeangliae	Humpback whale	Vulnerable	✓	✓	X
Balaenoptera edeni	Bryde’s whale	N/A	✓	✓	X
Orcinus orca	Killer whale	N/A	✓	✓	X
Physeter macrocephalus	Sperm whale	N/A	✓	✓	X
Tursiops aduncus	Spotted bottlenose dolphin (Arafura/Timor Sea populations)	N/A	✓	✓	X
Dugong dugon	Dugong	N/A	✓	✓	✓
Sousa chinensis	Indo-Pacific Humpback Dolphin	N/A	✓	✓	✓
Marine Reptiles					
Caretta caretta	Loggerhead turtle	Endangered	✓	✓	X
Chelonia mydas	Green turtle	Vulnerable	✓	✓	X
Dermochelys coriacea	Leatherback turtle	Endangered	✓	✓	X
Eretmochelys imbricata	Hawksbill turtle	Vulnerable	✓	✓	X
Natator depressus	Flatback turtle	Vulnerable	✓	✓	X
Aipysurus apraefrontalis	Short-nosed sea snake	Critically Endangered	X	✓	✓
Sharks and Rays					
Anoxypristis cuspidata	Narrow sawfish	N/A	✓	✓	X
Carcharodon carcharias	Great white shark	Vulnerable	✓	✓	X
Isurus oxyrinchus	Shortfin mako shark	N/A	✓	✓	X
Manta alfredi	Reef manta ray	N/A	✓	✓	X
Manta birostris	Giant manta ray	N/A	✓	✓	X
Pristis pristis	Freshwater sawfish	Vulnerable	✓	✓	X
Pristis zijsron	Green sawfish	Vulnerable	✓	✓	X
Rhincodon typus	Whale shark	Vulnerable	✓	✓	X
Carcharhinus longimanus	Oceanic whitetip shark	N/A	✓	✓	X
Isurus paucus	Longfin mako	N/A	✓	✓	✓
Pristis clavata	Dwarf sawfish	Vulnerable	X	✓	✓
Avifauna					
Numenius madagascariensis	Eastern curlew	Critically Endangered	✓	✓	X
Calidris canutus	Red knot	Endangered	✓	✓	X
Papasula abboti	Abbott’s booby	Endangered	X	✓	X
Fregata minor	Great frigatebird	N/A	✓	✓	X

Scientific Name	Common Name	Threatened	Migratory	Relevance to EP	
				Operational Area	EMBA
Actitis hypoleucos	Common sandpiper	N/A	✓	✓	X
Anous stolidus	Common noddy	N/A	✓	✓	X
Calidris acuminata	Sharp-tailed sandpiper	N/A	✓	✓	X
Calidris melanotos	Pectoral sandpiper	N/A	✓	✓	X
Calonectris leucomelas	Streaked shearwater	N/A	✓	✓	X
Fregata ariel	Lesser frigatebird	N/A	✓	✓	X
Pandion haliaetus	Osprey	N/A	✓	✓	X
Phaethon lepturus	White-tailed tropicbird	N/A	✓	✓	X
Calidris ferruginea	Curlew sandpiper	Critically Endangered	✓	✓	✓
Phaethon rubricauda	Red-tailed tropicbird	N/A	✓	✓	✓
Sternula albifrons	Little tern	N/A	✓	✓	✓
Sula leucogaster	Brown booby	N/A	✓	✓	✓
Sterna bengalensis	Lesser crested tern	N/A	✓	✓	✓
Sterna dougallii	Roseate tern	N/A	✓	✓	✓

4.3.5.1 Listed Threatened Species Recovery Plans and Conservation Advices

Species Recovery Plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities (DoEE, n.d.). Recovery plans are enacted under the EPBC Act and remain in force until the species is removed from the threatened list. Conservation advice provides guidance on immediate recovery and threat abatement activities that can be undertaken to ensure the conservation of a listed species or ecological community (DoEE, n.d.).

Table 4-4 lists the applicable recovery plans and/or conservation advice for EPBC Act-listed species within the Operational Area and EMBA, as identified by the PMST search. Any relevant requirements applicable to the activity will be considered as part of the Environmental Risk Assessment (Section 7 and Section 8).

Table 4-4 – Recovery Plans and Conservation Advice for EPBC Act-Listed Species Occurring Within the Operational Area and EMBA

Species	Recovery Plan / Conservation Advice	Key Threats Identified in the Plan/ Advice	Actions Relevant to the Sauropod 3D MSS	Environmental Risk Assessment Section
All vertebrate fauna	Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans (DoEE, 2018).	Marine-based sources of debris.	Contribute to long-term prevention of marine debris, through waste management and resource recovery. Limit the amount of single use plastic material lost to the environment in Australia.	Section 8.7
Mammals				
Sei whale	Conservation advice *Balaenoptera borealis* Sei whale (TSSC, 2015a).	Anthropogenic noise and acoustic disturbance. Vessel strike.	Assessing and addressing anthropogenic noise. Minimising vessel collisions.	Section 7.1, Section 7.2 Section 8.5
Blue whale	Conservation management plan for the Blue whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2015-2025 (DoEE, 2015a).	Noise interference. Vessel disturbance.	Assessing and addressing anthropogenic noise. Minimising vessel collisions.	Section 7.1, Section 7.2 Section 8.5
Fin whale	Conservation advice *Balaenoptera physalus* Fin whale (TSSC, 2015b).	Anthropogenic noise and acoustic disturbance. Vessel strike.	Assessing and addressing anthropogenic noise. Minimising vessel collisions.	Section 7.1, Section 7.2 Section 8.5
Humpback whale	Approved Conservation Advice for *Megaptera novaeangliae* (Humpback whale) (TSSC, 2015c).	Noise Interference (including seismic surveys). Vessel disturbance and strike.	Assessing and addressing anthropogenic noise. Minimising vessel collisions.	Section 7.1, Section 7.2 Section 8.5
Reptiles				
Loggerhead turtle	Recovery plan for marine turtles in Australia (DoEE, 2017)	Threats to the WA stock include: Light pollution. Vessel disturbance (strike) – rated as 'almost certain' likelihood of occurrence, minor consequence. Noise interference (acute) – rated as a 'likely' likelihood of occurrence, minor consequence. An "almost certain" rating means the event is expected to occur every year. A "minor" rating means that individuals are affected, but there is no effect at stock level.	Minimise light pollution No specific actions for vessel disturbance are identified by the plan. The Australian Government has developed a National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2017) to provide guidance on reducing the risk of vessel collisions and the impacts they may have on marine fauna. A precautionary approach to acute noise exposure should be applied to seismic surveys.	Section 7.7 Section 8.5 Section 7.1, Section 7.2
Hawksbill turtle	Recovery plan for marine turtles in Australia (DoEE, 2017)	Threats to the WA stock include: Light pollution. Vessel disturbance – rated as 'almost certain' likelihood of occurrence, minor consequence. Noise interference (acute) – rated as a 'possible' likelihood of occurrence, minor consequence.	Minimise light pollution No specific actions for vessel disturbance are identified by the plan. The Australian Government has developed a National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2017) to provide guidance on reducing the risk of vessel collisions and the impacts they may have on marine fauna. A precautionary approach to acute noise exposure should be applied to seismic surveys.	Section 7.7 Section 8.5 Section 7.1, Section 7.2
Green turtle	Recovery plan for marine turtles in Australia (DoEE, 2017)	Threats to the WA stock include: Light pollution. Vessel disturbance (strike) – rated as a 'likely'* likelihood of occurrence, minor consequence. Noise interference (acute and chronic) – rated as 'unknown' likelihood of occurrence, minor consequence. *A "likely" rating means the event is expected to occur at least once every five years.	Minimise light pollution No specific actions for vessel disturbance are identified by the plan. The Australian Government has developed a National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2017) to provide guidance on reducing the risk of vessel collisions and the impacts they may have on marine fauna. A precautionary approach to acute noise exposure should be applied to seismic surveys.	Section 7.7 Section 8.5 Section 7.1, Section 7.2
Flatback turtle	Recovery plan for marine turtles in Australia (DoEE 2017)	Threats to the Pilbara stock include: Light pollution. Vessel disturbance (strike) – rated as an 'almost certain' likelihood of occurrence, minor consequence.	Minimise light pollution No specific actions for vessel disturbance are identified by the plan. The Australian Government has developed a National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2017) to provide guidance on	Section 7.7 Section 8.5 Section 7.1, Section 7.2, 7.2

Species	Recovery Plan / Conservation Advice	Key Threats Identified in the Plan/ Advice	Actions Relevant to the Sauropod 3D MSS	Environmental Risk Assessment Section
		Noise interference (acute) – rated as a ‘likely’ likelihood of occurrence, minor consequence.	reducing the risk of vessel collisions and the impacts they may have on marine fauna. A precautionary approach to acute noise exposure should be applied to seismic surveys.	
Olive ridley turtle	Recovery plan for marine turtles in Australia (DoEE 2017)	Threats to the North-Western Cape York stock include: Light pollution. Vessel disturbance – rated as a ‘possible’ likelihood of occurrence, minor consequence. Noise interference (acute) – rated as an ‘unlikely’ likelihood of occurrence, no long-term effect.	Minimise light pollution No specific actions for vessel disturbance are identified by the plan. The Australian Government has developed a National Strategy for Mitigating Vessel Strike of Marine Mega-fauna (2017) to provide guidance on reducing the risk of vessel collisions and the impacts they may have on marine fauna. A precautionary approach to acute noise exposure should be applied to seismic surveys.	Section 7.7 Section 8.5 Section 7.1, Section 7.2
Leatherback turtle	Recovery plan for marine turtles in Australia (DoEE 2017) Approved conservation advice for *Dermochelys coriacea* (Leatherback turtle) (DEWHA 2008b)	Vessel disturbance	Minimising vessel collisions.	Section 8.5
Short-nosed sea snake	Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed sea snake) (DSEWPaC 2011)	No threats identified that are applicable to this EP.	N/A	N/A
Sharks and rays				
Great white shark	Recovery plan for the Great white shark (*Carcharodon carcharias*) (DSEWPaC 2013)	No threats identified that are applicable to this EP.	N/A	N/A
Dwarf sawfish	Approved conservation advice for *Pristis lavate* (Dwarf sawfish) (TSSC 2009) Sawfish and river shark multispecies recovery plan (DoE 2015b)	No threats identified that are applicable to this EP. No threats identified that are applicable to this EP.	N/A	N/A
Green sawfish	Approved Conservation Advice for Green sawfish (TSSC 2008) Sawfish and river shark multispecies recovery plan (DoE 2015b)	No threats identified that are applicable to this EP. No threats identified that are applicable to this EP.	N/A	N/A
Whale shark	Conservation advice *Rhincodon typus* Whale shark (TSSC 2015d)	Vessel disturbance	Minimising vessel collisions.	Section 8.5
Grey nurse shark	Recovery Plan for the Grey nurse shark (*Carcharias taurus*) (DoE, 2014)	No threats identified that are applicable to this EP.	N/A	N/A
Seabirds				
Red knot	Conservation advice *Calidris canutus* red knot (TSSC 2016)	Habitat degradation (oil pollution). Human disturbance (general).	Manage disturbance at important sites when Red knots are present.	Section 7.1, Section 7.2, Section 7.7, Section 8.5
Curlew sandpiper	Conservation advice *Calidris ferruginea* curlew sandpiper (DoE 2015c)	Habitat degradation (oil pollution). Human disturbance (general).	Manage disturbance at important sites when Curlew sandpipers are present.	Section 7.1, Section 7.2, Section 7.7, Section 8.5
Eastern curlew	Conservation advice *Numenius madagascariensis* eastern curlew (DoE 2015d)	Habitat degradation (oil pollution). Human disturbance (general).	Manage disturbance at important sites when Eastern curlews are present.	Section 7.1, Section 7.2, Section 7.7, Section 8.5
Common sandpiper, Red knot,Ppectoral sandpiper, Sharp-tailed sandpiper	Wildlife conservation plan for migratory shorebirds (Commonwealth of Australia 2015)	Habitat degradation (oil pollution).	Ensure all areas important to migratory shorebirds in Australia continue to be considered in development assessment processes.	Section 7.1, Section 7.2, Section 7.7, Section 8.5
Abbott’s booby	Conservation Advice *Papasula abbotti* Abbott’s booby (TSSC 2020)	No threats identified that are applicable to this EP.	N/A	N/A

4.3.5.2 Biologically Important Areas

Biologically Important Areas (BIAs) are regions where a particular species is known or likely to display important behaviours such as breeding, foraging, nesting or migration (DoEE n.d.). BIAs have no legal status; however they provide information to help inform regulatory and management decisions. Table 4-5 identifies the BIAs associated with threatened and migratory species potentially occurring within the Operational Area and wider EMBA, as identified during the PMST search (Appendix B:). Further information on BIAs is provided in the individual species descriptions below (Section 4.3.6 and Section 4.3.9).

Table 4-5 – Threatened and Migratory Species' BIAs within the Operational Area and EMBA

Species	BIA	Location	Distance from Operational Area
Humpback whale	Migration	North-west WA coast	15 km
Pygmy blue whale	Distribution	South and west Australia waters	Overlaps
	Migration	WA waters	72 km
Whale shark	Foraging	NWS 200 m isobath	Overlaps
Flatback turtle	Internesting	Eighty Mile Beach	20 km
	Internesting*	Eighty Mile Beach	60 km
Lesser frigatebird	Foraging	Bedout Island	Overlaps
	Breeding and foraging	Bedout Island	40 km
White-tailed tropicbird	Breeding and foraging	North-West and Rowley Shoals	Overlaps
Little tern	Resting	Rowley Shoals	23 km
Brown booby	Breeding	Pilbara coast	40 km

* Habitat critical to the survival of a marine turtle species (DoEE 2017).

4.3.6 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 27 marine mammal species known to occur regularly in the NWMR, including 16 whale species and at least 11 species of dolphin (DEWHA 2008a).

Four threatened and migratory and six migratory marine mammal species were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the EMBA.

Cetacean species, such as the Pygmy blue whale and Humpback whale, are known to transit between Southern Ocean feeding grounds and tropical water breeding grounds. However, some cetacean species (e.g. spotted bottlenose dolphin) are thought to be resident in the region throughout the year (DEWHA 2008a).

Dugongs are also present in the region, preferring shallow waters along the coast and around shoals where seagrass habitats are available (DEWHA 2008a). The Operational Area is highly unlikely to support Dugong populations, due to the open ocean location, water depths and lack of suitable habitat.

A description of the identified threatened and/or migratory marine mammals is provided in Table 4-6 including their distribution, migratory movements, preferred habitat and likely presence within the Operational Area and EMBA.

Two species have biologically important areas within the Operational Area and wider EMBA, as follows:

- The Humpback whale migration, breeding and calving BIAs extend along the length of the coast of WA, to its northernmost extent offshore of the Kimberley region. The migration BIA is located approximately 15 km south of the Operational Area. The breeding, nursing and calving BIA is located 255 km east of the Operational Area and outside the wider EMBA (Figure 4-10).
- Pygmy blue whale migration and distribution BIAs pass along the shelf edge at depths between 500 m and 1,000 m. The Operational Area overlaps with the distribution BIA; however the migration BIA is located 72 km to the north of the Operational Area (Figure 4-11).

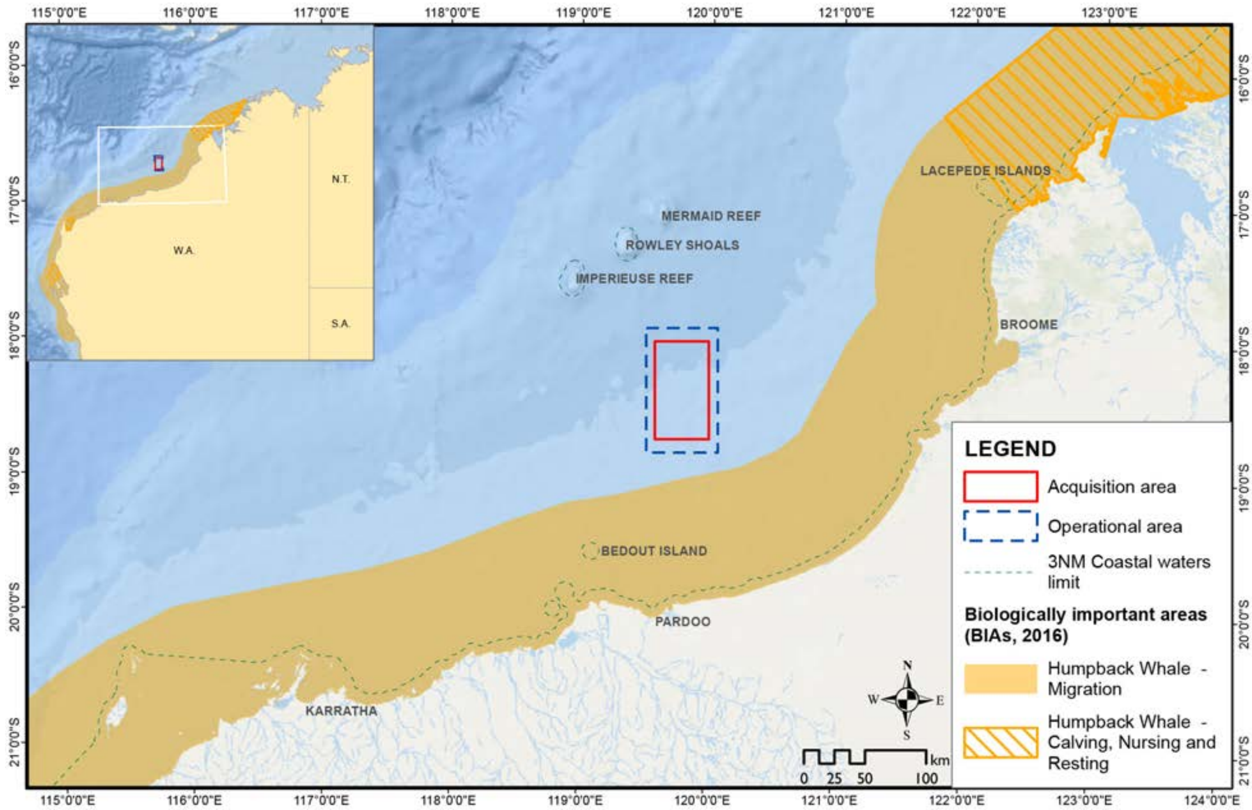


Figure 4-10 – Humpback Whale BIAs

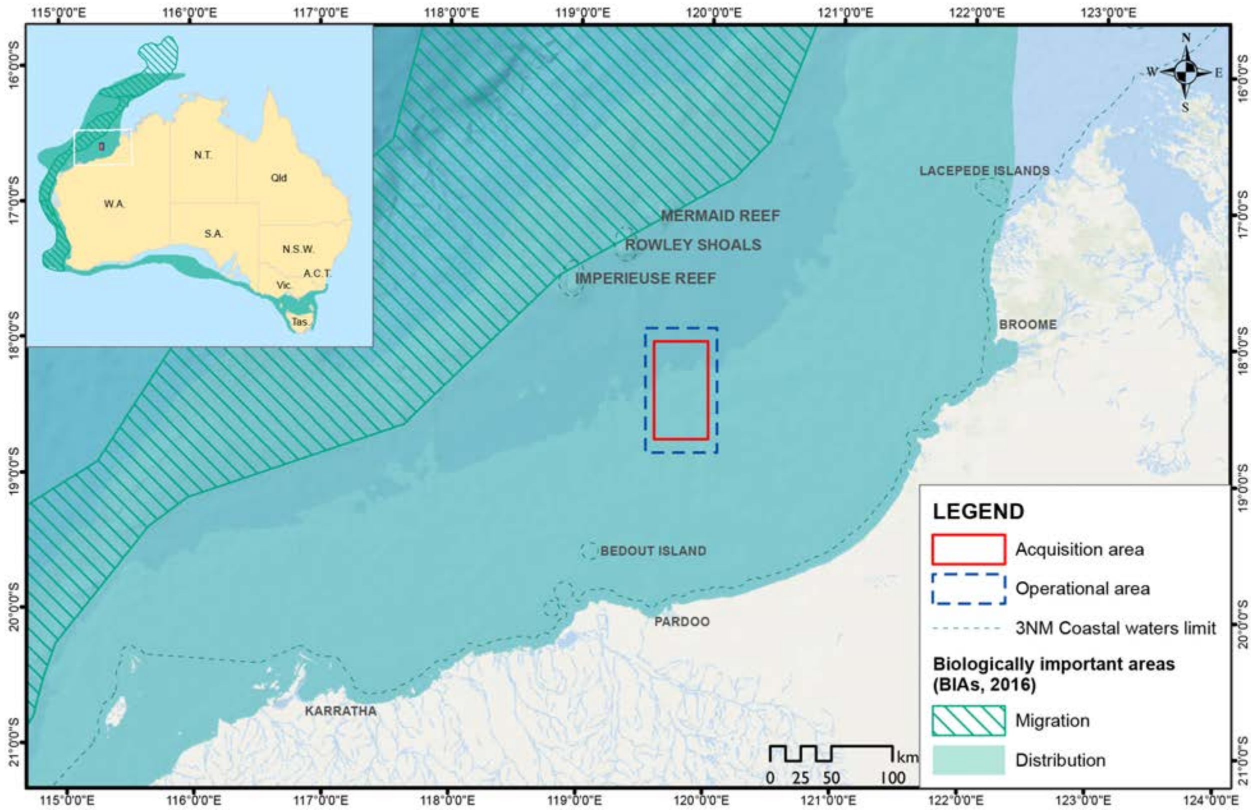


Figure 4-11 – Pygmy Blue Whale BIAs

Table 4-6 – Threatened and Migratory Mammals Potentially Occurring Within the Operational Area and EMBA

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Mammals Potentially Occurring Within the Operational Area			
Blue whale	Two subspecies of blue whale are found in the southern hemisphere: the Pygmy blue whale (*Balaenoptera musculus brevicauda*) and the Antarctic blue whale (*B. m. intermedia*). During the southern hemisphere summer, Antarctic blue whales are usually found south of 60ºS, while Pygmy blue whales are usually found north of 55ºS (DoEE 2019). Therefore, Antarctic blue whales are highly unlikely to be present within or nearby the Operational Area. The Pygmy blue whale has a worldwide oceanic distribution and are regularly sighted in Australian waters. Whilst the species prefer deep waters, whale sightings in Australia are usually related to migration purposes or opportunistic feeding. The Pygmy blue whale has BIAs for migration, foraging and distribution along the WA coastline. The Operational Area overlaps with the distribution BIA, and the wider EMBA overlaps with the migration BIA. Satellite tracking of Pygmy blue whales undergoing their northern migration indicates whales generally follow known migration paths, transiting north of the Rowley Shoals (Double *et al.* 2012, 2014).	The annual northbound migration past Exmouth and north-western Australia has been detected between April and August, with the return southbound migration from October to the end of December, peaking in November and early December (McCauley and Jenner 2010; McCauley and Duncan 2011; Double *et al.* 2012; Double *et al.* 2014).	The Operational Area is located within the Pygmy blue whale distribution BIA. However, due to the species' migration BIA being located approximately 72 km north of the Operational Area and absence of known foraging, resting and calving habitat, presence within the Operational Area EMBA is likely to be infrequent and consist of transitory individuals during migration months. Individuals may be present in the northern region of the wider EMBA during seasonal migrations. Acquisition of the survey may overlap the commencement of the northbound migration (April-August), but avoids the southbound migration period for Pygmy blue whales in the region (October to December).
Humpback whale	Humpback whales occur globally and throughout Australian waters with their distribution being influenced by migratory pathways and aggregation areas for resting, breeding and calving (DoEE 2019). There are two genetically distinct populations of Humpback whales in Australia (i.e. west coast and east coast) (DoEE 2019). Major breeding areas have been identified for the western Australian population in the Kimberley region and in particularly between Lacepede Islands and Camden Sound (Jenner *et al.* 2001). Camden Sound is the northern most limit for the majority of west coast whales and is considered to be an important breeding area (Jenner *et al.* 2001). The west coast population of the Humpback whale is thought to be increasing in size by about 9% per year (DoEE 2019); estimates conducted suggest that in 2008 the population migrating up the WA coast was at 21,750 individuals (Hedley *et al.* 2011). Humpback whale songs change in composition among age groups, but most energy is consistently between 200 – 500 Hz (Salgado Kent *et al.* 2012).	Humpback whales undergo an annual migration from the summer feeding grounds in Antarctica to the breeding and calving grounds in Camden Sound (approximately 540 km from the Operational Area) occurs between late May/June and October (DoEE 2019). During migration, individuals travel alone or in temporary aggregations of generally non-related individuals. The numbers of Humpback whales at Camden Sound peak between June and September each year (DoEE 2019). The migration corridor tends to be within the 200 m isobath (Jenner *et al.* 2001). Individuals are likely to be present in the southern region of the wider EMBA during seasonal migrations.	The Operational Area is located 15 km north of the migration BIA, with breeding known to occur within the area. However, due to the species' breeding and calving BIA being located approximately 250 km north-east of the Operational Area, the presence of the species within the Operational Area is likely to be infrequent and consist of transitory individuals.
Bryde's whale	Bryde's whales are distributed throughout oceanic and inshore, tropical and warm temperate waters, between 40˚N and 40˚S year-round. They have been recorded off all states of Australia, with the exception of the Northern Territory (DoEE 2019). The inshore form of the Bryde's whale is typically limited to the 200 m depth contour and breeds and 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). The nearest known area of aggregation is Ningaloo Reef (over 740 km away) (DoEE 2019). Aerial surveys carried out in 2009, between mainland Australia and Scott Reef (approximately 465 km north-east of the Operational Area) recorded Bryde's whales in low numbers (RPS 2010). Between September 2006 and June 2009 sea noise loggers deployed within Scott Reef also recorded Bryde's whales' calls year-round (McCauley 2011; RPS 2010). No specific feeding or breeding grounds have been discovered off Australia.	Inshore coastal forms appear to breed and give birth throughout the year, while the offshore form appears to have a protracted breeding and calving season over several months during winter. There is currently no evidence of large-scale movements of the inshore form of the Bryde's whale. However, the offshore form may migrate seasonally, heading towards warmer tropical waters during the winter months. It should be noted that there is limited data on migration, mating, breeding and calving patterns for Bryde's whales.	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 740 km away), the presence of the species within the Operational Area and wider EMBA is likely to be infrequent.
Fin whale	Fin whales occur from polar to tropical waters, but rarely in inshore waters (DoEE 2019). Fin whales are widely distributed in both hemispheres between latitudes 20–75° S (Mackintosh 1966). This species is common in temperate waters, the Arctic Ocean and Southern Ocean. Fin whales feed intensively in high latitudes and may feed to some extent, depending upon prey availability and locality, in lower latitudes. Fin whales feed on planktonic crustacea, some fish and cephalopods (crustaceans). Fin whales are killed by ship strike more than any other whale, which may be due to surface feeding (DoEE 2019). The Australian Antarctic waters are important feeding grounds for Fin whales. Sightings of Fin whales feeding in the Bonney Upwelling area indicate that this area is also a potentially important feeding ground. There is no known mating or calving areas for Fin whales in Australian waters.	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 2019).	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 wider EMBA is likely to be limited.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Sei whale	Sei whales are considered a cosmopolitan species, ranging from polar to tropical waters, but tend to be found more offshore than other species of large whales. They show well defined migratory movements between polar, temperate and tropical waters (Mackintosh 1965). Migratory movements are essentially north–south with little longitudinal dispersion. Sei whales have been infrequently recorded in Australian waters (Bannister *et al.* 1996). The similarity in appearance of sei whales and Bryde's whales has resulted in confusion about distributional limits and frequency of occurrence. This species is known to breed in tropical and subtropical waters, while Australian Antarctic waters are important feeding grounds for Sei whales, as are temperate, cool waters (Horwood 1987).	The movements and distributions of Sei whales in Australian waters are unpredictable and not well documented. Information suggests that Sei whales have the same general pattern of migration as most other baleen whales, although it is timed a little later and they do not go to such high latitudes (Gambell 1968).	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 wider EMBA is likely to be limited.
Killer whale	The Killer whale is found in all of the world's oceans, from the Arctic and Antarctic regions to tropical seas (Ford *et al.* 2005). 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 (DoEE 2019). The preferred habitat of the species includes oceanic, pelagic and neritic (relatively shallow waters over the continental shelf) regions, in both warm and cold waters. They may be more common in cold, deep waters, but off Australia, Killer whales are most often seen along the continental slope and on the shelf, particularly near seal colonies. Killer whales have regularly been observed within the Australian territorial waters along the ice edge in summer. No areas of significance and no determined migration routes have been identified for this species within waters off WA (DoEE 2019).	Killer whales are known to make seasonal movements and follow regular migratory routes. Mating is known to occur all year round, whilst the calving season spans several months.	Given the wide-ranging nature of this species, lack of nearby important habitat and a preference for coastal waters, the presence of the species within the Operational Area is unlikely. Presence within the wider EMBA is also likely to be limited.
Sperm whale	Sperm whales are abundant from polar waters to the equator and typically found in deep temperate and tropical offshore waters (greater than 600 m) or closer to the shore in water depths greater than 200 m (DoEE 2019). Sperm whales tend to be found where the seabed rises steeply from great depth and are probably associated with concentrations of major food in areas of upwelling (Bannister *et al.* 1996). There is limited information on their distribution in Australian waters, although they have been recorded off the coast of all Australian states, where they occur in groups of up to 50 individuals (DoEE 2019). Sperm whales have been recorded from all Australian states. Sperm whales have previously been recorded both acoustically and during aerial surveys, on the North West Shelf, suggesting that they occasionally occur in the deep, oceanic waters of the region (RPS 2010).	Sperm whales are seasonal breeders, but the mating season is prolonged, extending from late winter through to early summer. In the Southern Hemisphere, conceptions occur from July to March, peaking in September and December. Calves may be born in tropical and temperate waters and are mainly born between November and March.	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 wider EMBA is likely to be limited.
Spotted bottlenose dolphin (Arafura/Timor Sea populations)	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 2019). In Australia, the species is generally found in inshore areas such as bays and estuaries, nearshore waters, open coast environments and shallow offshore waters. 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 (Reeves *et al.* 2003). The closest calving BIA is located at Roebuck Bay, approximately 150 km from the Operational Area. The population present at Roebuck Bay is likely to be resident due to rich and consistent prey available.	Calving peaks occur in spring and summer or spring and autumn. Knowledge of the species seasonal migration and breeding is largely unknown; however, it is inferred that only the Arafura-Timor Sea population is migratory.	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 shallower southern region of the wider EMBA.
Mammals potentially occurring within the EMBA			
Dugong	Dugongs are also known to occur along the coast throughout the Kimberley to the Western Australia–Northern Territory border; however, population estimates for these areas are not available (DSEWPaC 2012). Dugongs inhabit protected shallow coastal areas, such as wide shallow bays and mangrove channels. Some of the coastal waters in the region support significant populations of Dugongs, including Shark Bay, which has an estimated population of around 10,000 individuals (DSEWPaC 2012). Specific areas supporting Dugongs in Western Australia include: Shark Bay; Ningaloo and Exmouth Gulf; the Pilbara coast (Exmouth Gulf to De Grey River) (Marsh *et al.* 2002); and Eighty Mile Beach and Kimberley Coast Region, including Roebuck Bay (Brown *et al.* 2014). 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 a total of 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 closest foraging BIA is located south of the Operational Area, along the Dampier Peninsula (approximately 650 km away).	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 are generally seasonal breeders, and the seasonality of breeding is more marked in the sub-tropics (mostly spring, early summer calving) than in the tropics.	The PMST search identified the species as potentially occurring within the EMBA, and not within the Operational Area. The closest foraging BIA for this species is 150 km away (Roebuck Bay) from the Operational Area. Due to the absence of suitable habitat and preference for shallow waters, presence of the species within the EMBA is likely to limited.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Indo-Pacific Humpback Dolphin	The Indo-Pacific Humpback dolphin is found in tropical/subtropical waters of North-west Australia to the southern waters of the island of New Guinea. In Australia, they are thought to be widely distributed along the northern Australian coastline from approximately the Queensland–New South Wales border to western Shark Bay, Western Australia (DAWE, 2021a). Within their geographical range, Australian Humpback dolphins generally occur close to the coast (within 20 km from land) and in relatively sheltered offshore waters near reefs or islands (DAWE, 2021a). In the North-west marine region, the species occurs off the Buccaneer Archipelago and from Cape Leveque to Roebuck Bay. They are generally found in depths of less than 20 metres although some have been recorded in waters up to 40 metres deep and 55 kilometres offshore (DSEWPaC, 2012a). The closest BIA is located at Roebuck Bay (breeding, calving, and foraging), approximately 150 km from the Operational Area (DAWE, 2016). The population present at Roebuck Bay is likely to be resident due to rich and consistent prey available.	Australian Humpback dolphins do not appear to undergo large-scale seasonal migrations, although seasonal shifts in abundance have been observed (DAWE, 2021), and are likely to migrate through the North-west Marine Region (DSEWPaC,2012a)	The PMST search identified that the species or species habitat may occur within the EMBA, and not within the Operational Area. Species BIA is located within close proximity to shore and given the species preference for shallow waters, the presence of the species within the operational area is likely to be limited. The species may occasionally be present in the shallower southern region of the wider EMBA.

4.3.7 Sharks and Rays

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

One threatened, four threatened and migratory, and six migratory shark and ray species were identified in the PMST search as potentially occurring in the Operational Area and EMBA (Table 4-3).

A description of the identified threatened and/or migratory sharks, sawfish and rays is provided in Table 4-7 including their distribution, migratory movements, preferred habitat and likely presence within the Operational Area and EMBA.

One BIA for the shark and ray species described in Table 4-3 has been identified within the Operational Area and wider EMBA: The Whale shark foraging BIA extends northwards from Ningaloo along the 200 m isobath. The Operational Area overlaps with the BIA (Figure 4-12).

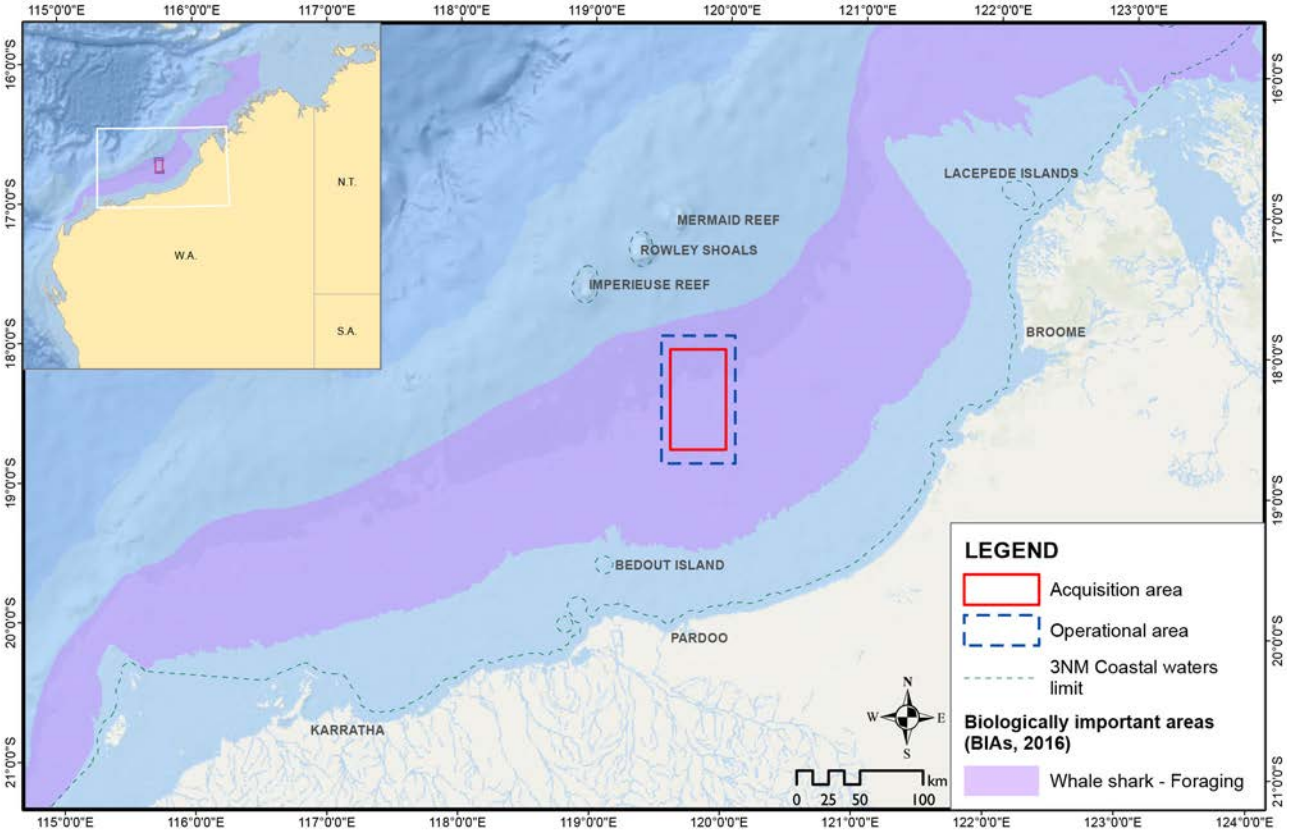


Figure 4-12 – Whale Shark BIAs

Table 4-7 – Threatened and Migratory Sharks and Rays Potentially Occurring Within the Operational Area and EMBA

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Sharks and rays potentially occurring within the operational area			
Whale shark	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 1,700 km away) between December and January and at Ningaloo Reef (approximately 740 km away) between March and July to feed on krill and baitfish associated with coral spawning events (DoEE 2019). After this period, Whale sharks disperse from Ningaloo and are understood to forage in continental shelf waters during spring. 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; Bradshaw *et al.* 2007). The Operational Area overlaps with the Whale shark foraging BIA (Figure 4-12 – Whale Shark BIAs), which extends northwards from Ningaloo along the 200 m isobath.	Whale sharks are regarded as highly migratory – although these 'migration patterns' are poorly understood. Individuals tagged at Ningaloo Reef have been shown to migrate north, north-east or north-west towards Indonesian waters (Sleeman *et al.* 2010; Wilson *et al.* 2006; Reynolds *et al.* 2017). Tagged Whale shark data includes records of Whale sharks departing from Ningaloo in spring and travelling north-west, following the 200 m isobath on the edge of the continental shelf. This route has been designated by the DoEE as a BIA for whale shark foraging between July and November, which extends from Ningaloo Reef to waters in the Timor Sea.	Given the recorded migratory routes in the region, individual whale sharks may be encountered in the Operational Area and wider EMBA. However, given that the proposed timing of the survey does not coincide with the July to November migration period when Whale sharks are most likely to utilise the BIA, whale sharks are expected to occur in low numbers.
Great white shark	They 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 2019). Great white sharks are frequently recorded in waters around Fur seal and Sea lion colonies such as the islands off the lower west coast of Western Australia (DoEE 2019).	Great white sharks 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 2019).	Due to their 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 wider EMBA is likely to be limited.
Shortfin mako shark	The shortfin mako is found in tropical and warm-temperate seas in water depths up to 500 m (Cailliet *et al.* 2009). 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). The species 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.	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 wider EMBA is expected to be low.
Narrow sawfish (previously known as the Knifetooth sawfish)	The exact distribution of the species is uncertain, but it is highly likely that its full range extends 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).	There is insufficient data to prescribe distribution behaviours, migration times and routes and seasonal patterns.	Given the species distribution, and preference for coastal/estuarine areas, the presence of the species within the Operational Area is expected to be limited. The species may occasionally be present in the shallower southern region of the wider EMBA.
Reef manta ray (coastal manta ray)	The Reef manta ray is found around the northern coast of Australia between south western Australia, and Central New South Wales (DoEE 2019). 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. The species is commonly sighted inshore, however is also found around offshore coral reefs, rocky reefs and seamounts (Marshall *et al.* 2018).	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 (IUCN 2019).	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 around Rowley Shoals and in the shallower southern region of the wider EMBA.
Giant manta ray	The Giant manta ray lives in tropical, marine waters worldwide, and occasionally in temperate seas between latitudes 30°N and 35°S. In Australia, the species is recorded from south-western WA, around the tropical north to the southern coast of New South Wales. Individuals have been recorded to travel up to 70 km over one day (van Duinkerken 2010).	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 around Rowley Shoals and in the shallower southern region of the wider EMBA.
Freshwater sawfish (also known as Largetooth sawfish)	The Largetooth sawfish may potentially occur in all large rivers of northern Australia from the Fitzroy River, Western Australia, to the western side of Cape York Peninsula, Queensland (Allen 2000; DoEE 2019). It is a marine/estuarine species that spends its first three–four years in freshwater (DoEE 2019). The preferred habitat of this species is mud bottoms of river embayments and estuaries, but they are also found well upstream. The species mainly feeds on fishes and benthic invertebrates.	A study on the movement patterns of other sawfish species, P. lavate and P. zijsron, showed that the species had a high fidelity to an area, with movements restricted to only a few square kilometres within the coastal fringe, and influenced by tides (Stevens *et al.* 2008).	Given the species preferred estuarine habitat, and the location of the pupping and foraging BIAs, the presence of the species within the Operational Area is expected to be low. The species may be present in the shallower southern region of the wider EMBA.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	The Fitzroy River has been identified as a likely important nursery site for the Largetooth sawfish (located 380 km from the Operational Area and outside the EMBA) (Whitty *et al.* 2008). The Freshwater sawfish pupping and foraging BIAs are located along Eighty Mile Beach and Roebuck Bay. Pupping is known to occur from the months of January to May at Eighty Mile Beach. The closest BIA is located 100 km from the Operational Area		
Green sawfish	In Australian waters, Green sawfish have historically been recorded in the coastal waters off Broome, Western Australia, around northern Australia and down the east coast as far as Jervis Bay, NSW (Stevens *et al.* 2005). 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 in very shallow water (1 m) to offshore trawl grounds in over 70 m of water (Stevens *et al.* 2005). Green sawfish are found in Indonesian waters and it is possible that individuals may migrate between Australia and Indonesia. It is probable that the Australian population can be considered geographically separate (Stevens *et al.* 2005). The Sahul Shelf system is known to support populations of Green sawfish (Donovan *et al.* 2008).	Sawfish are known to return seasonally to inshore coastal waters adjacent to the northern Australian region to breed and pup. Little is known about reproduction in Green sawfish. It is unknown whether there is migration into Australian waters of Green sawfish adults or juveniles from populations outside Australia. Green sawfish are found in Indonesian waters and it is possible that individuals may migrate between Australia and Indonesia, however it is probable that the Australian population can be considered geographically separate (Stevens *et al.* 2005).	Given the species preferred estuarine habitat and the location of the pupping and foraging BIAs, the presence of the species within the Operational Area is expected to be low. The species may be present in the shallower southern region of the wider EMBA.
Oceanic whitetip shark	The Oceanic whitetip has a global distribution, occurring in both tropical and subtropical waters, with a temperature range of 18–28°C but preferring >20°C (Rigby et al 2019b; Howey-Jordan et al 2013). The species is usually found offshore in the open sea with a preference for surface waters (< 200 m) but have been reported in depths of 1,082 m (Rigby, 2019b).	Across its range the Oceanic whitetip shark is highly migratory, however, there is limited information on the movement patterns and migration paths of this species (Young and Carlson 2020).	The PMST search identified that the species or species habitat may occur within the Operational Area and EMBA. Given the species' wide-distribution, the presence of the species within the Operational Area is expected to be low
Sharks and Rays Potentially Occurring Within the EMBA			
Longfin mako	Longfin makos inhabit oceanic and pelagic habits, typically in tropical regions. They are a highly mobile species and have a wide-ranging distribution (DSEWPaC 2012) but are rarely encountered. Longfin mako usually occur to depths of 760 m but have been reported to 1,752 m (Rigby *et al.* 2019; Ebert *et al.* 2013, Hueter *et al.* 2016, Weigmann 2016). In Australian waters, the species is found from Geraldton, in WA, and north to Port Stephens in New South Wales (Last and Stevens 2009). Given the species wide-distribution and preference for deeper waters, the presence of the species within the EMBA is expected to be low.	There is insufficient data to prescribe distribution behaviours, migration times and routes and seasonal patterns.	The PMST search identified the species as potentially occurring within the EMBA, and not within the Operational Area.
Dwarf sawfish	The Dwarf sawfish is found in Australian coastal waters extending north from Cairns around the Cape York Peninsula in Queensland to the Pilbara coast (DoEE 2019). Dwarf sawfish typically inhabit shallow (2 to 3 m) silty coastal waters and estuarine habitats, occupying relatively restricted areas and moving only small distances (Stevens *et al.*, 2008). The majority of capture locations for the species in WA waters have occurred within King Sound and the lower reaches of the major rivers that enter the sound, including the Fitzroy, Mary and Robinson rivers (Morgan *et al.*, 2009). Individuals have also been recorded from Eighty Mile Beach in the Pilbara and occasional individuals have also been taken from considerably deeper water from trawl fishing (Morgan *et al.*, 2009). A study in north-western Western Australia found that estuarine habitats are used as nursery areas by Dwarf sawfish, with immature juveniles remaining in these areas up until three years of age (Thorburn *et al.* 2007a). Adults are known to seasonally migrate back into inshore waters (Peverell 2007), although it is unclear how far offshore the adults travel, as captures in offshore surveys are very uncommon. The Dwarf sawfish pupping, nursing and foraging BIAs are located along Eighty Mile Beach, approximately 100 km from the Operational Area.	Dwarf sawfish may move into marine waters after the wet season and during the wet season enter estuarine or fresh waters to breed. Adults are known to seasonally migrate back into inshore waters (Peverell 2007), although it is unclear how far offshore the adults travel.	The PMST search identified the species as potentially occurring within the EMBA, and not within the Operational Area. Given the species distribution and nearby pupping, nursing and foraging BIAs, the presence of the species in the EMBA is expected to be low.

4.3.8 Marine Reptiles

4.3.8.1 Marine Turtles

Marine turtles have similar life cycle characteristics, which include migration 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 region is considered to be significant for supporting large feeding and nesting turtle populations.

Five 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 4-8.

There are several BIAs for turtle species in the region, including along the coastline and offshore islands adjacent to the Operational Area (Figure 4-13). No foraging, internesting, or nesting BIAs overlap with the Operational Area.

In 2017, the DoEE (now DAWE) identified “habitat critical to the survival of marine turtle species” in the Recovery Plan for Marine Turtles in Australia (DoEE 2017). It should be noted that this is different to Critical Habitat to Survival, as defined under the EPBC Act. No habitat critical to the survival of a marine turtle species occurs within the Operational Area. The closest habitat is the flatback turtle internesting buffer at Eighty Mile Beach, approximately 60 km from the Operational Area (Figure 4-14). The flatback turtle internesting buffer is the only habitat critical to the survival of a marine turtle species to overlap with the wider EMBA.

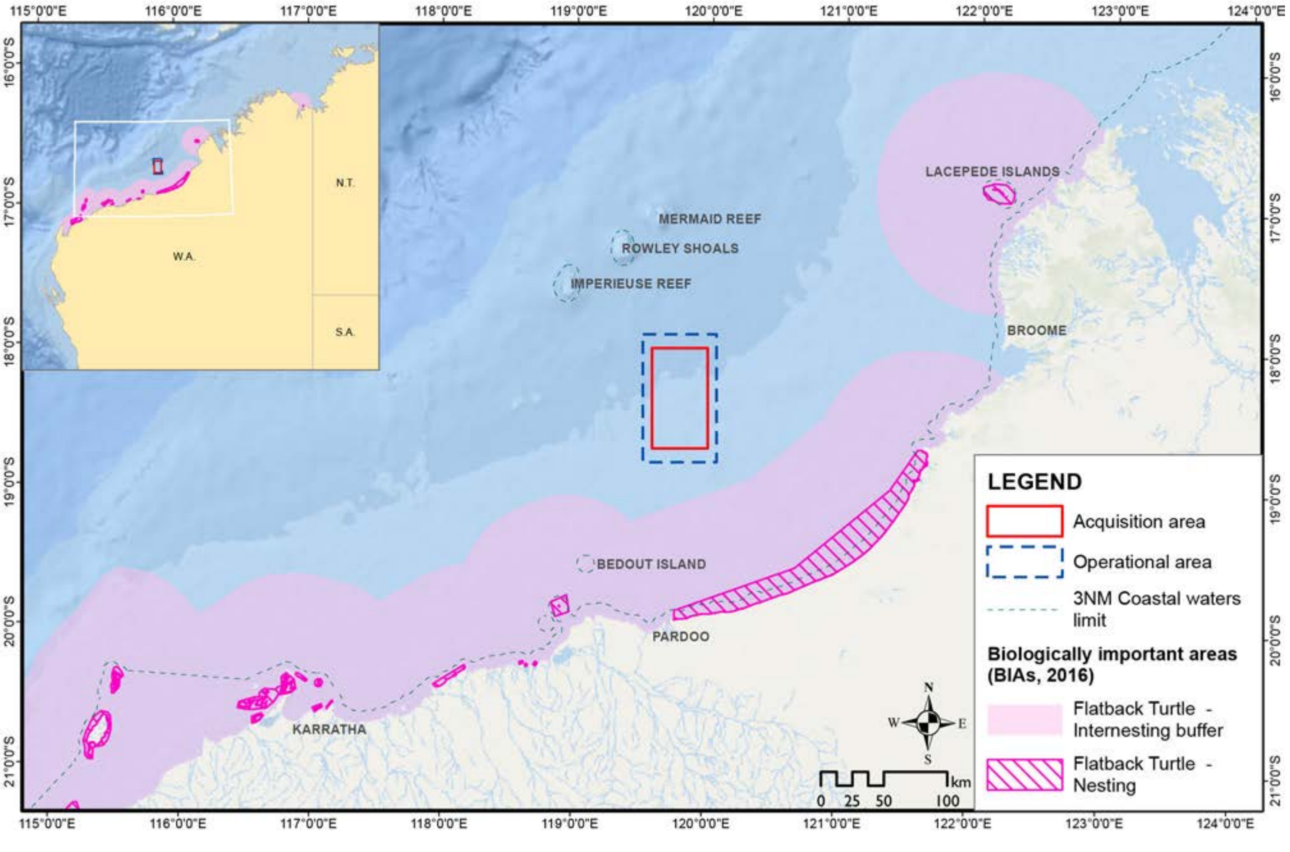


Figure 4-13 – Flatback Turtle BIAs

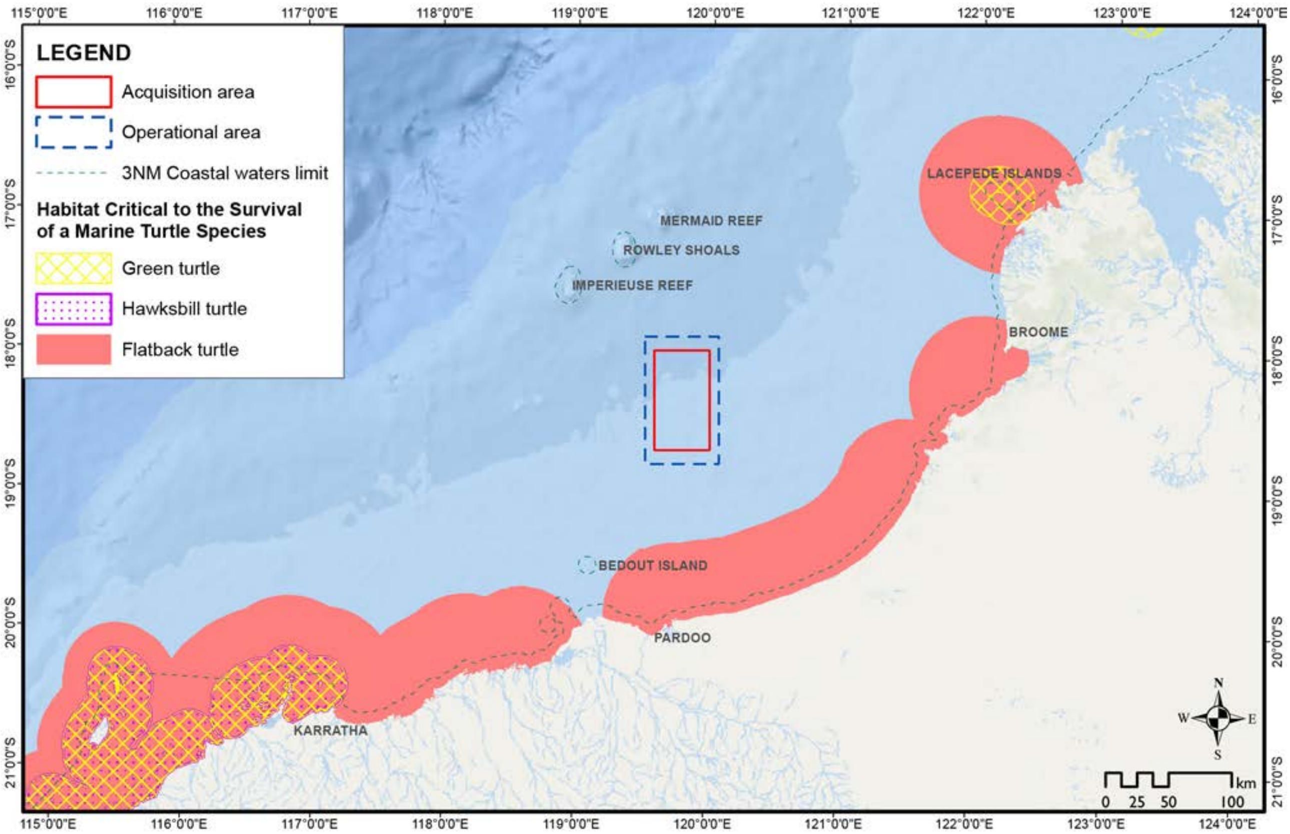


Figure 4-14 – Habitat Critical to the Survival of Marine Turtles

4.3.8.2 Sea Snakes

Sea snakes are essentially tropical in distribution and habitats reflect influences of factors such as water depth, nature of seabed, turbidity and season (Heatwole and Cogger 1993). Some species have extensive distributions and individuals may cover large distances, while other species have limited home ranges (Heatwole and Cogger 1993). Most sea snake species tend to be found in the shallower parts of the region to allow for increased benthic foraging time (DEWHA 2008a).

Sea snakes that inhabit coral reefs in the region 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 sea snakes at each reef form a discrete 'management unit' for each species and prevents species from occupying all reefs (PTTEP 2013).

At least 20 species of sea snake occur within the region (DEWHA 2008a). Amongst these species, one threatened sea snake species (the short-nosed sea snake) was identified in the EPBC Act Protected Matters Database search as having the potential to occur in the Operational Area and EMBA. Further details on its habitats, life stages and likely presence within the Operational Area is provided in Table 4-8.

No coral reefs or shoals occur within the Operational Area and therefore sea snakes are expected to occur in low numbers.

Table 4-8 – Threatened and Migratory Marine Reptiles Potentially Occurring Within the Operational Area and EMBA

Common Name	Habitat and Distribution	Phenology	Relevance to EP
Marine Reptiles Potentially Occurring Within the Operational Area			
Loggerhead turtle	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 2019). The species is known to forage nearshore, in water depths up to approximately 50–60 m (DoEE 2019). In WA, the species nests on the Muiron Islands (approximately 630 km away) and on the beaches of North West Cape (approximately 665 km away) (DoEE 2019; Guinea 1995). The species is known to nest between October and February, with a peak in December (DoEE 2019). As a juvenile, this species feeds on algae, pelagic crustaceans, molluscs and flotsam whilst as an adult it feeds on gastropod molluscs, clams, jellyfish, starfish, coral, crabs and fish (DoEE 2019).	Nesting occurs between October and February, with a peak in December (DoEE 2019).	There are no known Loggerhead turtle BIAs located within the Operational Area or EMBA and the Operational Area occurs outside of known foraging depths. Therefore, Loggerhead turtles may occur within the Operational Area in low numbers as transitory individuals. Foraging habitat potentially occurs in the wider EMBA where individuals may occur in higher numbers.
Green turtle	The Green turtle has a global distribution and occurs in tropical and subtropical waters, with WA supporting one of the largest Green turtle populations in the world (Limpus 2004). Principal rookeries in WA include the Lacepede Islands (approximately 250 km away), Barrow Island (approximately 475 km away), the Montebello Islands (approximately 450 km away), North West Cape (approximately 665 km away) and the Muiron Islands (630 km away) (Commonwealth of Australia 2012; Department of the Environment and Energy 2017). Smaller rookeries in the region include Ashmore Reef and Cartier Island (approximately 670 km away), Browse Island (approximately 550 km away), Cassini Island (approximately 740 km away), Maret Island (approximately 650 km away) and Sandy Islet at Scott Reef (approximately 250 km away) (Commonwealth of Australia 2012; Department of the Environment and Energy 2017). 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). The closest foraging BIA to the Operational Area is located at Bedout Island (approximately 90 km away) and James Price Point (approximately 190 km away). The nearest nesting BIA is located at Lacepede Islands (approximately 250 km away). Females are known to stay within approximately 20 km from nesting beaches (Commonwealth of Australia 2012). The Green turtle 'habitat critical to the survival of marine turtles' BIA is located approximately at Adele Island and Lacepede Island, 230 km to the east of the Operational Area.	Nesting occurs between November and March (DoEE 2019). Female Green turtles go into an inter-nesting cycle after each nesting occurrence. The inter-nesting 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 (Commonwealth of Australia 2012).	There are no known Green turtle BIAs located within the Operational Area or EMBA, and the Operational Area occurs outside of known foraging depths. Therefore, Green turtles are unlikely to occur within the Operational Area. Foraging habitat potentially occurs in the wider EMBA where individuals may occur in higher numbers.
Leatherback turtle	Leatherback turtles are pelagic feeders, spending extended periods of time in tropical, subtropical and temperate open ocean waters (Limpus 2009). The species has been recorded feeding in the coastal waters of all Australian states and territories in low densities. Leatherback turtles forage on pelagic soft bodied creatures (such as jellyfish, squid, salps, siphonophores and tunicates) all year round in Australian waters (DoEE 2019). No BIAs have been identified for the species within the Operational Area or wider EMBA.	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 (DoEE 2019)	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	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. Australia has the largest breeding population of Hawksbill turtles in the world (Limpus 2008). 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 2019). The closest foraging BIA to the Operational Area is located at Bedout Island (approximately 90 km away). The nearest nesting BIA is located at the Dampier Archipelago (i.e. islands to the west of the Burrup Peninsula), 270 km from the Operational Area. The nesting BIA is surrounded by an internesting BIA (buffer of 20 km). The 'habitat critical to the survival of marine turtles' BIA is also located at the Dampier Archipelago.	Hawksbill turtles nest year-round, with a peak between October and December (DEWHA 2008a). Inter-nesting 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 (DSEWPaC 2012), whilst breeding in the WA population peaks around October to January. 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 2019).	Given the species nesting, internesting and foraging BIAs are located in close proximity to the Operational Area, transient turtles may be present within the Operational Area and wider EMBA.

Common Name	Habitat and Distribution	Phenology	Relevance to EP
Flatback turtle	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). The NWMR is an important nesting area, with major rookeries present from Exmouth to the Lacepede Islands (approximately 250 km away) and along the Kimberley coast and islands. There are significant rookeries on Barrow Island, Thevenard Island, Montebello Islands and Lowendal Islands (Commonwealth of Australia 2012). Nesting occurs between November and March, peaking in January (Commonwealth of Australia 2012). The nearest nesting BIA is located at Eighty Mile Beach, approximately 95 km from the Operational Area (Figure 4-13). A 'habitat critical to the survival of marine turtles' (internesting) is also located along Eighty Mile Beach, approximately 60 km from the Operational Area (Figure 4-14). Nesting occurs between May and July (DoEE 2019). Internesting habitat is located immediately seaward of nesting habitat. Female Flatback turtles may occur within 60 km of nesting beaches during the internesting period (DoEE 2019). An internesting BIA is located 60 km from the Operational Area, at Eighty Mile Beach. Flatback turtles are known to feed on gastropod molluscs, squid, soft corals, hydroids and jellyfish (DoEE 2019). The closest foraging BIA to the Operational Area is located at Bedout Island (approximately 90 km away) and James Price Point (approximately 190 km away).	In the Kimberley and Pilbara regions of Western Australia, from approximately the Lacepede Islands to Exmouth, there is a mid-summer peak nesting season. 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 (Commonwealth of Australia 2012). Although turtles remain close to nesting beaches during the internesting period, there is evidence that some Flatback turtles undertake long-distance migrations between breeding and feeding grounds. A survey carried out in the region between 2005 and 2012 identified the distances 73 female Flatback turtles travelled to their foraging grounds; 11 remained within 100 km of their rookeries, four migrated an average of 400 km and 58 migrated between 1,000 and 1,500 km (Pendoley *et al.* 2014).	Given the species internesting BIA located approximately 15 km from the Operational Area, and Congregation/aggregation is known to occur in area, transient turtles may be present within the Operational Area. Foraging habitat potentially occurs in the wider EMBA where individuals may occur in higher numbers.
Marine Reptiles Potentially Occurring Within the EMBA			
Short-nosed sea snake	The Short-nosed sea snake is endemic to WA and has been recorded from Exmouth Gulf to the reefs of the Sahul Shelf (Commonwealth of Australia 2012). The species is thought to have a very restricted distribution. The species can be found in reef flats and shallow water, in water depths to 10 m (Commonwealth of Australia 2012). The species is typically found within 70 km from the shoreline, preferring shallow depths of 10 m; the species' limited range results in the species only occupying an area of less than 10 km^2 around the reef (Lukoschek *et al.*2010). Few Short-nosed sea snakes move further than 50 m from the reef flats (DoEE 2019).	Sea snakes are long-lived and slow growing with small broods and high juvenile mortality. Little is known of the age at which sea snakes reach sexual maturity. Sea snakes have a gestational period of 6-7 months, indicating that females are unlikely to breed every year. The species is expected to be restricted to shallow waters and may occur in the shallow coastal waters of the wider EMBA.	The PMST search identified the species as potentially occurring within the EMBA, and not within the Operational Area.

4.3.9 Marine Birds

Many migratory shorebirds (including those frequenting offshore islands) and seabird species are known to occur in the NWMR. 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 may also breed within the region.

There are 23 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.

Two threatened, two threatened and migratory, and 14 migratory marine birds were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the Operational Area and EMBA. Several biologically important areas for marine bird species have been identified within the Operational Area and EMBA (see Table 4-5).

A description of the distribution, migration movements, and preferred habitat and life stages of the identified marine bird species is provided in Table 4-9, including commentary on their likely presence in the Operational Area.

Table 4-9 – Threatened and Migratory Seabirds Potentially Occurring Within the Operational Area And EMBA

Common Name	Habitat and distribution	Phenology	Relevance to EP
Marine Birds Potentially Occurring Within the Operational Area			
Eastern curlew	Within Australia, the Eastern curlew has a primarily coastal distribution. They have a continuous distribution from Barrow Island and Dampier Archipelago, Western Australia, through the Kimberley and along the Northern Territory, Queensland, and NSW coasts and the islands of Torres Strait. Elsewhere they are patchily distributed (DoEE 2019). This species does not breed in Australia, rather in the Northern Hemisphere summer, between early May and late June (DoEE 2019). They start to depart in 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 2019).	This species does not breed in Australia, rather in the Northern Hemisphere summer, between early May and late June (DoEE 2019). They start to depart in early March and begin to arrive back in late July.	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 density may be encountered in the nearshore waters of the wider EMBA.
Red knot	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 shallow 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 at 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 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 are usually between September and October.	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 density may be encountered in the nearshore waters of the wider EMBA.
Abbott's booby	Currently, Abbott's booby is only known to breed on Christmas Island and to forage in the waters surrounding the island. Christmas Island is close to a number of cold-water upwellings that probably provide food that is seasonal in nature, and upon which a number of the seabirds may depend for raising their young. Abbott's booby is a marine species. It spends much of its time at sea but needs to come ashore to breed. It nests in tall rainforest trees in the western, central and northern portions of Christmas Island. Abbott's booby feeds on fish and squid (Marchant and Higgins 1990; Reville *et al.* 1990).	Abbott's boobies travel large distances to feeding grounds during breeding season. It appears that some adults leave Christmas Island for 4-5 months and return in April. Breeding commences in March, when established pairs begin returning to nest sites and start collecting nest material.	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.
Common sandpiper	Distributed along all coastlines of Australia and many areas inland, the Common sandpiper is widespread in small numbers. The area of national importance along the coast of Western Australia is Roebuck Bay (approximately 160 km away from the Operational Area). 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.	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 wide distribution and migration pattern, this species may be present in the Operational Area in low numbers or isolated individuals/groups. Higher population density may be encountered in the nearshore waters of the wider EMBA.
Common noddy	In Australia, the Common noddy occurs mainly in the ocean off the Queensland coast, but the species also occurs off the north-west and central Western Australian 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 Common noddy feeds mainly on fish, although they are known to also take squid, pelagic molluscs, medusa and aquatic insects.	The seasonality of breeding varies greatly between sites. At some locations, birds breed annually and at others, birds breed twice a year (spring to early summer and again at autumn).	Given the wide distribution of the species and location of breeding habitat, this species may be present in the Operational Area and EMBA in low numbers.
Sharp-tailed sandpiper	The Sharp-tailed sandpiper spends the non-breeding season in Australia with small numbers occurring regularly in New Zealand. Most of the population migrates to Australia, mostly to the south-east and are widespread in both inland and coastal locations. In Western Australia they are widely distributed from Cape Arid to Carnarvon, around coastal plains of the Pilbara Region to south-west and east Kimberly Division. 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. Eighty-mile beach (approximately 120 km away from the Operational Area) is the closest international important site for the species.	Most of the population migrates to Australia, mostly to the south-east and are widespread in both inland and coastal locations. 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.	Given the wide distribution of this species and the migratory pattern, it is likely the presence of this species will be encountered in low number or isolated individuals within the Operational Area. Higher population density may be encountered in the nearshore waters of the wider EMBA.
Pectoral sandpiper	In Australasia, the Pectoral sandpiper prefers shallow fresh to saline wetlands. 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 Lake, Wittecarra, Harding River, coastal Gascoyne, the Pilbara and the Kimberley.	The Pectoral sandpiper breeds in the northern hemisphere during the boreal summer, before undertaking long distance migrations to feeding grounds in the southern hemisphere. The species occurs throughout mainland Australia between spring and autumn.	Given the wide distribution of this species and the migratory pattern, it is likely the presence of this species will be encountered in low number or isolated individuals within the Operational Area. Higher population density may be

Common Name	Habitat and distribution	Phenology	Relevance to EP
			encountered in the nearshore waters of the wider EMBA.
Streaked shearwater	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 it does not breed in Australia, it is known to forage in the region. 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 2019)	The species breeds in temperate regions of East and South-east Asia before migrating to tropical regions near the equator, however little is known about their movements during the non-breeding period (Yamamoto *et al.* 2010).	Given the distribution of the species and habitat, this species may be present in the Operational Area and EMBA
Lesser frigatebird	The Lesser frigatebird is usually seen in tropical or warmer waters off northern Western Australia, Northern Territory, Queensland and northern New South Wales. 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 2019). In Australia, the Lesser frigatebird's egg laying occurs mostly about mid-year. A breeding BIA overlaps with a small portion of the southern section of the Operational Area.	The Lesser frigatebird breeds between May and December and usually stays within 100 – 200 km of the colony during the breeding season, but when not breeding they range widely throughout tropical seas (Lindsey 1986).	Given the distribution of the species and habitat, this species may be present in the Operational Area and EMBA.
Osprey	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 Western Australia 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 breeds from April to February in Australia.	Given the distribution of the species and habitat, this species may be present in the Operational Area and EMBA.
White-tailed tropicbird	The White-tailed tropicbird is found in pelagic waters and tropical waters. The White-tailed tropicbird forages in warm waters and over long distances – many kilometres from its breeding sites. A breeding BIA has been identified at the Rowley Shoals, which overlaps with the northern portion of the Acquisition Area.	Breeding is recorded in May and October at the Rowley Shoals.	Given the distribution of the species and nearby breeding habitat, this species may be present in the Operational Area and EMBA.
Great frigatebird, Greater frigatebird	Great frigatebirds are found in tropical waters globally. It 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.	Breeding is known to occur between May to June and in August (DoEE 2019).	Given the distribution of the species and nearby breeding habitat, this species may be present in the Operational Area and EMBA.
Marine Birds Potentially Occurring Within the EMBA			
Curlew sandpiper	The Curlew sandpiper's breeding areas are mainly restricted to the Arctic of northern Siberia (DoEE 2019). 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 2019). 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 2019).	The species is known to 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 (DoEE 2019).	Given the distribution of the species and nearby foraging habitat, this species may be present in the nearshore waters of the EMBA.
Red-tailed tropicbird	The Red-tailed tropicbird nests in the southern Indian Ocean and just north of the Tropic of Cancer and south of the Tropic of Capricorn in the Pacific Ocean. It breeds on islands but can also be found on the south-west coast of Australia. This species feeds mostly on fish, especially flying-fish, large quantities of squid and occasionally crustaceans. Prey is caught by plunge-diving but flying-fish can be taken in flight. Breeding occurs seasonally in loose colonies on small, remote oceanic islands mostly on inaccessible cliffs.	No regular migrations are known; adults can be found in the vicinity of colonies all year round (del Hoyo *et al.* 1992).	Given the wide distribution of this species and the migratory pattern, it is likely the presence of this species will be encountered in low number or isolated individuals within the EMBA.
Little tern	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 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 2019). The Little tern is a coastal seabird, which usually forages in very shallow water, more often in brackish lagoons and saltmarsh creeks (DoEE 2019). The Little tern usually forages close to breeding colonies (DSEWPaC 2012d). The closest breeding site to the Operational Area for the non-Asian migrants of the species is on the coastline of the Kimberley. A resting BIA is located around the Rowley Shoals, approximately 25 km from the Operational Area. In addition, a breeding BIA is located approximately 85 km south of the Operational Area.	The migration habits of this species are poorly known. However, it is recorded that breeding typically occurs in late April-July and September to early January.	Given the distribution of the species and habitat, this species may be present in the nearshore waters of the EMBA.

Common Name	Habitat and distribution	Phenology	Relevance to EP
Brown booby	The Brown booby occurs in, but is not restricted to, tropical waters of all major oceans. They often stay close to their breeding islands. The species is also known to be present along coastal waters, harbours and estuaries; however, they seldom fly over land. The Brown booby generally feeds in inshore water, in both shallow and deep waters (DoEE 2019). The Brown booby nests on rugged rocky terrain such as cliffs and steep slopes, on larger islands, beaches, coral rubble and guano flats on cays (DoEE 2019). The species is known to be resident and partly nomadic (i.e. birds dispersing widely between breeding seasons). Breeding occurs in and adjacent to the region, including on Ashmore Reef, Adele Island, White Island, Lacepede Islands and Bedout Island. The closest breeding BIA is located approximately 40 km south of the Operational Area.	The species typically leaves breeding islands when not breeding, in search of better foraging grounds (DoEE 2019). Breeding times are unknown.	Given the distribution of the species and habitat, this species may be present in the nearshore waters of the EMBA.
Lesser crested tern	This species can be found on islands and coastlines of the tropical and subtropical, ranging from the Atlantic coast of South Africa, south around the Cape and continuing along the coast of Africa and Asia almost without break to south-east Asia and Australia. The species inhabits tropical and subtropical coastlines, foraging in the shallow waters of lagoons, coral reefs, estuaries, bays, harbours and inlets, along sandy, rocky, coral or muddy shores, on rocky outcrops in open sea, in mangrove swamps and offshore waters. The species prefers nesting on offshore islands, low-lying coral reefs, sandy or rocky coastal islets, coastal spits, lagoon mudflats, and artificial islets in saltpans.	The species nests in dense colonies with neighbouring nests very close together (rims may be touching) and usually forages within 3 km of the breeding colony (del Hoyo *et al.* 1996).	Given the distribution of the species and nearby breeding habitat, this species may be present in the nearshore waters of the EMBA.
Roseate Tern	The Roseate tern occurs in both coastal and marine subtropical/tropical areas. The species inhabits rocky and sandy beaches, coral reefs, sand cays and offshore islands (DAWE 2021b). In Western Australia, the Roseate terns are regularly recorded north from Mandurah to Eighty Mile Beach, in the Pilbara Region (DAWE 2021b). Around the Kimberley coastline, the species occurs at scattered sites, north to the Bonaparte Archipelago and potentially further (DAWE 2021b).	The movements of the Roseate tern are poorly known. Breeding in Western Australia occurs in two quite distinct periods, with peak months for laying April to November. At some sites including the Montebello Islands breeding occurs during both late spring-summer and late autumn-winter (DAWE 2021b).	Given the distribution of the species and habitat, this species may be present in the nearshore waters of the EMBA.

4.3.10 Timing of Biological Sensitivities

A number of biological sensitivities related to the phenology of marine fauna are expected to occur within the Operational Area and wider EMBA.

Table 4-10 identifies the timing of key biological sensitivities relevant to the Operational Area and wider EMBA. The fauna listed in Table 4-10 are species listed under the EPBC Act and considered relevant to this EP. The fish species are those identified as key indicator species for the relevant fisheries identified in Section 4.4.4, or brood stock that have habitat that may occur within the Operational Area.

Table 4-10 – Timing of Key Biological Sensitivities Relevant to the Operational Area and Wider EMBA

Sensitivity	January	February	March	April	May	June	July	August	September	October	November	December
Proposed Sauropod 3D MSS timing	■	■	■	■	■							
Humpback whale (north migration)[1]						■	■	■				
Humpback whale (south migration)[1]								■	■	■		
Pygmy blue whale (north migration)[2]				■	■	■	■	■				
Pygmy blue whale (south migration)[2]										■	■	■
Whale shark foraging BIA[3]								■	■	■	■	
Goldband snapper spawning (Pilbara stock)[4]	■	■	■	■	■					■	■	■
Rankin cod spawning[4]								■	■	■		
Red emperor spawning[4]	▦	▦	▦	■	■	■			▦	▦	▦	■
Blue-spotted emperor spawning[4]	■	■	■				■	■	■	■	■	■
Giant ruby snapper spawning[4]	▦	▦	▦	■								■
Silver-lipped pearl spawning	■	■	■	■	■				■	▦	▦	▦
Other demersal fish species spawning[4]	■	■	■	■	■					■	■	■
Blacktip shark breeding[4]											■	■
Sandbar shark breeding[4]	■									■	■	■
White-tailed tropicbird foraging BIA[5]					■					■		
Lesser frigatebird foraging BIA[5]			■	■	■	■	■	■	■	■		
*Flatback turtle internesting[6]	■	■	■							■	■	■
*Spanish mackerel (Pilbara stock)[4]									■	■	■	■

[1] (Source: DoEE 2019), [2] (Source: DoE 2015, McCauley & Jenner 2010; McCauley & Duncan 2011; Double *et al.* 2012; Double *et al.* 2014)

[3] (DoE, 2015; CALM 2005, Environment Australia 2002), [4] (Source: DPIRD 2019), [5] (Source: DoEE 2015), [6] (Source: DoEE 2017, CALM 2005, DSEWPaC 2012).

Hatched cell = peak period.

* occur in EMBA only

4.4 Socio-Economic and Cultural Environment

4.4.1 Commonwealth Protected Areas

4.4.1.1 Argo-Rowley Terrace Australian Marine Park

The Argo-Rowley Terrace Australian Marine Park (AMP) is located approximately 20 km north of the Operational Area and approximately 270 km west-north-west of Broome (Figure 4-15). The Argo-Rowley Terrace MP covers an area of 146,003 km^2 in water depths between 220–6,000 m from the continental slope to the edge of the Exclusive Economic Zone (EEZ) (Director of National Parks, 2018). The MP includes an 83,379 km^2 Marine National Park Zone (IUCN II), a 62,720 km^2 Multiple Use Zone (IUCN VI), and a 1,140 km^2 Special Purpose Zone (Trawl). The Argo-Rowley Terrace AMP boundary is contiguous with the Rowley Shoals State Marine Park (Section 4.4.2.1) and Mermaid Reef Australian Marine Park (Section 4.4.1.2), providing continuous protection to the three coral atolls - Clerke Reef, Imperieuse Reef and Mermaid Reef (collectively known as the Rowley Shoals).

The Argo-Rowley Terrace AMP contains habitats, species and ecological communities associated with the Northwest Transition and Timor Province (Director of National Parks 2018). The Northwest Transition is an area of shelf break and continental slope, of which the Rowley Shoals are a key topographic feature. The Timor Province is dominated by warm, nutrient-poor waters. The AMP contains a range of sea floor features such as canyons on the slope between the Argo Abyssal Plain. These geomorphic features are thought to contribute to small, periodic upwellings that result in localised higher levels of biological productivity (Director of National Parks 2018).

The marine park supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically important areas within the marine park include resting and breeding habitat for seabirds and a migratory pathway for the Pygmy blue and Humpback whales. The marine park is thought to be an important area for sharks, which are found in abundance around the Rowley Shoals and provides important foraging areas for migratory birds and the endangered loggerhead turtle (DoEE n.d).

The Argo-Rowley Terrace AMP contains two KEFs: the canyons linking the Argo Abyssal Plain with the Scott Plateau and the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals. The canyons linking the Argo Abyssal Plain with the Scott Plateau KEF are thought to contribute to high productivity and aggregations of marine life through the upwelling of nutrient rich water (DoEE n.d.). The Mermaid Reef and Commonwealth waters surrounding the Rowley Shoals KEF is valued for enhanced productivity, aggregations of marine life and high species richness (DoEE n.d.). These KEFs are further described in Section 4.4.3.

4.4.1.2 Mermaid Reef Australian Marine Park

Mermaid Reef AMP is located approximately 69 km from the Operational Area, but within the wider EMBA (Figure 4-15). The AMP covers an area of approximately 540 km^2 and is listed as a National Park Zone (IUCN II). The AMP is near the edge of Australia's continental slope and is surrounded by waters that extend to a depth of over 500 m. The AMP contains Mermaid Reef, the most north-easterly of three reef systems forming the Rowley Shoals. Mermaid Reef is totally submerged at high tide and therefore falls under Australian Government jurisdiction. The other two reefs of the Rowley Shoals (Clerke Reef and Imperieuse Reef) are managed by the Western Australian Government as part of the Rowley Shoals State Marine Park. Mermaid Reef–Rowley Shoals is listed on the Commonwealth Heritage List.

Mermaid Reef AMP contains habitats, species and ecological communities associated with the Northwest Transition (Director of National Parks 2018). The reefs of the Rowley Shoals are one of the few offshore reef systems on the North-West Shelf and are thought to provide ecological steppingstones for reef species originating in Indonesian/Western Pacific waters (Director of National Parks 2018). The Rowley Shoals may also provide a degree of connectivity between these reefs and reefs located further south.

Mermaid Reef is a biodiversity hot spot and key geomorphic feature of the Argo Abyssal Plain (Director of National Parks 2018). Collectively, Mermaid Reef, Clerke Reef and Imperieuse Reef support over 200 species of hard corals and 12 classes of soft corals with coral formations in pristine condition. The shoals are an important area for sharks, including the grey reef shark, the whitetip reef shark and the silvertip whaler; important foraging area for marine turtles; toothed whales; dolphins; tuna and billfish; an important resting and feeding site for migratory seabirds; and a migratory pathway for Pygmy blue whales (DoEE n.d.).

The AMP contains the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF, valued for its high species richness, high productivity and aggregations of marine life (DoEE n.d.). The Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF is further described in Section 4.4.3.2. The marine park contains one known shipwreck, the *Lively* (wrecked in 1810), which is located to the north-west side of Mermaid Reef. The wreck is listed under the *Underwater Cultural Heritage Act 2018*.

4.4.1.3 Eighty Mile Beach Australian Marine Park

Eighty Mile Beach AMP is located approximately 72 km south of the Operational Area and outside the wider EMBA (Figure 4-15), however the AMP is considered relevant to this EP. The AMP is located approximately 74 km north-east of Port Hedland and adjacent to the Western Australian Eighty Mile Beach Marine Park. The marine park covers an area of 10,785 km² and water depth ranges between less than 15 m and 70 m. The entire marine park is zoned as a Multiple Use Zone (IUCN VI).

The Eighty Mile Beach AMP consists of shallow shelf habitats, including terrace, banks and shoals. The marine park supports a range of species including threatened, migratory, marine and cetacean species. Biologically important areas within the marine park include breeding, foraging and resting habitat for seabirds, internesting and nesting habitat for marine turtles, foraging, nursing and pupping habitat for sawfish and a migratory pathway for Humpback whales (Director of National Parks 2018).

The Eighty Mile Beach Ramsar site lies adjacent to the AMP and is recognised as one of the most important areas for migratory shorebirds in Australia.

The marine park contains three known shipwrecks listed under the *Historic Shipwrecks Act 1976*, *Lorna Doone* (wrecked in 1923), *Nellie* (wrecked in 1908), and *Tifera* (wrecked in 1923).

Eighty Mile Beach AMP has a range of cultural values for the community. Sea country is valued for Indigenous cultural identity, health and wellbeing. The sea country of the Nyangumarta, Karajarri and Ngarla peoples extends into Eighty Mile Beach AMP (Director of National Parks 2018). Sea country is culturally significant and important to their identity.

4.4.2 State Protected Areas

4.4.2.1 Rowley Shoals

The Rowley Shoals are located approximately 48 km from the Operational Area, while the wider EMBA overlaps with the Rowley Shoals State Marine Park (Figure 4-15).

Rowley Shoals (state managed) consist of three reefs – Mermaid Reef (managed under Commonwealth legislation), Clerke Reef (30 km south-west of Mermaid Reef), and Imperieuse Reef (40 km south-west of Clerke Reef), which is the largest of the three reefs.

Rowley Shoals State Marine Park is covered by the ‘Rowley Shoals Marine Park Management Plan 2007–2017’, which is still in effect. The boundary of the Argo-Rowley Terrace MP bounds Rowley Shoals to the north and Mermaid Reef AMP to the east.

Rowley Shoals and surrounding waters are important to the region in supporting high species richness, higher productivity and aggregations of marine life associated with the reefs. The enhanced productivity in Rowley Shoals is facilitated by the breaking of internal waves in the waters surrounding the reef system, therefore, causing mixing and resuspension of nutrients from water depths of 500–700 m (DoEE n.d.).

The marine environments within the shoal are typical of clear-water environments and include resident organisms and migrant species (Department of Environment and Conservation 2007). Given the remote location of the reefs, there is no history of disturbance by coral predators, and therefore creating a diverse number of marine species, including many molluscs, echinoderms and finfish that are not recorded anywhere else in Western Australia and similar habitats in Eastern Australia (DoEE n.d).

The Rowley Shoals contain intertidal and subtidal coral reefs, which support a diverse number of marine fauna and a range of reef biota. Surveys carried out by the Western Australian Museum identified 184 species of corals, primarily Indo-West Pacific species, indicating the strong affinity of the Rowley Shoals communities with Indonesia. In terms of other species, 264 species of molluscs, 82 species of echinoderms and 389 species of finfish were also identified (Department of Environment and Conservation 2007).

As per Section 4.4.1.2, Mermaid Reef has a diverse shark population, which extends to Rowley Shoals. Aside from sharks, reef edges also attract migratory pelagic species such as dolphins, tuna and billfish (DoEE n.d.). Furthermore, Rowley Shoals provides important habitat, feeding, resting and breeding grounds for a number of migratory birds, including the red-tailed tropicbird, white-tailed tropicbird and little tern.

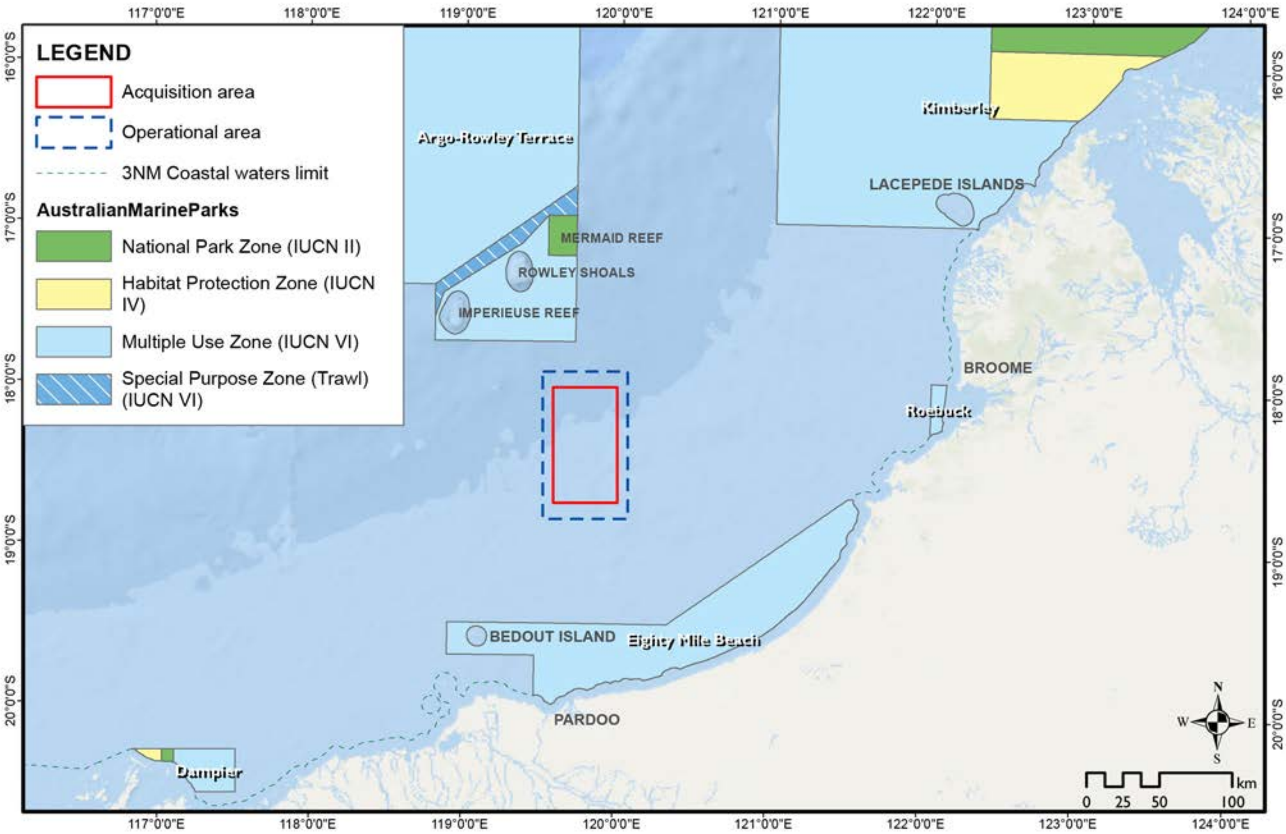


Figure 4-15 – Commonwealth and State Protected Areas

4.4.3 Key Ecological Features

KEFs are the parts of the marine ecosystem that are considered to be of importance for a marine region's biodiversity or ecosystem function and integrity (DoEE n.d.). KEFs have been identified by the Australian Government on the basis of advice from scientists about the ecological processes and characteristics of the area.

One KEF occurs within the Operational Area (the ancient coastline at 125 m depth contour), and two KEFs occur within the wider EMBA (the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals, and the Continental Slope Demersal Fish Communities) (Figure 4-16). These KEFs are described below.

4.4.3.1 Ancient Coastline At 125 m Depth Contour

Several steps and terraces as a result of Holocene sea level changes occur in the region with the most prominent of these features occurring as an escarpment along the NWS and Sahul Shelf at a water depth of 125 m. These steps and terraces form the ancient coastline at 125 m depth contour KEF, which covers an area of approximately 16,190 km^2. The ancient coastline at 125 m depth contour is defined as a key ecological feature as it is a unique sea floor feature with ecological properties of regional significance. The ancient coastline is not continuous and is fragmented along the 125 m depth contour.

Where the ancient, submerged coastline provides areas of hard substrate, it may contribute to higher diversity and enhanced species richness relative to soft sediment habitat (DSEWPaC 2012d). Parts of the ancient coastline, represented as rocky escarpment, are considered to provide biologically important habitat in an area predominantly made up of soft sediment.

The topographic complexity of escarpments associated with this feature may facilitate vertical mixing of the water column, providing relatively nutrient-rich localised environments. Migratory pelagic species (e.g. Humpback whales and whale sharks) may use this escarpment as a guide.

Although the ancient coastline adds habitat types to a representative system, the habitat types are not unique to the coastline as they are widespread on the upper shelf (Falkner *et al.* 2009).

The Operational Area and the wider EMBA overlap with the ancient coastline at 125 m depth contour. In particular, the Operational Area spatially covers approximately 1,535 km^2 or 9% of the KEF.

4.4.3.2 Mermaid Reef and Commonwealth Waters Surrounding Rowley Shoals

Mermaid Reef and Commonwealth waters surrounding Rowley Shoals are regionally important in supporting high species richness, higher productivity and aggregations of marine life associated with the adjoining reefs themselves. The Mermaid Reef and Commonwealth waters surrounding Rowley Shoals are listed as a KEF due to its high productivity and aggregations of marine life. The Rowley Shoals are a collection of three atoll reefs, Clerke, Imperieuse and Mermaid. Mermaid Reef lies 29 km north of Clerke and Imperieuse reefs and is totally submerged at high tide. Mermaid Reef falls under Commonwealth jurisdiction (DOEE 2019). Clerke and Imperieuse reefs constitute the Rowley Shoals Marine Park, which falls under Western Australian Government jurisdiction (EA 2000).

The reefs provide a distinctive biophysical environment in the region, with steep and distinct reef slopes, which attract a range of migratory pelagic species and associated fish communities. In evolutionary terms, the reefs may play a role in supplying coral and fish larvae to reefs further south via the southward flowing Indonesian Throughflow. The Rowley Shoals are known to contain 214 coral species and approximately 530 species of fishes, 264 species of molluscs and 82 species of echinoderms (Done *et al.* 1994; Gilmour *et al.* 2007).

Rowley Shoals' reefs are different from other reefs in the chain of reefs on the outer shelf of the North-west Marine Region, both in structure and genetic diversity as there is little connectivity between Rowley Shoals and other outer-shelf reefs (Done *et al.* 1994; Hooper and Ekins 2004; Underwood *et al.* 2009). An additional difference is that sea snakes do not occur at the Rowley Shoals (Done *et al.* 1994).

The wider EMBA overlaps with the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals, while the Operational Area is located approximately 46 km north-east away from the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals.

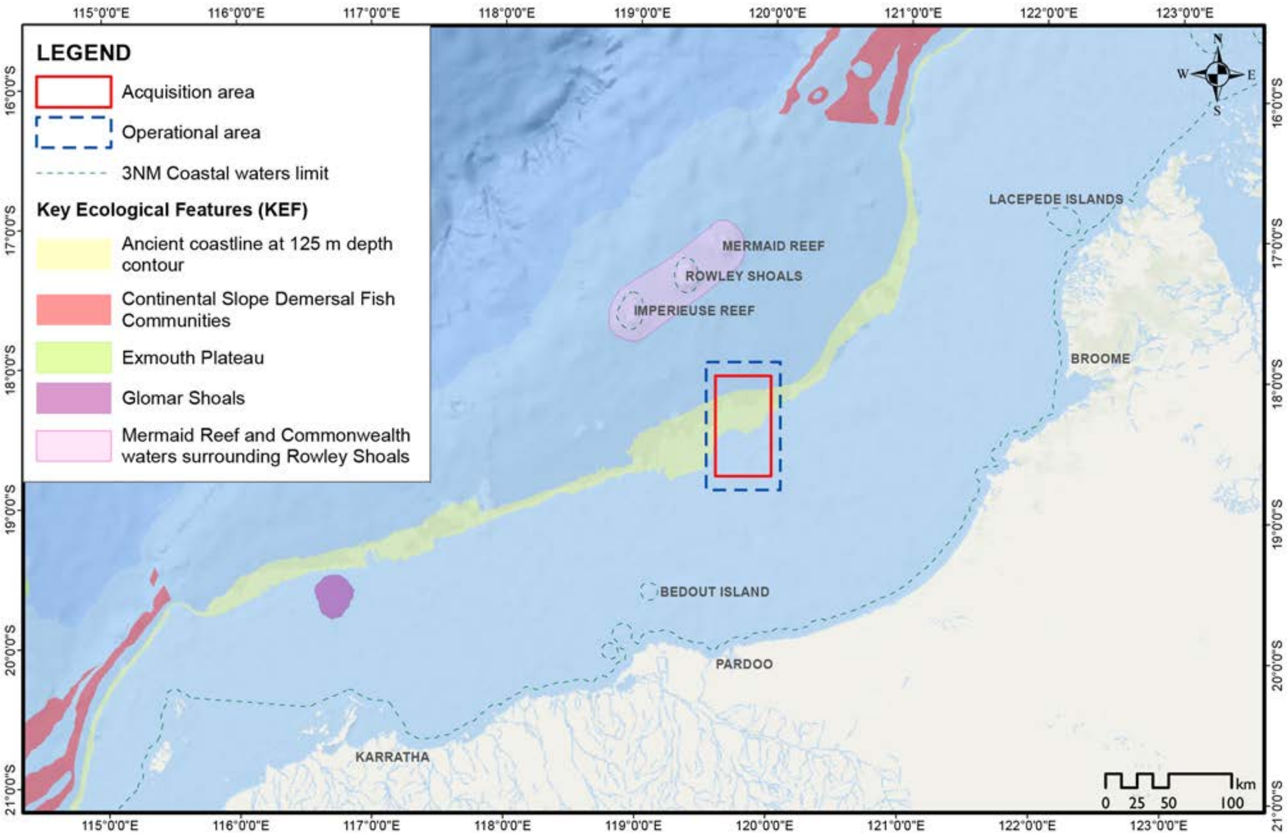


Figure 4-16 – Key Ecological Features

4.4.4 Commercial Fisheries

Commercial fishing in Western Australia is comprised of WA state managed fisheries and Commonwealth managed fisheries, and is mainly based on low-volume, high-value products (DPIRD, 2018).

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 the Operational Area and EMBA include the:

- Southern Bluefin Tuna Fishery (SBTF)
- Western Tuna and Billfish Fishery (WTBF)
- Western Skipjack Tuna Fishery (WSTF)
- North-West Slope Trawl Fishery (NWSTF).

The Department of Primary Industries and Regional Development (DPIRD) manage fisheries that take place predominantly within the offshore waters of Western Australia and within 3 nm of the coastline. WA state managed fisheries with management boundaries that overlap the Operational Area include the:

- Mackerel Managed Fishery (MMF)
- Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)
- Pilbara Trap Managed Fishery (PTMF)
- Pilbara Line Fishery (PLF)
- Northern Demersal Scalefish Managed Fishery (NDSMF)
- Nickol Bay Prawn Managed Fishery (NBPMF)
- Beche-de-mer Managed Fishery
- Marine Aquarium Managed Fishery (MAMF)
- Specimen Shell Managed Fishery (SSMF)
- Western Australian North Coast Shark fishery (WASF).

The Commonwealth and WA state managed commercial fisheries with the licence to operate within the Operational Area and/or EMBA are described in Table 4-11.

Table 4-11 – Commonwealth and WA State Managed Fisheries

Fishery	Operational Area	EMBA	Description	Catch/effort potentially in the Operational Area	Relevance to EP
Commonwealth Managed Fisheries					
Southern Bluefin Tuna Fishery (SBTF)	✓	✓	The SBTF management area covers the entire Australian Fishing Zone and overlaps with the Operational Area. The fishery targets Southern bluefin tuna (*Thunnus maccoyii*) using purse seine, pelagic longline and some minor line. The SBTF fishing season runs for 12 months, beginning 1 December. In the 2016–2017 fishing season, 22 active vessels caught 5,334 tonnes of Southern bluefin tuna (Patterson *et al.* 2018). Effort is concentrated in the Great Australian Bight and no catch or effort from the SBTF occurs in WA. The only known spawning grounds of the Southern bluefin tuna occurs in the Java Sea, beyond the wider EMBA.	X	No effort from the SBTF occurs in Western Australia. Therefore, the activities of the SBTF are considered to be outside the scope of this EP.
Western Tuna and Billfish Fishery (WTBF)	✓	✓	The WTBF management area covers the western portion of the AFZ from the SA–Victorian border to the Cape York Peninsula and overlaps with the Operational Area. The fishery targets bigeye tuna (*Thunnus obesus*), yellowfin tuna (*T. alacares*), striped marlin (*Kajikia audax*), swordfish (*Xiphias gladius*), and albacore (*T. alalunga*) using pelagic longline, minor line and purse seine. The WTBF fishing season runs for 12 months, beginning 1 February. In the 2016-2017 season, four active vessels caught 322 tonnes of the various target species (Patterson *et al.* 2018). The WTBF typically fish in Australia's Economic Zone and the high seas of the Indian Ocean. In recent years, effort has been concentrated off south-west Western Australia and South Australia.	X	The Operational Area partially overlaps with the management area of the WTBF; however, the proposed survey is not expected to affect the actual activities of this fishery.
Western Skipjack Tuna Fishery (WSTF)	✓	✓	Australia's Skipjack Tuna Fishery is divided into the Eastern Skipjack Tuna Fishery and the Western Skipjack Tuna Fishery (WSTF). As a whole, the Skipjack Tuna Fishery covers the entire Australian Fishing Zone. The WSTF management area covers the western portion of the AFZ from the SA–Victorian border to the Cape York Peninsula and overlaps with the Operational Area. The management boundaries also reflect the two stocks of Skipjack tuna in Australia, one on the east coast and the other on the west coast. The fishery targets Indian Ocean Skipjack tuna (*Katsuwonus pelamis*) using purse seine (predominant) and pole-and-line methods. There has been no fishing effort of Western skipjack tuna since the 2008–2009 season.	X	The Operational Area partially overlaps with the management area of the WTBF; however, the proposed survey is not expected to affect the activities of this fishery since the fishery has been inactive since 2008.
North-West Slope Trawl Fishery (NWSTF)	X	✓	The NWSTF management boundary is located from the coast of the Prince Regent National Park to Exmouth, between the 200 m depth contour to the outer limit of the Australian Fishing Zone. The Operational Area is located approximately 10 km south-east of the NWSTF boundary (Figure 4-17). The fishery targets Scampi (*Metanephrops australienis, M. boschmai*, and *M. velutinus*) using demersal trawl. The NWSTF fishing season runs for 12 months, beginning 1 July. In the 2016–2017 season, two active vessels caught 57.8 tonnes of Scampi (Patterson *et al.* 2018). Effort is concentrated mostly towards the 200 m isobaths boundary of the NWSTF from north of the Montebello Islands to Scott Reef.	X	No effort occurs within the Operational Area.
State Managed Fisheries					
Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)	✓	✓	This fishery is licensed to fish in the offshore waters of the Pilbara region, subject to specific closure areas (Figure 4-18). The PFTIMF targets red emperor (*Lutjanus sebae*); bluespotted emperor (*Lethrinus punctulatus*); and rankin cod (*Epinephelus multinotatus*) and a variety of other demersal snappers, emperors and groupers using demersal trawl techniques. Trawl fishing is permitted in the southern third of the Operational Area. Of the total commercial catches of demersal scalefish in the Pilbara in 2017–2018 (2,529 t), the majority (71%, 1,795 t) was landed by the trawl sector (Newman *et al.* 2019). This has been a common pattern in previous years when between 66% and 78% of the retained catch in the Pilbara demersal scalefish fisheries was retained by the trawl sector, with the trap and line fisheries making up significantly smaller catches. Three vessels were active in the fishery between 2013–2014 and 2015–2016, reducing to two vessels in the 2016–2017 and 2017–2018 seasons (Newman *et al.* 2018a, 2019). Total catch by the trawl sector has increased steadily in the same period with 1,105 t, 1,172 t, 1,529 t, 1,795 t, 1,975 t and 1,977 t retained in 2014, 2015, 2016, 2017, 2018 and 2019 respectively (Newman *et al.* 2018a, 2019, Gaughan and Santoro 2020).	✓	The Operational Area overlaps with the management area of the PFTIMF, and trawl fishers may be active within this overlap. There is low catch and fishing effort within the Operational Area, relative to other areas within the fishery (refer to Section 4.4.4.1).
Pilbara Trap Managed Fishery (PTMF)	✓	✓	This fishery is licensed to fish in the offshore waters of the Pilbara region, subject to specific closure areas (Figure 4-18). The PTMF targets red emperor (*Lutjanus sebae*); bluespotted emperor (*Lethrinus punctulatus*); and rankin cod (*Epinephelus multinotatus*) using fish traps. In the 2016 fishing season, three vessels reported a total catch of 495 tonnes (Newman *et al.* 2018a). Current data indicate that fishers have potentially been active in the Operational Area between 2013–2017 (DPIRD 2019b). In the 2018/19 season a total commercial catch of 563 t was reported (Gaughan and Santoro 2020).	✓	The Operational Area overlaps with the management area of the PTMF. There is low catch and fishing effort within the Operational Area, relative to other areas within the fishery (refer to Section 4.4.4.1).
Pilbara Line Fishery (PLF)	✓	✓	This fishery is licensed to fish in the offshore waters of the Pilbara region and operates as an exemption-based fishery. The PLF targets pink snapper (*Pagrus auratus*), red emperor (*Lutjanus sebae*); bluespotted emperor (*Lethrinus punctulatus*); and rankin cod (*Epinephelus multinotatus*) using pole-and-line techniques. In the fishing season 2018/19 a total catch of 93 t was reported.	X	The Operational Area overlaps with the management area of the PLF, however, there is no catch or fishing effort within the Operational Area (refer to Section 4.4.4.1).

Fishery	Operational Area	EMBA	Description	Catch/effort potentially in the Operational Area	Relevance to EP
Northern Demersal Scalefish Managed Fishery (NDSMF)	✓	✓	The Northern Demersal Scalefish Managed Fishery operates off the north-west coast of Western Australia. The NDMSF is divided into an inshore sector (Area 1), and an offshore sector (Area 2). Area 1 occurs between the high-water mark and the 30 m isobath where only line fishing is permitted. Area 2 extends from the 30 m isobath to the AFZ, and permits handline, dropline and fish traps. Fishing access to the research-fishing zone can only be facilitated through an agreed research Framework. The fishery targets goldband snapper (*Pristipomoides mutidens*); and red emperor (*Lutjanus sebae*) using trap and line techniques. The NDSMF season runs for 12 months from 1 January. In the 2018/19 fishing season, the fishery reported a total catch of 1,297 t (Gaughan and Santoro 2020).	✓	The Operational Area partially overlaps with Area 2 of the NDSF at the far eastern portion of the Operational Area and trap fishers may be active within this overlap. There is low catch and fishing effort within the Operational Area, relative to other areas within the fishery (refer to Section 4.4.4.1). The Acquisition Area does not overlap the NDSMF, and so the potential for interaction with fishers is limited.
Mackerel Managed Fishery (MMF)	✓	✓	The MMF is divided into three management areas, Area 1 (Kimberley), Area 2 (Gascoyne), and Area 3 (Gascoyne-West Coast). Each area has its own management arrangements. The MMF targets Spanish mackerel (*Scomberomorus commerson*) using surface trolling techniques. The MMF is predominately active in the North Coast and Gascoyne Coast Bioregions. The Area 2 (Pilbara) fishing season runs from 1 April to 30 September. In the 2018/19 season, the fishery reported 214 t of commercial catch and 21-31 t of recreational catch of Spanish mackerel (Gaughan and Santoro 2020).	X	The Operational Area overlaps with the management area of the MMF, however, there is no catch or fishing effort within the Operational Area (refer to Section 4.4.4.1).
Beche-de-mer Managed Fishery	✓	✓	The Beche-de-mer Managed Fishery is a nearshore hand-harvest fishery operating from Exmouth Gulf to the Northern Territory border. The fishery targets Sandfish (*Holothura scabra*); and Redfish (*Actinopyga echinities*) by nearshore diving and wading. In the 2016 fishing season, it was reported that there was a total catch of 93 tonnes. It should be noted, the majority of effort is concentrated around the Kimberley region. However, there have been several years where substantial effort was within the Pilbara region.	X	The Operational Area overlaps with the management area of the Beche-de-mer Managed Fishery. Since the Beche-de-mer Managed Fishery is shore-based, the proposed survey is not expected to overlap with the actual activities of this fishery.
Marine Aquarium Managed Fishery (MAMF)	✓	✓	The Marine Aquarium Managed Fishery is able to operate in all state waters (between the Northern Territory border and South Australia border). The MAMF sources up to 1,500 species of marine aquarium fishes, as well as coral, live rock, algae, seagrass and invertebrates. The fishery collects species by diving and hand collection. In 2018, the MAMF reported a total catch of ~27,300 fish, 219 syngnathid, ~61,600 invertebrates, ~11,400 kg of coral, ~4,800 sponges, among other marine organisms (Gaughan and Santoro 2020). Typically, the fishery is most active in waters south of Broome and the highest amount of effort is generally around the Capes region, Perth, Geraldton, Exmouth and Dampier.	X	The Operational Area overlaps with the management area of the MAMF; however the proposed survey is not expected to overlap with the actual activities of this fishery.
Specimen Shell Managed Fishery (SSMF)	✓	✓	The Specimen Shell Managed Fishery is based on the collection of individual shells for the purposes of display, collection, cataloguing, classification and sale. The fishery covers the entire coastline of Western Australia. The SSMF collects shells by hand by a small group of drivers in shallow waters or wading along coastal beaches. 7,628 shells distributed over 197 species were collected in the 2018 fishing season across 20 licence holders (Gaughan and Santoro 2020). The majority of effort is located adjacent to population centres such as Broome, Exmouth, Perth, Mandurah, the Cape Areas and Albany.	X	The SSMF management boundary overlaps with the Operational Area, however the proposed survey is not expected to impact the activities of this fishery.
Nickol Bay Prawn Managed Fishery (NBPMF)	✓	✓	The NBPMF operates along the western part of the North-West Shelf between Dampier and the western extend of Eighty Mile Beach. The fishery targets Banana prawns (Penaeus esculentus) using high opening otter trawl systems. The Nickol Bay Prawn Managed Fishery season is year-round, with designated nursery areas closed between August and November. In the 2018/19 season, a total catch of 81 t was reported (Gaughan and Santoro 2020).	X	The Operational Area partially overlaps with the management area of the NBPMF, however, there is no catch or fishing effort within the Operational Area (refer to Section 4.4.4.1).
Western Australia North Coast Shark Fishery (WASF)	✓	✓	The WASF management area extends from longitude 114°06´E (North West Cape) to 123°45´E (Koolan Island), however the area between North-West Cape and 120°E and all waters south of latitude 18°S has been closed indefinitely. The WASF targets Dusky whaler, Sandbar, Gummy and Whiskery sharks using demersal gillnets. No fishing activity has been recorded in the WASF since the 2008–2009 fishing season.	X	The WASF management boundary partially overlaps with the Operational Area, however the fishery has not been active since 2008. Therefore, the proposed survey is not expected to impact the activities of this fishery.

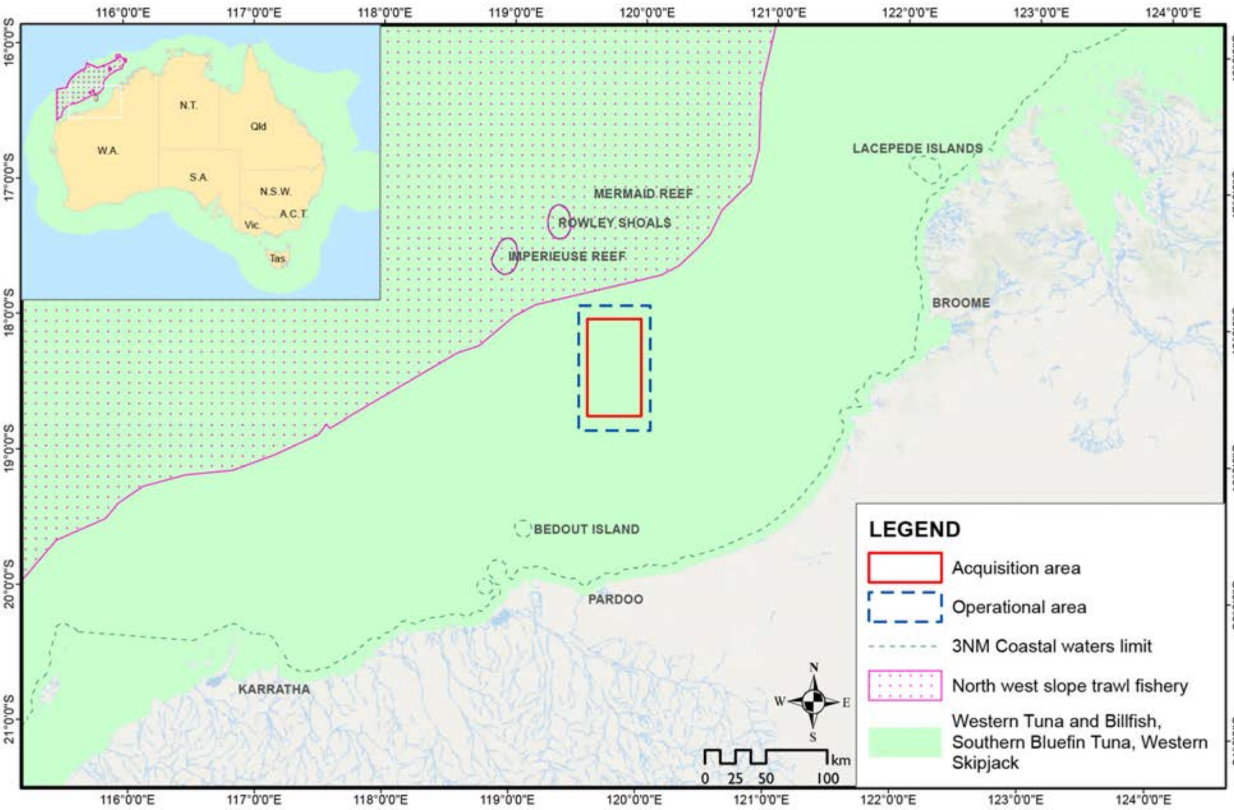


Figure 4-17 – Commonwealth Fisheries within the Operational Area and wider EMBA

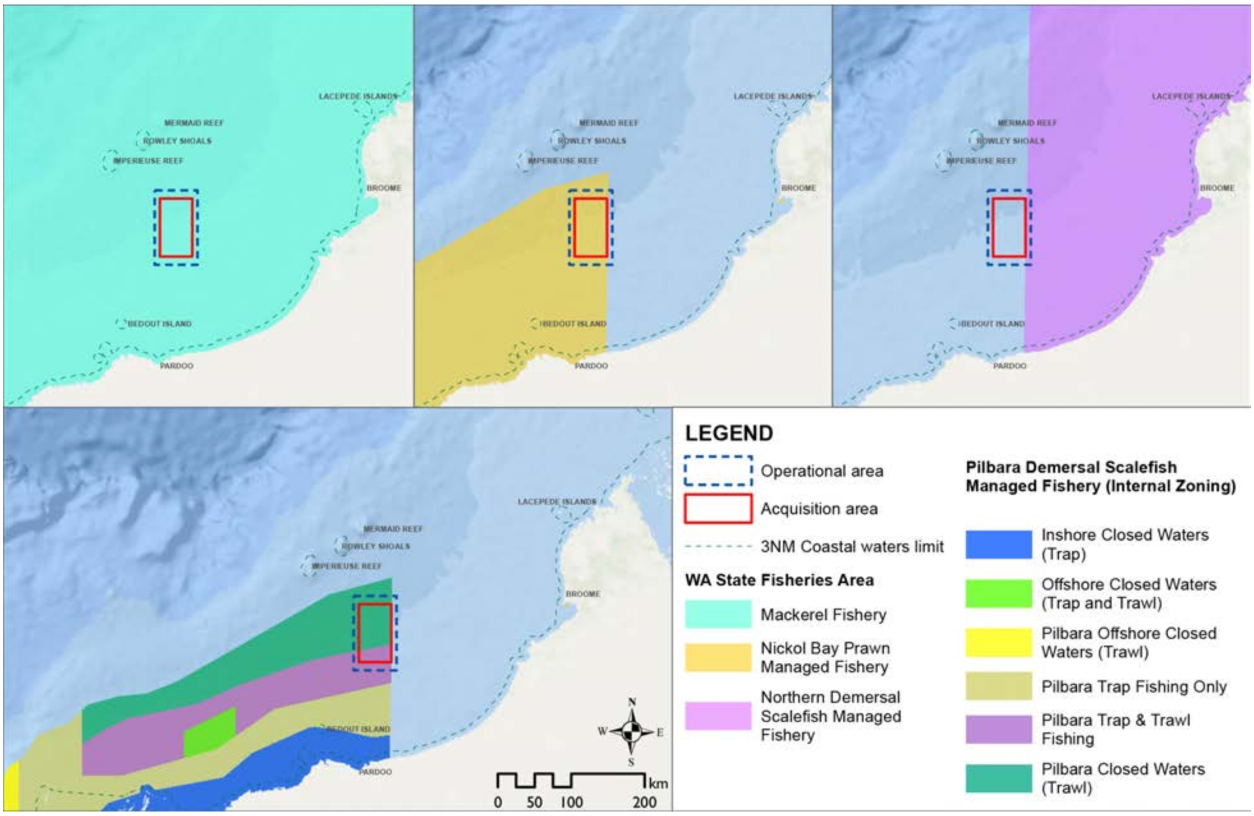


Figure 4-18 – WA State Fisheries within the Operational Area

4.4.4.1 Review of Catch and Effort Data

CGG requested annual catch and effort data (FishCube data) from DPIRD for WA managed fisheries understood to operate within or near to the Operational Area. FishCube data is not available for Commonwealth managed fisheries.

Data was assessed for 60 nm × 60 nm and for 10 nm × 10 nm Catch and Effort System (CAES) blocks for annual catch and effort data for each of the most recent five years of available data (2016–2020). 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
- 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 is unable to 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 month). Where this applies, the Vessel Count is marked 'Less than 3 vessels', 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.

It is important to recognise the limitations of referring to blocks with less than three vessels; although the number of vessels may be less than three, a block may experience high catch or effort by just one or two vessels. However, these blocks may experience less effort than other blocks where three or more vessels frequent the area to fish.

4.4.4.1.1 Mackerel Managed Fishery

Analysis of FishCube data shows that the Operational Area overlaps with approximately 29 km^2 of the area of fishing effort for the five-year period between 2016 and 2020 (Figure 4-19). This effort was by 'Less than 3 vessels' in September 2020. No other effort was recorded in this block for the five-year period between 2016 and 2020. In general for this fishery, fishing effort is located in shallower waters, approximately 10 km south-east of the Operational Area (Figure 4-19). Fishing effort occurs relatively consistently across the entire year with no identified peak periods.

4.4.4.1.2 Nickol Bay Prawn Managed Fishery

Analysis of FishCube data shows that the Operational Area does not overlap with the area of fishing effort for the five-year period between 2016 and 2020. Fishing effort is located in shallow nearshore waters, around bays and river mouths such as De Grey River mouth approximately 130 km south of the Operational Area between June and October.

4.4.4.1.3 Northern Demersal Scalefish Managed Fishery

Analysis of FishCube data shows that the Operational Area overlaps with approximately 532 km^2 of the area of fishing effort (Figure 4-20). The Acquisition Area does not overlap with the area of effort. The eastern edge of the Operational Area overlaps with the most westerly extent of fishing within the NDSMF and three of the four blocks that are reported to have been fished by less than three vessels during the entire five-year period from 2016 to 2020. The south eastern block that overlaps the Operational Area has Fishing effort that appears to be more greatly focussed on waters to the west of Broome, over 20 km to the east of the Operational Area (refer to Figure 4-20). Fishing effort occurs relatively consistently across the entire year with no identified peak periods.

4.4.4.1.4 Pilbara Demersal Scalefish Fisheries

Fishing effort within the Pilbara Demersal Scalefish Fisheries (PFTIMF, PTMF and PLF) is known to be highest in western areas of the fisheries, which are closest to the home ports of the fishers and have higher historical and current levels of effort compared to the eastern areas of the fisheries (where the Sauropod 3D MSS is located); these are more distant from port (i.e. there are increased fuel costs to operate further east) (Gaughan *et al.* 2018). It was further established by Santos during consultation with the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF) for their Keraudren 3D MSS that the main home port for the two main operators in the fisheries were Exmouth (MG Kailis) and Point Samson (Westmore Seafoods) (Santos 2020). Further analysis of the distribution of fishing effort for these fisheries, in relation to the Sauropod 3D MSS, is provided in the following subsections.

Pilbara Fish Trawl (Interim) Managed Fishery

FishCube data for the PFTIMF was only available in a coarse 60 nm CAES block resolution. As such, the area of fishing effort and overlap is likely to be overestimated, as fishing is likely limited spatially to discrete locations rather than over the entire area of the 60 nm blocks. Analysis of FishCube data shows that the Operational Area overlaps with approximately 1,360 km^2 of the area of fishing effort, and the Acquisition Area overlaps with approximately 3,500 km^2 of fishing effort. Reported fishing effort within the southern portion of the Operational Area is relatively low (56 days effort during the entire five-year period from 2016 to 2020). Fishing effort is more greatly focussed on waters south-west of the Operational Area and to the north-west of Dampier and Karratha (refer to Figure 4-21). Fishing effort occurs relatively consistently across the entire year with no identified peak periods.

Pilbara Line Fishery

FishCube data for the PLF was only available in a coarse 60 nm CAES block resolution. As such, the area of fishing effort and overlap is likely to be overestimated, as fishing is likely limited spatially to discrete locations rather than over the entire area of the 60 nm blocks. Analysis of FishCube data shows that the Operational Area does not overlap with the area of fishing effort for the five-year period between 2016 and 2020. Fishing effort is located in waters further to the south and west of the Operational Area, particularly near Dampier, Karratha, Onslow and Barrow Island. Fishing effort occurs between May to September each year.

Pilbara Trap Managed Fishery

FishCube data for the PFTIMF was only available in a coarse 60 nm CAES block resolution. As such, the area of fishing effort and overlap is likely to be overestimated, as fishing is likely limited spatially to discrete locations rather than over the entire area of the 60 nm blocks.

Analysis of FishCube data shows that the Operational Area overlaps with approximately 1,360 km^2 of the area of fishing effort, and the Acquisition Area overlaps with approximately 3,500 km^2 of fishing effort (Figure 4-22). The available FishCube data indicates a low level of activity in relation to the PFTIMF sector of the Pilbara Demersal Scalefish Fisheries (mentioned above), with less than three vessels typically fishing across the fishery. In 2018, the PTMF accounted for 11% of the total catch for the Pilbara Demersal Scalefish fisheries.

FishCube data reports that less than three vessels have typically operated in the Operational Area each year for the last five years (2016 - 2020), compared with greater fishing effort located to the south-west of the Operational Area, between Exmouth and Dampier (up to five vessels operating). Fishing effort occurs relatively consistently across the entire year with no identified peak periods.

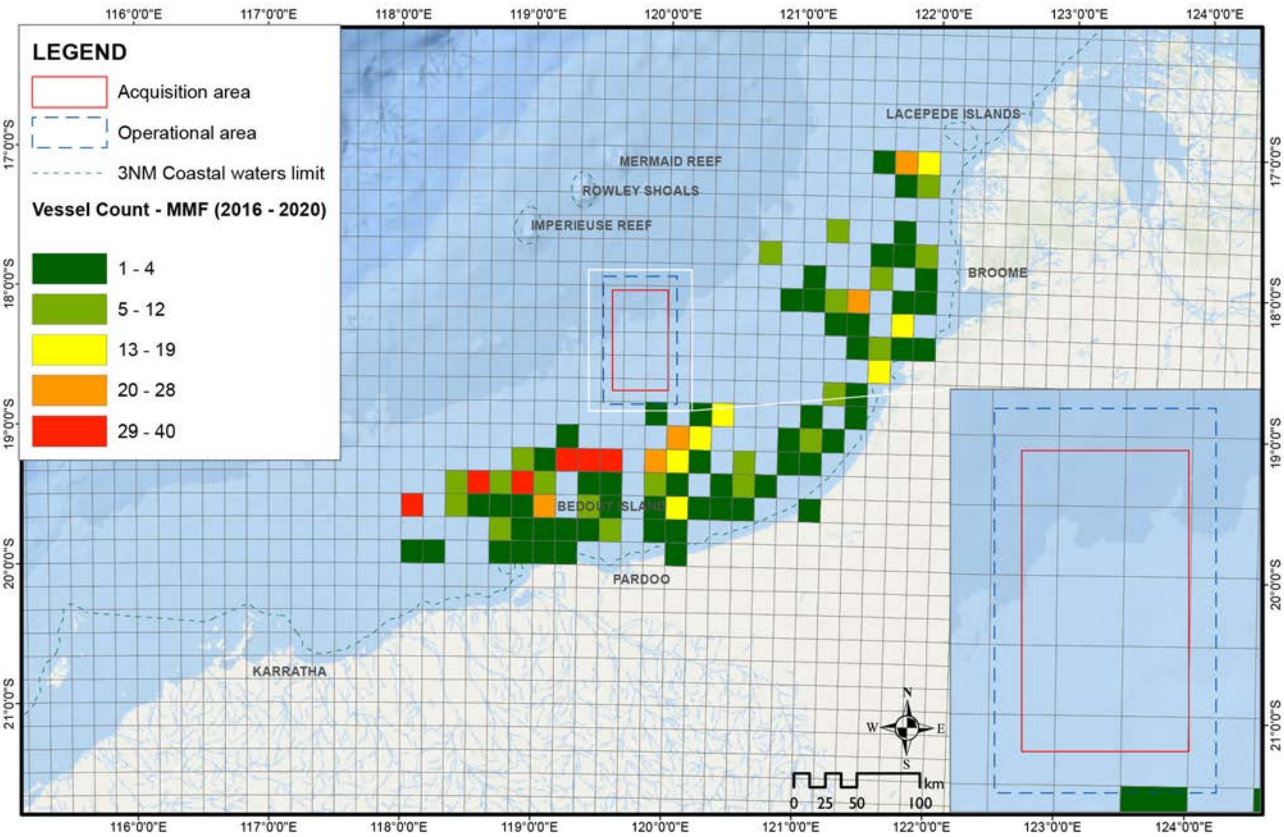


Figure 4-19 – Mackerel Managed Fishery Total Vessel Count (2016-2020)

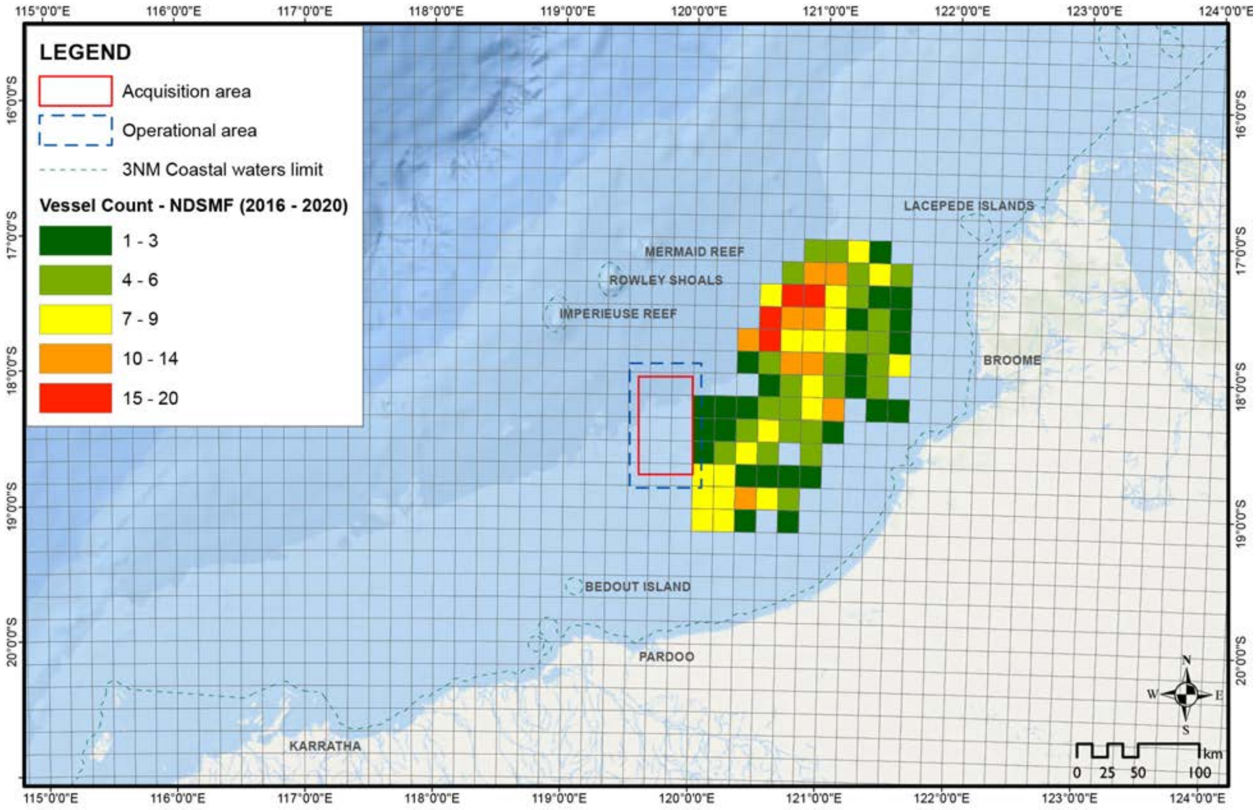


Figure 4-20 – Northern Demersal Scalefish Managed Fishery Total Vessel Count (2016-2020)

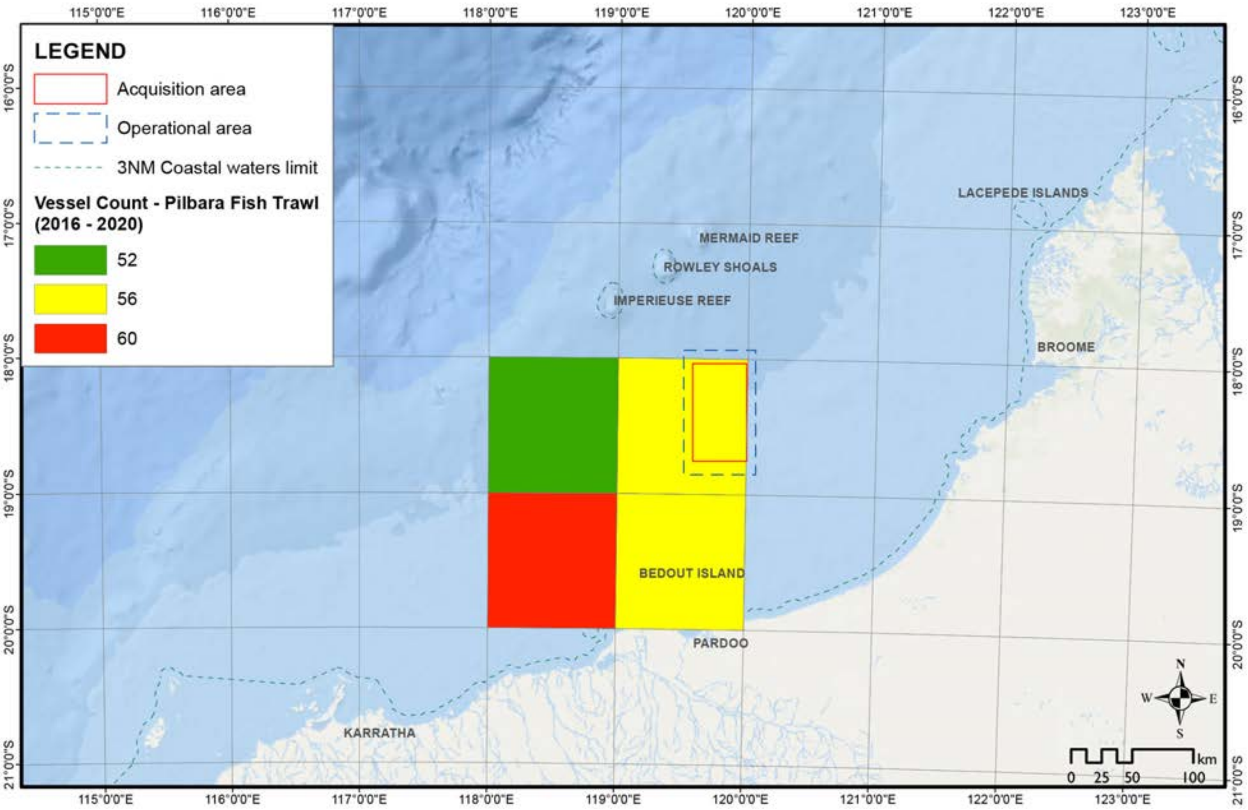


Figure 4-21 – Pilbara Fish Trawl (Interim) Managed Fishery Total Vessel Count (2016-2020)

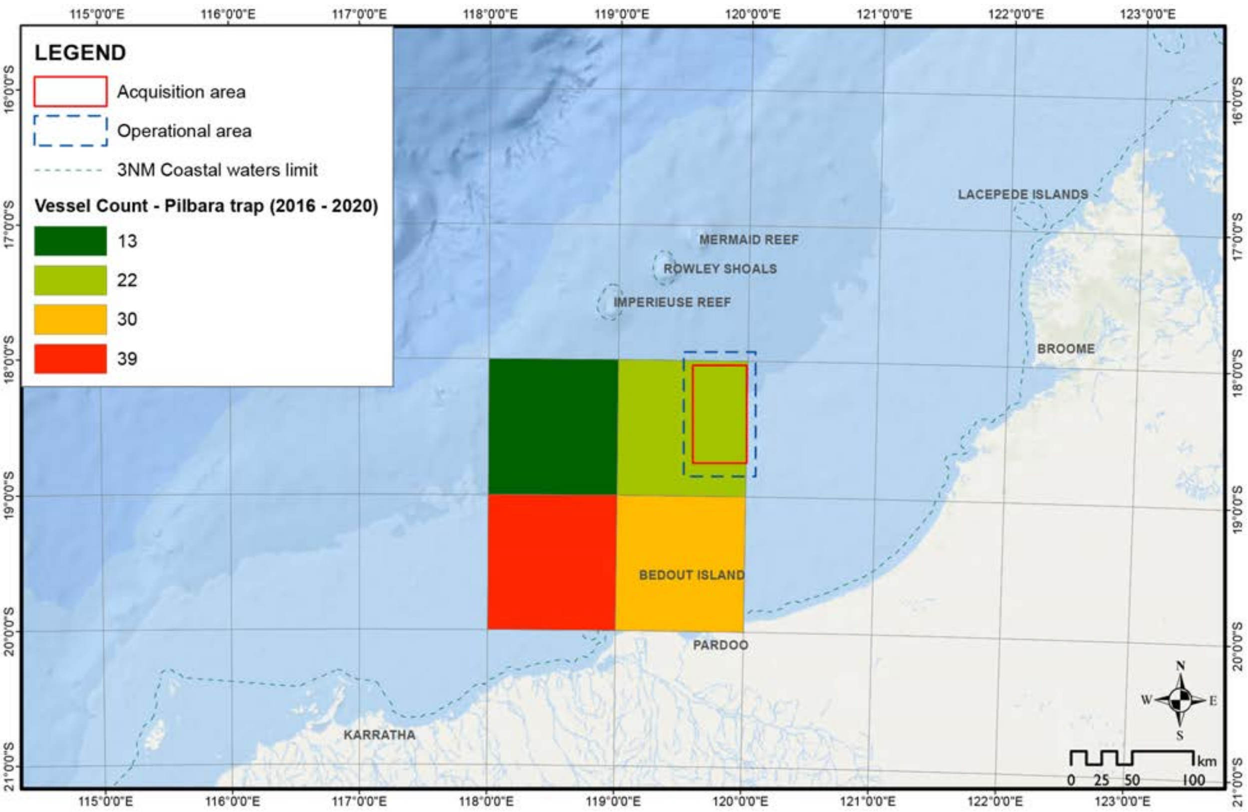


Figure 4-22 – Pilbara Trap Managed Fishery Total Vessel Count (2016-2020)

4.4.5 Tourism and Recreation

No tourism activities are known to take place specifically within the Operational Area; however, it is acknowledged that there are growing tourism and recreational sectors in north-west Western Australia. Potential for growth and further expansion in tourism and recreational activities in the Pilbara and Gascoyne regions is recognised, particularly with the development of regional centres and a workforce associated with the resources sector (Gascoyne Development Commission 2012).

Recreational fishing in the NSW bioregion is mainly concentrated on the continental shelf south of the Kimberley and within the North West Shelf Province, the Central Western Shelf Transition Province and the Central Western Shelf Province. An estimated 640,000 fishers participate in recreational fishing each year (Fletcher and Santoro 2012). Given the depth of waters (95 m–150 m) and the distance offshore, it is unlikely that recreational fishing occurs within the Operational Area.

Recreational fishing occurs at Rowley Shoals, which are located within the EMBA. However, Mermaid Reef that forms part of Rowley Shoals does not permit recreational fishing. Whilst recreational fishing does occur at Rowley Shoals, it is occasional due to the remote location. Clerke Reef and Imperieuse Reef are also subject to tourism, with charter boat operators taking visitors to these remote islands (Department of Environment and Conservation 2007). Scuba diving, snorkelling and other water sports are known to take place at the Rowley Shoals (Department of Environment and Conservation 2007). Boat charter trips of two days or longer regularly visit the Rowley Shoal between September to December when conditions are at their best (Tourism Western Australia 2019).

4.4.6 Oil and Gas Activities

The region currently supports a number of industries including petroleum exploration and production. Petroleum titleholders with titles that are adjacent to the Operational Area are listed in Table 4-12.

A number of other seismic surveys may take place in the region. Based on the information published on the NOPSEMA website (EPs that are either accepted or under assessment), the other seismic surveys that have the potential to occur in 2022 are presented in Table 4-13. The extent of seismic activities in the vicinity of the title area in the previous year is detailed in Table 4-14.

Table 4-12 – Oil and Gas Permits Relevant to the Operational Area

Permit	Permit Type	Operator	Distance from the Operational Area
WA-487-P	Exploration Permit	Pathfinder Energy Pty Ltd	Within Operational Area
WA-436-P	Access Authority	Santos WA Northwest Pty Ltd	Within Operational Area
WA-438-P	Exploration Permit	Santos WA Northwest Pty Ltd	Within Operational Area
WA-533-P	Exploration Permit	INPEX Browse E and P Pty Ltd	63 km east
WA-435-P	Exploration Permit	Santos WA Northwest Pty Ltd	51 km west

Table 4-13 – Other Potential Seismic Surveys Occurring in 2022 within 150 km of the Sauropod 3D MSS

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
Santos Limited, Keraudren Extension 3D MSS	The full-fold acquisition area is 8,620 km^2.	The Keraudren Extension 3D MSS ramp-up zone and full power zone partially overlap with the western edge of the Sauropod 3D MSS Acquisition Area. A maximum of 132–162 days of acquisition is proposed.	Seismic acquisition is planned to occur between 1 February–31 July in 2020, 2021 and 2022.*	Accepted and valid to 2022.

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
INPEX Browse EandP Pty Ltd, 2D Seismic Survey (WA-532-P, WA-533-P, WA-50-L)	The Acquisition Area is 65,138 km^2.	The Sauropod Acquisition Area is located approximately 70 km south-west of the INPEX 2D Acquisition Area.	1 November 2020–31 December 2023. No seismic acquisition between 1 June–31 October 2020 or 2021. A maximum of 210 days of acquisition is proposed.	The EP is accepted and valid to 2023
PGS Australia Pty Ltd, Rollo Multi-client Marine Seismic Survey	The Operational Area is 117,833 km^2. Note – Based on restrictions in the EP, it has been assumed that acquisition is limited to a maximum of 25,000 km^2 per calendar year.	The Sauropod Acquisition Area is located approximately 60 km east of the Rollo-Beagle Operational Area.	The specific commencement dates and durations of individual surveys have not been confirmed.	Accepted and valid to 2023.
TGS-NOPEC Geophysical Company Pty Ltd, Capreolus-2 3D MSS	The Acquisition Area is 26,897 km^2. Acquisition is limited to a maximum of 10,000 km^2 per calendar year.	The Sauropod 3D MSS Acquisition Area is located approximately 140 km east of the TGS Acquisition Area.	Oct 2020–Dec 2024. The specific commencement dates and durations of individual surveys have not been confirmed.	Accepted and valid to 2024

*Some acquisition has occurred in 2021, see Table 4-14.

Table 4-14 – Extent of seismic activities in within 150 km of the survey area in the past 5 years

Survey Name	Survey Location	Survey Timing and Duration
Santos Limited, Keraudren Extension 3D MSS	The Keraudren Extension 3D MSS ramp-up zone and full power zone partially overlap with the western edge of the Sauropod 3D MSS Acquisition Area.	Seismic acquisition is planned to occur between 1 February–31 July in 2020, 2021 and 2022.*
Santos WA Northwest Pty Ltd, Keraudren 3D	Sauropod Acquisition Area is located approximately 40 km from the Keraudren survey area.	Acquired May – July 2019
Searcher Seismic Pty Ltd Bilby 2D Phase 3 Multi-client Marine Seismic Survey	The Sauropod 3D MSS Acquisition Area overlaps with the area acquired by Searcher (i.e. Bilby survey area).	Completed between June – July 2016.
TGS-NOPEC Canning-Northern Carnarvon Multi Client Marine Seismic Survey	Sauropod Acquisition Area overlaps approximately 500 km^2 of the TGS survey area.	Completed between June – September 2016.

*Further acquisition is planned for 2021/22.

4.4.7 World, National and Indigenous heritage Areas

World Heritage sites are natural or manufactured sites, areas, or structures recognised as being of outstanding universal value by the United Nations Educational, Scientific and Cultural Organization (UNESCO). There are no World or National Heritage sites within the Operational Area.

Australia's National Heritage List contains natural, historic and Indigenous places of significance to the nation and are protected under the EPBC Act (DoEE n.d.). One Commonwealth Heritage listed place occurs within the EMBA, the Mermaid Reef – Rowley Shoals. Mermaid Reef – Rowley Shoals was listed for values meeting Category A, B, C and D of the Commonwealth Heritage List criterion (Commonwealth of Australia n.d.). The significance and values of Mermaid Reef and the Rowley Shoals are described above in Section 4.4.1.2 and Section 4.4.2.1.

There are no known sites of Indigenous cultural heritage significance within the Operational Area or the wider EMBA. The closest recorded sites of Indigenous significance and occur terrestrially, approximately 72 km south-west of Broome and around the Port Hedland area (DPLH 2019).

4.4.8 Ramsar Wetlands

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.). No Ramsar wetlands occur within the Operational Area or EMBA. The closest Ramsar wetlands are located in the coastal waters of Eighty Mile Beach, approximately 113 km south-east of the Operational Area and beyond the wider EMBA.

4.4.9 Marine Archaeology

All shipwrecks more than 75 years old are protected under the Underwater Cultural Heritage (Consequential and Transitional Provisions) Act 2018 (DAWE n.d.). A search of the National Shipwreck Database (DoEE 2019b) indicated that no known historic shipwrecks occur within the Operational Area. The closet known wreck is the *Koombana* near Bedout Island and is approximately 86 km south-west of the Operational Area. Five other wrecks are situated near the Operational Area (

Table 4-15); however, none are listed as a Protected Place under the EPBC Act.

Table 4-15 – Recorded Shipwrecks Near the Operational Area

Vessel Name	Year Wrecked	Wreck Location	Distance from Operational Area
Koombana	1908	Bedout Island	86 km south-west
Lively	1810	Mermaid Reef	93 km north
Korda	1903	Cape Frezier	98 km east
See Taube	1954	Rowley Shoals	130 km north-east
Pelsart (Pelsaert)	1908	Rowley Shoals	130 km north-east
Alfred	1908	Rowley Shoals	130 km north-east

4.4.10 Commercial Shipping

The Pilbara offshore region facilities high shipping activity associated with mining and oil and gas activities. Port Hedland is the closest major port to the Operational Area, which is also the world's largest bulk export port. Vessels transiting the region during the proposed survey will primarily include oil tankers, bulk carrier ships and general cargo ships.

AMSA has introduced a network of marine fairways on the NWS of WA to reduce the risk of vessel collisions with offshore infrastructure. None of these fairways intersect with the Operational Area, however one fairway facilitating heavy traffic lies approximately 1 km north-west of the Operational Area (Figure 4-23). AMSA confirmed that only light traffic occurs within the Operational Area. Moderate to heavy shipping traffic occurs within the wider EMBA and is generally confined to the AMSA shipping fairways.

4.4.11 Defence Activities

The Department of Defence operates military firing practice and exercise areas at several locations around Australia. There are no designated defence practice areas within the Operational Area. The closest designated defence practice area is located on the Dampier Peninsula, approximately 127 km east of the Operational Area and partially within the wider EMBA. A search of the Department of Defence’s unexploded ordinance (UXO) map confirmed UXO are not known to occur within the Operational Area or EMBA (AGDD, 2021)

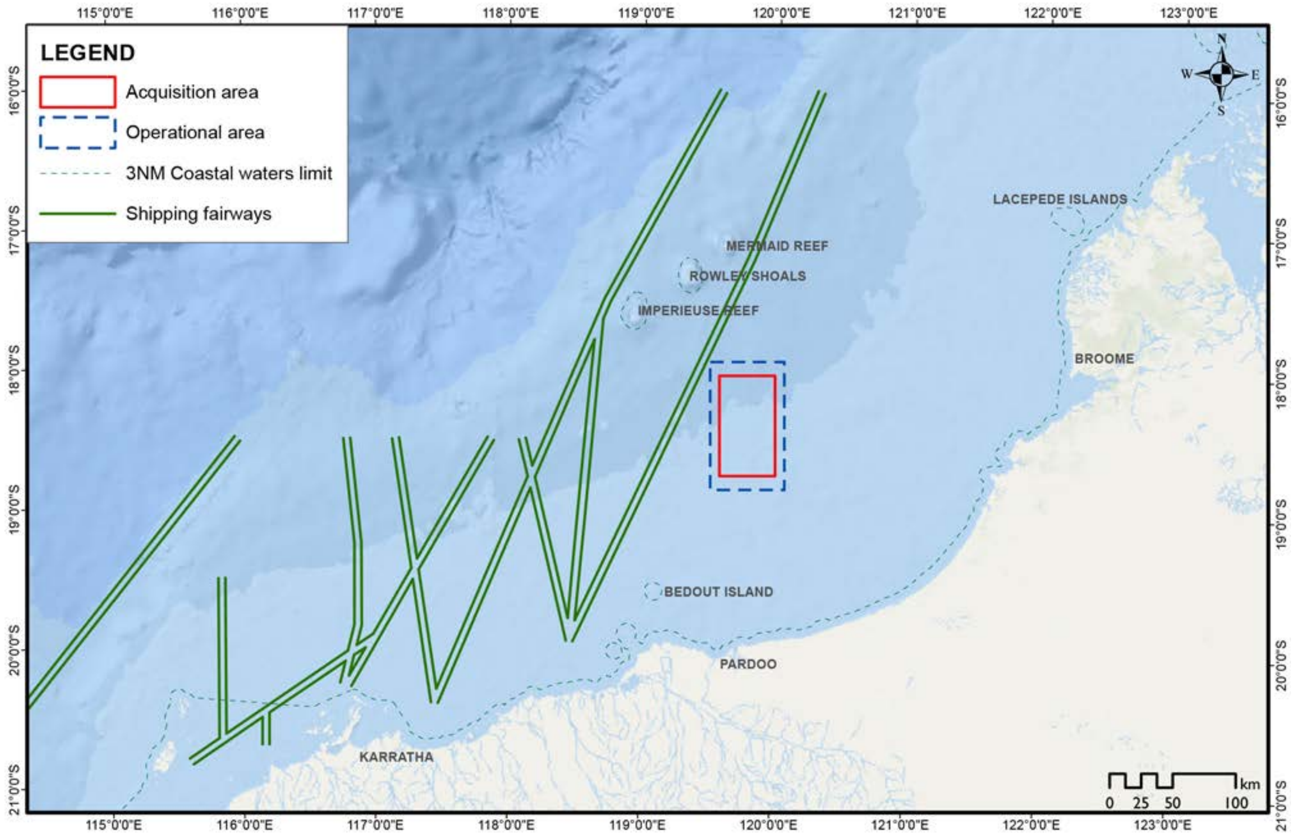


Figure 4-23 – Commercial Shipping

5 Stakeholder Engagement

For the purpose of this EP, and in accordance with Regulation 11A of the OPGSS (E) Regulations, relevant stakeholders are defined as person(s) whose functions, interests or activities may be affected by the activities to be carried out under the EP. This may include persons who could be affected during emergency conditions.

5.1 Consultation Approach

Consultation has been planned and undertaken with the aim of:

- Informing relevant stakeholders of the 3D seismic survey
- Gathering information about the stakeholders' interests and activities in the Operational Area during the period over which the survey is proposed to be conducted
- Providing stakeholders with the opportunity to raise issues and concerns about the survey.

The consultation approach has been guided by the following:

- NOPSEMA's Information Paper: Consultation Requirements under the OPGGS (E) Regulations 2009
- NOPSEMA's Guidance Note: Petroleum Activities and Australian Marine Parks. June 2020
- WA DMIRS Consultation Guidance Note: For the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
- AFMA's Guidelines Form Petroleum Industry Consultation with AFMA (AFMA 2015)
- DoIIS Guidance – Offshore Petroleum and Greenhouse Gas Activities: Consultation with Australian Government agencies with responsibilities in the Commonwealth Marine Area
- WA DPIRD Fisheries Guidance Statement: Oil and gas industry consultation with the Department (2013)
- WA DoT Guidance Statement for Marine Oil Pollution: Response and Consultation Arrangements (2018)
- Commonwealth of Australia inquiry report - Making waves: the impact of seismic testing on fisheries and the marine environment (2021).

5.2 Relevant Stakeholders

Relevant stakeholders were identified by considering interests and activities that occur within or around the Operational Area. The survey activities, timing and potential environmental impacts and risks of both planned activities and potential unplanned events were also taken into consideration during the stakeholder identification process.

Relevant stakeholders were identified as:

- Departments and agencies of the Commonwealth and the State of Western Australia to which the activities to be carried out may be relevant
- Persons and organisations whose functions, interest or activities may be affected by the 3D seismic survey activities to be carried out
- Any other person or organisation that CGG considers relevant.

The identified relevant stakeholders are listed in Table 5-1.

Relevant stakeholders were then reviewed to understand how the survey activities may affect the person or the organisation's functions, interest and activities and the most appropriate method of consultation to be utilised.

CGG understands that the list of relevant stakeholders is not exhaustive and additional stakeholders may be identified as part of ongoing consultation. Should additional stakeholders be identified prior to, or during the survey, these stakeholders will be contacted, provided appropriate information about the survey and invited to make comment. Evidence of additional stakeholder consultation will be documented in the Stakeholder Consultation Log (Appendix C:). The Stakeholder Consultation Log is a "living document" which will be updated throughout the survey and will be used during the post-survey review of environmental performance.

Fisheries stakeholders were identified from the AFMA and DPIRD (Fisheries) annual status reports, based on their licence areas of operation and known activities (Section 4.4). Contact details (postal addresses) of individual licence holders were provided by DPIRD and AFMA.

Table 5-1 – Identified Relevant Stakeholders

Commonwealth Government	
Australian Border Force Australian Fisheries Management Authority (AFMA) Australian Hydrographic Office (AHO) Australian Institute of Marine Science (AIMS) Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australian Maritime Safety Authority (AMSA) Department of Agriculture, Water and the Environment – Biosecurity (Marine Pests)	Department of Agriculture, Water and the Environment - Fisheries Department of Infrastructure, Transport, Regional Development and Communications- Australian Communications and Media Authority (subsea cables) Department of Industry, Science, Energy and Resources Department of Defence Department of Agriculture, Water and the Environment (DAWE) - Director of National Parks National Native Title Tribunal (NNTT)
Western Australian Government	
Department of Mines, Industry Regulation and Safety (DMIRS) Department of Primary Industries and Regional Development (DPIRD) - Fisheries WA Department of Transport - Marine (DoT WA)	
Other Relevant Parties	
Australian Marine Oil Spill Centre (AMOSC) INPEX Browse E&P Pty Ltd Pathfinder Energy Pty Ltd PGS Australia Pty Ltd TGS-NOPEC Geophysical Company Pty Ltd Searcher Seismic	Santos WA Northwest Pty Ltd Kimberley Land Council (KLC) Conservation Council of WA (CCWA) Wilderness Society World Wildlife Fund for Nature (WWF) Tourism Western Australia
Commercial and Recreational Fisheries and Representative bodies	
Western Australian Fishing Industry Council (WAFIC) Pearl Producers Association of WA (PPA) Australian Fisheries Management Authority - Commonwealth Fisheries Association (CFA) Australian Southern Bluefin Tuna Industry Association Mackerel Managed Fishery Pilbara Demersal - Line Fishery	Pilbara Demersal - Trap Fishery Pilbara Demersal - Trawl Fishery North Coast Prawn - Nickol Bay Prawn Fishery North-west Shelf Trawl Fishery Northern Demersal Scalefish Managed Fishery Recfishwest

5.3 Consultation Method

Initial stakeholder consultation consisted of an information sheet and map of the Operational and Acquisition Area (refer to the Sensitive Matters Report) distributed by email and post to relevant stakeholders as listed in Table 5-1 on 28th May 2021. The information presented in the information sheet was a general overview of the survey including location, extent, survey design and environmental setting. Proposed changes to the activity description, including source array and activity timing, were detailed. The proposed management measures, many of which were agreed through previous consultation with stakeholders, were also included where possible. A specific fisheries factsheet was sent to stakeholders with commercial fishery interests. Stakeholders were provided with a dedicated email address and phone number for the project to respond to the consultation documents.

The dedicated email address also aided in the tracking and recording of stakeholder and titleholder communication. Some stakeholders were contacted directly regarding information specific to the proposed activity that may potentially impact on the stakeholder.

Follow-up emails were completed as required following the distribution of the consultation information on 5th July 2021 to stakeholders that had not yet responded to consultation.

CGG has undertaken an assessment of the merit of any objections or claims by stakeholders. Where concerns, objections or claims have been raised by stakeholders, these have been addressed in the assessment of environmental impacts and risks (Section 7 and Section 8). Stakeholders have been informed about how the issues have been assessed and any relevant controls that will be adopted to reduce the potential impacts and risks to ALARP and acceptable levels.

Consultation will be ongoing throughout the life of the EP, as outlined in Section 9.

5.4 Consultation Results

A summary of the key issues and concerns raised by stakeholders during consultation, including an assessment of the merits of objections and claims are provided in Appendix C:.

Full copies of the consultation records are included in the Sensitive Matters Report.

5.5 Public comment

The public were invited to comment on the contents of this environment plan over a period of 30 days after this EP was published on the NOPSEMA website under Regulations 9(AB) and 11(B) in September 2019. CGG published notices inviting comments on the EP within the designated comment period, including in:

- The CGG website
- A national newspaper – The Australian
- A state-wide daily newspaper – The West Australian
- Regional newspaper close to location of the activity – The North West Telegraph.

Copies of these notices are included in the Sensitive Matters Report.

There were no comments received during the public comment process. As such, CGG is not required to submit a report on public comment.

6 Environmental Risk Assessment Methodology

6.1 Introduction

Regulations 13(5) and 13(6) of the OPGGS(E) Regulations require CGG to identify, analyse and evaluate the risks and potential environmental impacts associated with the Sauropod 3D MSS.

CGG's impact and risk management process is based on the principles, framework and processes defined by the International Standards Organization (ISO) 31000:2009 Risk Management – Principles and Guidelines (Figure 6-1). The following sections describe the steps in the risk management process, including the legislative framework, approach taken to identify and evaluate potential impacts associated with the activity and risk treatment (control) measures that will be adopted to reduce the impacts and risks to as low as reasonably practical (ALARP) and to an acceptable level.

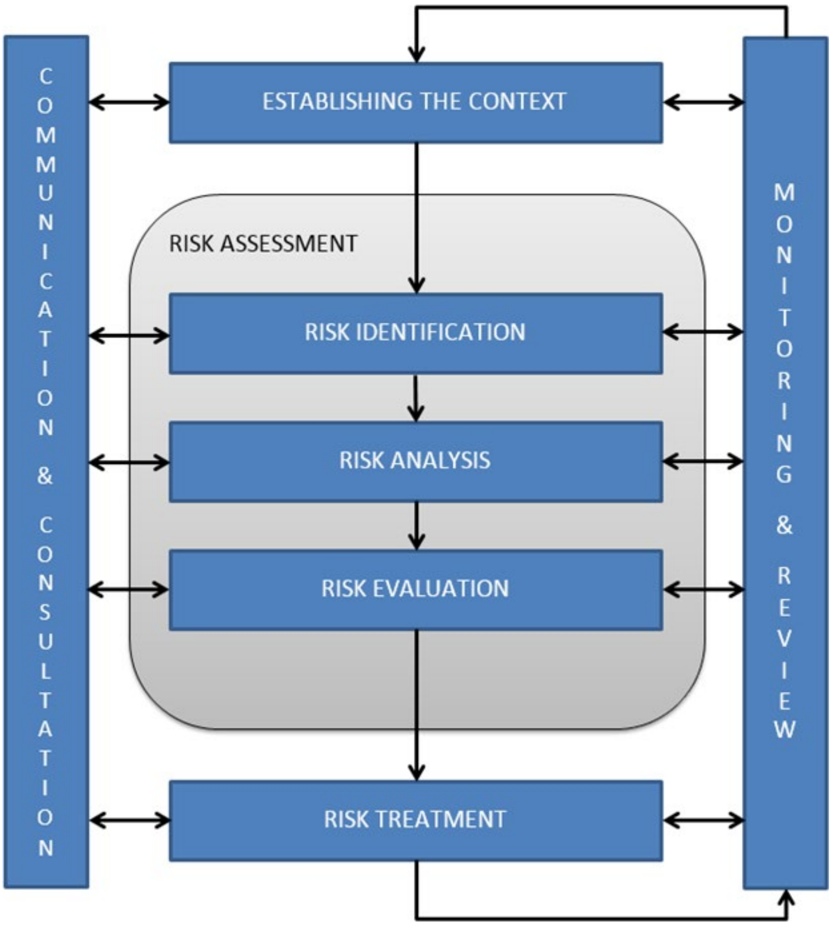


Figure 6-1 – AS/NZS ISO 31000 – Risk Management Methodology

6.2 Communication and consultation

Communication and consultation with internal and external stakeholders take place during all stages of the risk management process. The ISO 31000:2009 standard requires effective stakeholder communication and consultation in order to ensure that those accountable for implementing the risk management process (namely, CGG and any appointed contractors), and stakeholders understand the basis on which decisions are made, and the reasons why particular actions are required. This is also consistent with NOPSEMA's guidance.

The OPGGS Act and OPGGS(E) Regulations are guiding principles that underpin the process of external stakeholder communication and consultation in the development of EPs. NOPSEMA's Information Paper "Consultation requirements under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009" (N-04750-IP1411) outlines how the regulations relate to EPs and its recommendations have been followed herein.

CGG is committed to consulting with relevant stakeholders who may be affected by the activity, to identify and understand any concerns and issues, to mitigate impacts and risks highlighted in meritorious submissions and to openly communicate the process with the stakeholders. Input from stakeholders will help to inform the preparations for and execution of the Sauropod 3D MSS as appropriate. The process of stakeholder engagement is described in Section 5.

6.3 Establishing the context

The purpose of establishing the context in the risk management process is to define the external and internal parameters to be considered when managing risk and to define the risk criteria. This requires assessment of the external and internal environments in which CGG seeks to achieve its objectives.

The external context comprises the description of the activity (Section 3), the physical, biological and socio-economic environments (Section 4) and associated potential environmental impacts and risks specific to the nature and scale of the activity (Sections 7 and 8), the legislative framework, applicable management plans, standards and guidance (Section 2) and the perceptions and values of external stakeholders (Section 5).

The internal context relates to CGG's culture, processes, structure and strategy, and includes anything within the organisation that can influence the way in which environmental risk is managed. CGG's commitment to minimising environmental harm and to operating and maintaining a safe and healthy work environment for its employees, contractors and project partners is reflected in its corporate HSE Policy (Appendix A) and HSE management framework (Section 9).

6.4 Impact and risk assessment

The environmental impact and risk assessment process uses a systematic, evidence-based approach to evaluate and interpret the impacts and risks associated with its activity and the potential for harm to physical, biological and human receptors. The environmental impacts and risks associated with the Sauropod 3D MSS have been assessed using the following steps:

- Definition of the activity (Section 3) and identification of associated aspects and hazards with potential for environmental harm (i.e. physical, chemical or biological entity or incident which induces an adverse response or impact e.g. operation of airguns)
- Identification of the environmental values within the area that may be affected by the activity, i.e. the environmental context of the activity (Section 4)
- Identification of aspects of the activity with potential for environmental harm (e.g. underwater noise, light, seabed disturbance) in the context of its nature and scale and location (Section 7)
- Definition of acceptable levels for each impact and risk (Section 7 and 8)
- Identification of impacts from routine aspects and risks from unplanned/accidental events, and the inherent impact or risk (Sections 7 and 8)
- Identification of the 'decision context' and 'assessment technique' relevant to the impact or risk (Section 6.7.1)
- Identification of control measures to be implemented for each aspect in order to reduce the impacts and risks to ALARP (Section 6.7.2)
- Determination of the residual risk of each environmental impact and risk with identified control measures adopted (Section 6.9)
- Determination of whether the residual risk is acceptable
- In the event that an impact or risk is not considered acceptable, further practical control measures are considered and adopted until the impacts and risk are considered ALARP and acceptable (Section 6.8).

6.5 Hazards, impact and risk identification

Information used in identifying the impact and risks associated with the activity has been obtained from the following sources:

- CGG's description of the location, timing of survey and activities to be undertaken in acquiring seismic data (e.g. airgun discharges, sail lines)
- An understanding of general vessel activities/operations during seismic surveys and the potential threats and hazards to stakeholders and the marine environment and where appropriate, terrestrial environments

- Literature reviews on the environmental sensitivity of the receiving environment with respect to species' presence, "biological calendars", habitat distribution and location of environmentally sensitive areas (breeding, migration, resting areas); identification of environmental values at risk within and adjacent to the Acquisition Area;
- Feedback from stakeholders (onshore and marine) to understand socio-economic activities that may be affected by the proposed activity.

The identified environmental impacts and risks associated with activities proposed under this EP are listed below and assessed within Sections 7 to 8:

- Impacts (expected to occur during planned events)
  - Noise emissions – seismic source
  - Cumulative impacts from seismic surveys
  - Noise emissions: vessel, helicopter and mechanical equipment
  - Physical presence: disruption/ interference with other marine users
  - Discharge: treated sewage, grey water and putrescible waste
  - Discharge: drains, deck and bilge water
  - Artificial light emissions: vessels
  - Atmospheric emissions: vessels and mechanical equipment
- Risks (not expected to occur during routine operations)
  - Hydrocarbon and chemical spills
  - Hydrocarbon spill – vessel collision
  - Hydrocarbon spill – bunkering
  - Chemical spill: single point failure
  - Physical presence: entanglement / collision with marine fauna
  - Physical presence: loss of equipment
  - Discharge: loss of hazardous or non-hazardous solid waste
  - Introduction of invasive marine species: ballast water and biofouling.

6.6 Impact and risk analysis and evaluation

The hazards for each potential environmental aspect were identified using a qualitative assessment process in accordance with the methods and principles described by the ISO 31000:2018 Risk Management – Principles and Guidelines (2018), and Standards Australia Handbook HB 203:2012, Managing Environment-related Risk (2012). Some useful definitions from the ISO guidelines and the associated Handbook on Environmental Risk Management – Principles and Process (Standards Australia 2006), are included in Table 6-1.

Table 6-1 - Risk Management Terms

Term	Synonymous terms	Meaning
Stressor	Source of risk Hazard Environmental aspect	Physical, chemical or biological entity or incident, which induces an adverse response or impact.
Impact	Effect Consequence	Change to the environment, adverse or beneficial, relating to an organisation's activities. May be defined in terms of severity of consequences
Consequence	Outcome Impact	Impact of an event or incident e.g. a loss, injury or concern. May be expressed qualitatively or quantitatively.
Likelihood	Probability Frequency Qualitative likelihood	The series of 'conditional probabilities' or 'conditional likelihoods' for the chain of events leading to an impact, need to be factored into determining final likelihood of environmental impact occurring.
Risk		Considered in terms of environmental consequences of a given severity, and the likelihood of that particular consequence occurring.
Residual risk		Risk remaining when controls are in place.

The Sauropod 3D MSS impact and risk assessment is based on the evaluation of impacts and risks that are credible, realistic and appropriate to the nature and scale of the activity, and the values and sensitivities of the environment that may be affected (EMBA).

Each impact and risk associated with the planned seismic activity has been evaluated by determining the consequences or effects, including the extent, duration, timing and potential for recovery (Table 6-2 and Table 6-3), and assessing the likelihood or probability that those consequences may occur (Table 6-4). Potential maximum quantities released, time-scale of release, biological exposure and sensitivities, and regulatory requirements were considered in determining the consequence of the impact/risk. The likelihood of the effect or consequence is based largely on professional judgement of the conditional likelihoods leading to the effect, including the presence of the stressor (impact/risk), the exposure of receptors to the stressor and the sensitivity of the receptors to the stressor. The outcome of this evaluation provides the 'inherent' impact or risk ranking, i.e. the impact/risk without the application of control measures. The shaded region of the risk matrix signifies the tolerability of the risk ranking.

Table 6-2 - Definition of Consequence Terms

Term	Meaning
Localised	Operational Area extent
Extensive / Medium scale	Within Oil EMBA extent
Regional / Large scale	Northern Carnarvon Basin extent
Short-term	Days to weeks
Medium term	<12 months
Long-term	>12 months

Table 6-3 – Definition of consequence

Category		Environment	Socio-economic
0	Negligible	Full recovery expected in days to weeks	No or very limited effect on commercial and/or recreational users
1	Minor	Minor disruption and temporary effect (days) on individuals within a protected species, including impacts on health, critical habitats, or critical behavioural processes. No overall threat to populations. Localised scale (immediate area) and temporary effect on other habitats/communities. No effects on ecosystem function. Full recovery expected in days to weeks	Minor disruption, localised scale (immediate area) and temporary effect (days) on commercial and/or recreational users
2	Moderate	Moderate disruption and short-term effect (weeks) on a proportion of a protected species' population, including impacts on health, critical habitats or critical behavioural processes. No overall threat to populations. Localised scale and short-term effect (weeks) on other habitats/communities No effects on ecosystem function. Recovery in months to 1 year.	Moderate disruption, localised scale and short-term effect (weeks) on commercial and/or recreational users
3	Severe	Moderate disruption and effect (months) on a significant proportion of a protected species' population, including impacts on health, critical habitats or critical behavioural processes. No overall threat to populations. Localised scale and medium-term effect (months) on other habitats/communities. No effects on ecosystem function. Recovery >1 to 3 years.	Moderate disruption and effect (months) on commercial and/ or recreational users.
4	Major	Major disruption and medium to long-term effect (years) on a protected species' population, including impacts on health, critical habitats or critical behavioural processes. No overall threat to populations. Injury or death of individuals of a protected species. Medium scale and medium-term effect (years) on other habitats/communities. Effects are at an ecosystem function level. Recovery >3 to 10 years.	Major disruption and medium to long-term effect (years) leading to loss of commercial and/or recreational use
5	Catastrophic	Extensive disruption and long-term effect (decades) on a protected species' population, including impacts on health, critical habitats or critical behavioural processes. No overall threat to populations. Injury or death of a significant proportion of a protected species population. Large scale and long-term effect (decades) on other habitats/communities. Effects are at an ecosystem function level. Recovery >10 years.	Extensive disruption and long-term effect (decades) leading to loss of commercial and/or recreational use.

Table 6-4 – Definition of Likelihood

Category		Definition/experience (history of occurrence)	Probability
A	Rare	Almost impossible / unheard of in the industry	Event occurs once within 10 years
B	Unlikely	Could occur but would not be expected / has occurred once or twice in the industry	Event occurs once within 5 years
C	Possible	Might occur at some point / has occurred many times in the industry but not before within CGG	Event occurs once a year
D	Likely	Will probably occur at some point / has occurred frequently within the company	Event occurs monthly
E	Almost Certain	Expected to occur in most circumstances / has occurred at the location	Event occurs weekly

All identified impacts and risks associated with the activity were analysed and evaluated in accordance with the CGG modified risk matrix (Table 6-5). The coloured region signifies the tolerability of the risk criteria. Environmental impact and risks ranked as Low or Medium are considered generally ALARP and acceptable (i.e. acceptable providing that it can be shown that all practicable impact and risk reduction measures have been taken and they will continue to be taken). Impacts and risks ranked as High and Very High are undesirable or unacceptable and require additional control measures to be implemented to reduce the residual level of risk to ALARP and Acceptable.

Table 6-5 - CGG Modified Risk Matrix

Consequence		Likelihood				
		A	B	C	D	E
		Rare	Unlikely	Possible	Likely	Almost certain
0	Negligible					
1	Minor					
2	Moderate					
3	Severe					
4	Major					
5	Catastrophic					

Term	Definition
Low	No effect, or those that are beneath levels of perception, within normal bounds of variation. Good industry practice (including legislation and standards) have been applied. Acceptable without further reduction measures being required.
Medium	Acceptable (tolerable), providing that it can be shown that all practicable control measures have been implemented, if the sacrifices are not grossly disproportionate to the environmental benefit gained, with continual review of these measures and any potential new ones. Deemed to be “as low as reasonably practical” (ALARP) and acceptable.
High	Undesirable, CGG management decision required to accept risks and proceed. Additional control measures are required to be considered and implemented, if the cost is not grossly disproportionate to the environmental benefit gained, to prevent or reduce the impact/risk to ALARP and an acceptable residual level.
Very High	Unacceptable (intolerable) and may require re-design of project and/or its parameters, additional control measures are required to be implemented (regardless of cost) to prevent or reduce the impact/risk to ALARP and be acceptable.

6.7 Impact and risk treatment

The treatment of the inherent impacts and risks identified in the assessment process requires application of control measures to reduce them to ALARP and acceptable levels. CGG has taken the following approach for each of the identified impacts and risks during the assessment:

- Determination of inherent risk (potential risk) without controls
- Identification of appropriate control measures aligned with the decision type
- Demonstration of ALARP (and determination of the residual risk)
- Demonstration of acceptable level of impact or risk
- Determination of residual risk rating (including controls aligned with decision type).

6.7.1 Decision context and assessment techniques

CGG applies the Oil and Gas UK (OGUK) (2014) Guidance on Risk Related Decision Making (Figure 6-2) to determine the assessment technique applied for each impact or risk. CGG has considered previous impact and risk assessments for similar activities, review of relevant published studies (peer reviewed and grey literature) and stakeholder consultation concerns/feedback. Wherever possible, site-specific and activity-specific data has been used in the impact/risk assessment; however, in order to address areas of uncertainty, a precautionary approach has been taken and a conservative or “worst case” approach has been applied where there is uncertainty in the level of harm.

The extent to which identified stakeholders have an interest in the decision depends upon the nature of the impact/risk (e.g. magnitude, complexity, uncertainty) and their perception of the impact/risk. The values, views, attitudes, perceptions and concerns of stakeholders consulted for the Sauropod 3D MSS have been used in the determination of the decision context. Stakeholder concerns have been assessed for merit and adopted control measures (where relevant) are summarised in each impact and risk section.

Once the decision context is established for the impact/risk, this determines the assessment technique to use to identify appropriate control measures. The arrows in the Figure 6-2 show the assessment technique(s) likely to be needed to make the decision. Good practice forms the basis of the assessment for all decision contexts. Moving from decision context A to B to C increases the relevance for additional assessment techniques and the role these play in the identification of control measures and decision-making.

- Good Practice: in accordance with recognised guidelines, standards and control measures that are used to manage well-understood impacts and risks arising from activities. This also includes control measures required to meet legislative requirements, codes and standards, including guiding principles such as the principles of ESD as defined in the EPBC Act.
- Engineering (or Environmental) Impact and Risk Assessment: this method may involve application of a range of techniques such as engineering analysis (e.g. underwater sound modelling), impact/risk assessment, cost benefit analysis, professional judgement.
- Precautionary Approach: this method requires uncertainty in the analysis to be addressed by using conservative assumptions that may result in a control measure being more likely to be adopted.

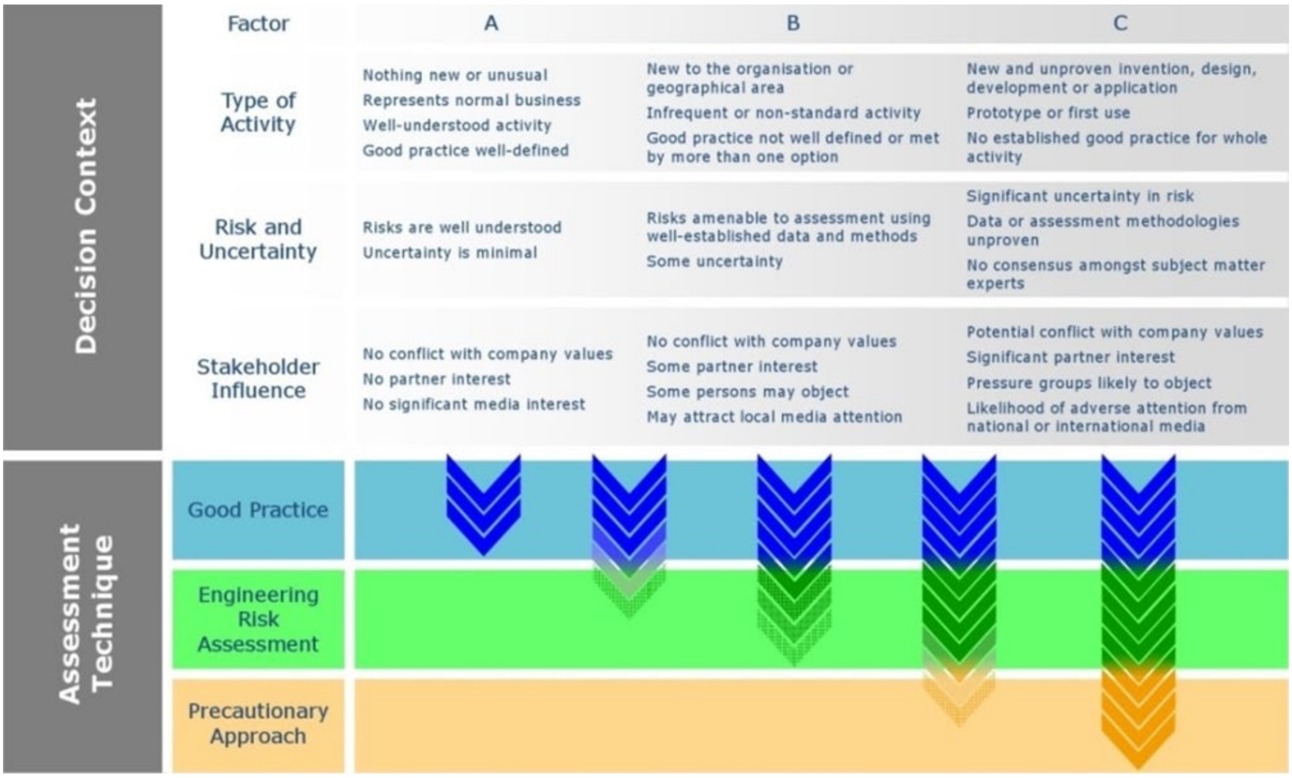


Figure 6-2 - Risk Related Decision Support Framework (OGUK 2014)

6.7.2 Hierarchy of Control Measures

CGG has established a hierarchy of controls in accordance with their impact and risk management process as part of their HSE Management System (Table 6-6). Although commonly used in the evaluation of occupational health and safety hazard control, the hierarchy of controls philosophy is also a useful framework to evaluate potential environmental controls to ensure reasonable and practicable solutions have not been overlooked.

Table 6-6 – Hierarchy of Controls

Control type	Description
Eliminate	Selection of method based on appropriate design, elimination of methods with higher risks, e.g. eliminating seabed damage from anchors by using dynamically positioned vessels.
Substitute	Replace with a lower risk situation, e.g. use gel-filled streamers instead of fluid-filled streamers.
Reduce	Reduce the impact/ risk, e.g. soft-starts during operation of the seismic source to encourage marine fauna to move out of the area, thereby reducing exposure to elevated noise levels.
Engineering/Isolation	Engineer out the impact/risk, e.g. automatic flotation devices to aid in recovering lost streamers.
Administration	Provide instructions, procedures or training to reduce the risk, e.g. use of procedures for management of risks for refuelling at sea, waste management and marine fauna interactions, training of crew through environmental inductions.
Protective	Use appropriate protective equipment, (including emergency response and contingency planning), when other control measures are not practical or have not totally removed the hazard.

6.8 Demonstration of ALARP

Regulation 13(5)(c) of the OPGGS (E) Regulations require that where significant effects are identified, details of the control measures that will be used to reduce the impacts and risks of the activity to as low as reasonably practicable (ALARP) and an “acceptable level”, must be included in the EP. Risk treatment involves a process of selecting additional control measures for reducing impact and risks that have not been demonstrated to be ALARP during the risk analysis and evaluation processes, and then establishing whether the residual impact/risk can be deemed acceptable. In the case of higher order impacts or risks, it is also expected that reasonable effort has been used to identify and evaluate alternative, additional, and improved control measures that may further reduce impacts and risks (NOPSEMA Guideline N-4750-GL1721).

Ideally, the control measures adopted during the assessment should bring the residual impact/risk to a low level and broadly acceptable region. All identified impacts and risks associated with the activity were analysed and evaluated in accordance with the CGG modified risk matrix (Table 6-5). Environmental impact and risks ranked as Low or Medium are considered generally ALARP and acceptable (i.e. acceptable providing that it can be shown that all practicable impact and risk reduction measures have been taken and they will continue to be taken). Impacts and risks ranked as High or Very High are undesirable or unacceptable and require additional control measures to be implemented to reduce the residual level of risk to ALARP and Acceptable.

However, if the residual impact/risk remains at the medium level, CGG must determine if the impact or risk has been reduced to ALARP. If CGG identify additional control measures that can be implemented without the cost being grossly disproportionate to the benefit of impact or risk reduction, then these additional controls are adopted. If it is considered that the impact or risk is sufficiently low, ALARP has been reached and no further development of control measures is practicable, or if the costs of implementing further controls are grossly disproportionate to the environmental benefit, then the residual impact/risk is deemed to be acceptable.

If a residual impact/risk is high or very high, then this is determined as an unacceptable impact or risk and requires additional control measures to reduce to ALARP. It is important to note that to maintain an impact or risk as ALARP, ongoing action is required to ensure the integrity of control measures is maintained. Therefore, the emphasis on feedback and continuous improvement is a key feature of the management of impacts/risks to ALARP.

Additional control measures for the ALARP demonstration have been identified using the decision methods described below. Where the residual impact/risk is low, good industry practice (including recognised guidelines and standards) has been assessed to determine if additional control measures are appropriate. Where the residual impact/risk is medium, good practice and engineering (or environmental) assessment methods have been considered in introducing additional controls to reduce the impact/risk further. Where the residual impact/risk is high or very high, then additional control measures have been developed from a combination of good practice, assessment, and a precautionary approach. The latter precautionary approach requires conservative assumptions to be made in the development of additional control measures where there is uncertainty in the process.

Once additional control measures have been identified, each has been assessed on its merits of impact/risk reduction and the proportionality of the sacrifice associated with each measure. This assessment considers the practicality, effectiveness, and the cost benefit of implementing the control measure, as described below.

6.8.1 Practicability

Additional control measures were assessed to demonstrate whether the impact or risk could be further reduced, or if the impact or risk level is ALARP. Treatments considered by CGG to be reasonably practicable have been implemented, while those considered to be not reasonably practicable have not been implemented, e.g. the cost, time and effort required to implement the measure is grossly disproportionate to the environmental benefit gained.

6.8.2 Effectiveness

CGG's QHSE and SD Risk Management Guidance Note requires that the effectiveness of control measures must be assessed before they are implemented. Determination of effectiveness is subjective and thereby based on professional judgement, considering:

- Availability – will the control exist and be available when and where you need it?
- Reliability – will the control work as it was designed and intended?
- Impact – what will be the scale of effect if this control works perfectly?
- Duration – what will be the duration or time that the control will have its effect?

6.8.3 Cost Benefit Analysis

The estimated cost criterion consisted of a qualitative assessment by people familiar with the practicalities of implementing the control measures, to evaluate and rate the estimated cost impact of the additional control measure. Monetary values were not quantified; however, the cost was qualitatively ranked as follows:

- High – Very significant cost associated with the implementation of this measure and the cost may be prohibitive or not warranted based on the potential benefit gained. The level of cost is likely to compromise the Sauropod 3D MSS objectives and viability.
- Medium – Significant cost associated with implementation of this measure, however it is not considered prohibitive, when compared to the potential risk reduction benefit.
- Low – No significant cost associated with implementation of this measure.

The expected net benefit of the additional control measure in reducing either the likelihood or the consequence of the impact or risk, beyond that achieved by the previously identified control measures was evaluated on a qualitative basis. If a control measure reduced the potential impact or risk significantly, but did not change the residual risk ranking, it may still be considered as a net benefit and a contribution to reaching ALARP.

The potential for each additional control measure to generate negative environmental impacts, health and safety issues or operational risks was considered. Where effects were considered to negate the potential benefit partially or fully, the control measure was not considered for implementation, as it had no net benefit and contribution to reaching ALARP.

Where the benefit (i.e. reduction in impact or risk) of an additional control measure was considered grossly disproportionate to the cost of implementation or the effect on survey efficacy, the control measure was not accepted. As such, the control measures presented in the impact and risk assessment constitute only those that were deemed to result in a reasonable, practicable and effective reduction in the likelihood or consequence of an impact or risk becoming realised, and thereby demonstrating ALARP whilst achieving the objectives of the survey.

6.9 Residual Impact Ranking

The residual impact and risk ranking process is undertaken to assess the effect of control measures in mitigating the inherent risk levels. It follows the identification of the decision context type, ALARP process and establishing appropriate control measures.

Residual risk rankings were based on re-assessment of the likelihood and consequence of the impacts with the mitigating controls in place. Residual risk was assigned using CGG's risk matrix in Table 6-5. All identified impacts and risks associated with the activity were analysed and evaluated in accordance with CGG risk matrix. The coloured region signifies the tolerability of the risk criteria Environmental impact and risks ranked as low or medium are generally considered ALARP and acceptable (provided that it can be shown that all practical impact and risk reduction measures have been taken and they will continue to be taken). Impacts and risks ranked high are undesirable or unacceptable and require additional control measures to be implemented to reduce the residual risk to ALARP and Acceptable.

6.10 Demonstration of Acceptability

Regulation 13(5)(c) of the OPGGS(E) Regulations requires a demonstration that residual environmental impacts and risks are of an acceptable level. Acceptance is often represented as an inverted triangle (Figure 6-3), where the level of risk increases from a low risk or “broadly acceptable region” through a “tolerable region” (if impacts/risks are demonstrated to be higher, but ALARP) and then to an “unacceptable region”. These principles have been adopted in CGG’s definitions of acceptability:

- Low: Good industry practice (including legislation and standards) has been applied and the impact/risk is acceptable without further reduction measures being required. Further effort towards impact/risk reduction is not reasonably practicable without sacrifices (costs, loss of opportunities, or loss of technical quality) grossly disproportionate to the impact/risk reduction benefit.
- Medium: Acceptable (acceptable / tolerable), providing that it can be shown that all practicable control measures have been implemented, if the sacrifices are not grossly disproportionate to the environmental benefit gained, with continual review of these measures and any potential new ones.
- High (undesirable): CGG management decision required to accept impacts/risks and proceed. Additional control measures are required to be considered and implemented, if the sacrifices are not grossly disproportionate to the environmental benefit gained, to prevent or reduce the impact/risk to ALARP and be acceptable.
- Very high (unacceptable / intolerable): May require re-design of project and/or its parameters, additional control measures are required to be implemented (regardless of sacrifice) to prevent or reduce the impact/risk to ALARP and be acceptable.

CGG’s model for demonstrating acceptable levels of impacts and risks for the Sauropod 3D MSS is based upon the criteria described in Table 6-7. Using the appropriate criteria from Table 6-7, acceptable levels of impact were defined prior to conducting the evaluation of individual impacts and risks in Section 7 and 8. However, not all the criteria for acceptance in Table 6-7 will apply to defining levels of acceptability for all impacts and risks assessed within this EP. CGG has therefore distinguished between higher and lower order environmental impacts and risks.

Higher order impacts/risks are generally more complex and include those where the environment or receptor affected is protected/threatened, vulnerable to the impact/risk, not widely distributed, or where there is uncertainty in the effectiveness of adopted control measures. Such impacts/risks relevant to the MSS include underwater noise from seismic operations, accidental oil spill (due to vessel collision) and physical interaction with other marine users. It is expected that reasonable effort has been used to identify and evaluate alternative, additional, and improved control measures that may further reduce impacts and risks (NOPSEMA Guideline N-4750-GL1721). Lower order impacts include atmospheric emissions, routine discharges, light emissions, accidental loss of materials, introduced marine species and fuel spills.

Following demonstration that all reasonable and practicable control measures have been adopted to reduce the impacts and risks to ALARP, the pre-defined acceptable levels of impact have been compared with the residual levels of impact and risk. If the residual impact levels lie within the boundaries of the pre-defined acceptable levels, the impact or risk is considered acceptable.

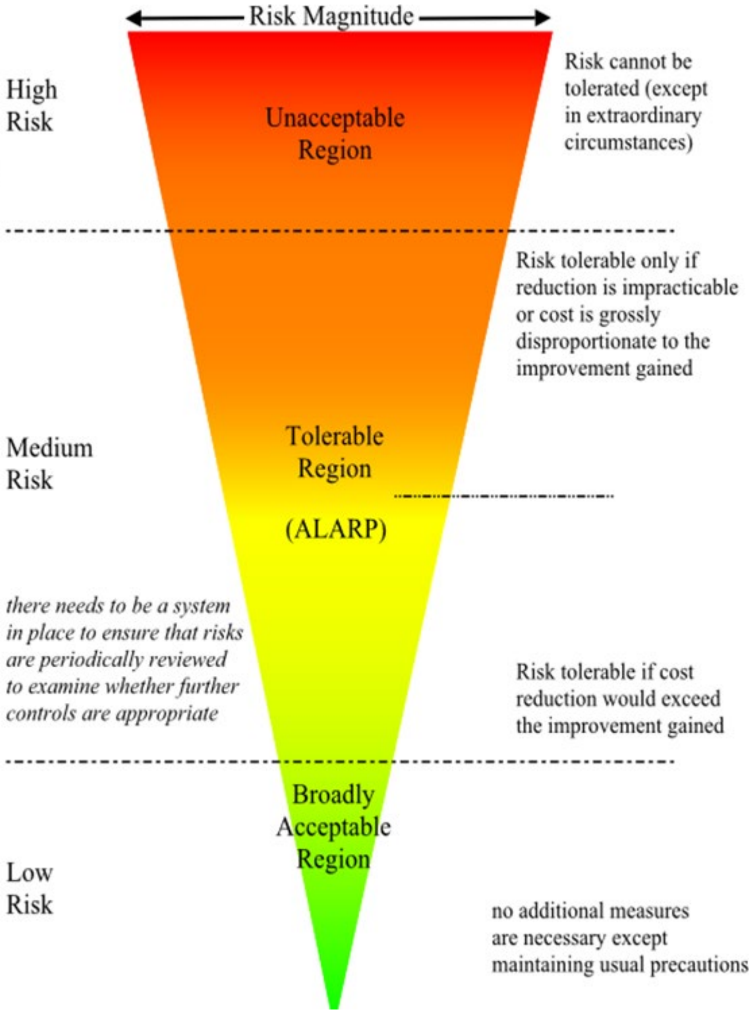


Figure 6-3 - Approach to Demonstrating ALARP and Acceptable Levels (Reg 13(5)(c))

Table 6-7 - Criteria for Defining Acceptable Levels of Impact

Criteria for acceptance	Criteria	
Internal	CGG Policy	Alignment with CGG's Environment Policy and the environmental management system for the Sauropod 3D MSS described in Section 9.
	Company Standards/Systems	CGG impact/risk matrix defines 'low risk' as acceptable, 'medium risk' as acceptable providing ALARP has been demonstrated, 'high risk' as undesirable (i.e. requiring ALARP demonstration and decision to accept based on CGG management decision), and 'very high risk' as unacceptable (Table 6-5). As such, have all reasonable and practical control measures been adopted to reduce the risk or impact without sacrifices being disproportionate to the benefit of the risk reduction?
External	Values and Sensitivities of the Natural Environment	The proposed management of the impact/risk is aligned with species-specific or protected area management plans/conservation advice actions or conservation objectives. The proposed management of the impact/risk is aligned with the identified conservation values for the existing environment.

Criteria for acceptance	Criteria	
		Is the effect on the environment or receptor localised, short-term and recoverable? Have potential impacts to environmental values or sensitivities been assessed as local, regional (and if applicable global) level in terms of population level and long-term effects? As such, are adopted controls appropriate and adequate in avoiding such effects and thereby reducing risks to ALARP.
	Relevant Persons Expectations	Concerns raised during stakeholder consultation have been assessed for their merits and control measures developed, if appropriate, to manage those concerns. There are no outstanding merited concerns that have not been assessed.
Legislation and Other	Legal Requirements	The impact/risk is being managed in accordance with existing Australian or international legislation, conventions and/or standards, such as MARPOL 73/78, AMSA Marine Orders, and Marine Notices, Policy Statements (refer to Section 2).
Industry Standards	Industry Standards and Best Practices	The impact/risk is being managed in accordance with industry good practice (APPEA Code of Environmental Practice and IAGC guidelines), and national and international standards (ISO 31010:2009 Risk Management, Standards Australia / Standards New Zealand Risk Management Guidelines) APPEA Code of Environmental Practice and IAGC guidelines.
Ecological Sustainability Development (ESD)	ESD Application	Aligned with the principles of Ecological Sustainable Development (ESD), including application of the precautionary, integration, intergenerational, biodiversity and valuation principles, and/or how uncertainty has been reduced.

6.11 Environmental Performance Outcomes and Standards

Regulation 4 of the OPGGS(E) Regulations provides definitions for the following:

- Environmental performance outcome: A measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks will be of an acceptable level.
- Environmental performance standard: A statement of the performance required of a control measure.

Environmental performance outcomes, standards and measurement criteria for each aspect of the activity that has the potential to cause adverse environmental impacts or risks are detailed in the assessments presented in Section 7 and 8. Environmental performance will be measured and reported against these standards and measurement criteria, as part of CGG's commitment to continuous improvement of environmental, health and safety performance as described in Section 9.

6.12 Monitoring and review

Ongoing monitoring and review are essential to ensure the impact and risk assessments within this EP remain relevant. Introduction of new impacts/risks due to changes in the activity or context, changes in the consequence of impacts/risks, and maintaining effectiveness of adopted controls are addressed in CGG's Management of Change procedure described in Section 9.

7 Environmental Risk Assessment – Planned Events

This section presents the evaluation of the environmental impacts and risks completed for planned / routine aspects of the Sauropod 3D MSS using the methodology described in Section 6, as required by OPGGS (E) Regulations 13(5) and 13(6). A summary of the residual rankings for all impacts and risks identified and assessed in this Section is provided in Table 7-1. Where there has been a decrease in the level of predicted impact or no change, the assessment has not been revised apart from to update project details.

This section also presents the environmental performance outcomes, performance standards and measurement criteria for each of the identified environmental impacts and risks. These terms are defined as follows:

- Environmental Performance Outcome (EPO) – a measurable level of performance required for the management of the environmental aspects of the activity to ensure the environmental impacts or risks will be of an acceptable level
- Environmental Performance Standard (EPS) – a statement of performance required of an adopted control measure
- Measurement Criteria – defines the measure by which environmental performance will be measured to determine whether the EPO has been met.

Table 7-1 – Environmental Impact Ranking Summary

Impact/Risk	EP Section No.	Residual Risk		
		Consequence	Likelihood	Risk Ranking
Noise Emissions: Seismic Source	7.1	Moderate (2)	Unlikely (B)	Medium
Noise Emissions: Cumulative Seismic Sound	7.2	Moderate (2)	Unlikely (B)	Medium
Noise Emissions: Vessels, Helicopter and Mechanical Equipment	7.3	Negligible (0)	Rare (A)	Low
Physical Presence: Disruption/Interference with Other Marine Users	7.4	Minor (1)	Unlikely (B)	Low
Discharge: Treated Sewage, Grey Water and Putrescible Waste	7.5	Minor (1)	Rare (A)	Low
Discharge: Drains, Deck and Bilge Water	7.6	Negligible (0)	Rare (A)	Low
Artificial Light Emissions: Vessels	7.7	Negligible (0)	Rare (A)	Low
Atmospheric Emissions: Vessels and Mechanical Equipment	7.8	Negligible (0)	Rare (A)	Low

7.1 Noise emissions: Seismic source

This EP is a revision of the 3D Oil Sauropod MSS EP, which was accepted by NOPSEMA on 13th July 2020, see further detail in Section 0. The potential for noise impacts is reduced and therefore the underwater noise impact assessment has not been significantly changed from the previously accepted EP. The impact assessment and subsequent management of impacts (controls) for seismic noise emissions is presented for the larger seismic array, as modelled assessed in the previously accepted 3D Oil Sauropod MSS EP (see modelling in Appendix D:). This is considered a conservative approach to assessing the effects of noise emissions because the potential for impacts is lower but the same level of mitigation and management will be applied, and the net environmental risk is reduced.

The impacts of underwater noise are predicted to be lower under the revised plan than under the accepted EP because:

- the seismic source that will be used in the survey is lower volume, decreased from 3090 in^3 to 2820 in^3
- the source array produces lower sound energy levels
- the wider spacing of the sail-lines reduces the number of sail-lines and reduces ensonification between the lines and cumulatively for the survey.
- the survey area, shot interval and line orientation have not been changed (Table 7-2).

This section provides reasoned and supported evidence to demonstrate that the seismic source used in this survey will produce similar or lower sound energy levels than the array used throughout the impact assessment.

Jasco was engaged to compare noise emissions from the original 3,090 in^3 and 2,820 in^3 arrays at the source and propagation from locations modelled for the 3D Oil Sauropod MSS EP (Appendix E:). This study confirms that the smaller array produces lower noise levels at the source (Table 7-3)

Table 7-2 The Difference Between the Seismic Source Acoustic Parameters to be Used in the Sauropod 3D MSS and Those Used in the Impact Assessment.

Survey Parameter	CGG Revised Survey	Accepted Sauropod EP Survey
Length of sail lines	83 km	83 km
Time to traverse a sail line	~10 hours	~10 hours
Orientation of sail lines	North–south	North–south
Distance between sail lines	675 m – 716 m	450 m
Turn radius	5,200 m	3500 m
Seismic vessel sail line speed	4.5 knots	Modelled at 4.4 knts
Turn time	4 h	Modelled at 5.2 h
Shot point interval	12.5 m (5.4 seconds)	12.5 m (5.4 seconds)
Seismic Source		
Type	Airgun / three arrays, which will be discharged alternately	
Size	2820 in^3	3090 in^3
Pressure	2,000 psi	2,000 psi
Sound source tow depth	Modelled at 6 m	Modelled at 6 m
Streamers		
Number	12	12
Streamer length	7050 m	7000 m
Distance from seismic vessel bow to tail buoy	7800 m	7525 m
Distance between streamers	112.5 m	75 m

Table 7-3 Far-field Source Level Specifications for the 3090 in^3 and 2820 in^3 Sources with 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 SPL (LS,pk; dB re 1 µPa m)	Per-pulse source SEL (LS,E; dB 1 µPa2m2s) 10–25,000 Hz
3090	Broadside	249.4	225.1
2820		248.8	224.5
3090	Endfire	245.7	223.3
2820		244.8	223.0
3090	Vertical	255.0	228.2
2820		254.9	227.9

Sound propagation modelling of per pulse fields was conducted at the sites in Figure 7-1 to compare energy emission between the 3090 in^3 and 2820 in^3 arrays across the survey area. Figure 7-2 to Figure 7-5 show the results of the per pulse fields at each site for both SEL and SPL metrics. These figures clearly show the energy emission of both arrays is very similar or slightly lower for the smaller array at all modelling sites, in both SEL and SPL metrics. Furthermore, since the line spacing in this survey is greater, the SEL_{24h} sound field will be smaller due to the additional propagation loss between sail lines.

These data demonstrate the sound that will be produced during the seismic survey will not be greater than the noise prediction that underpins the impact assessment and will generally be lower. As a result, the impact assessment in this EP and the management controls that will be implemented are applicable to the seismic noise emissions generated during this survey.

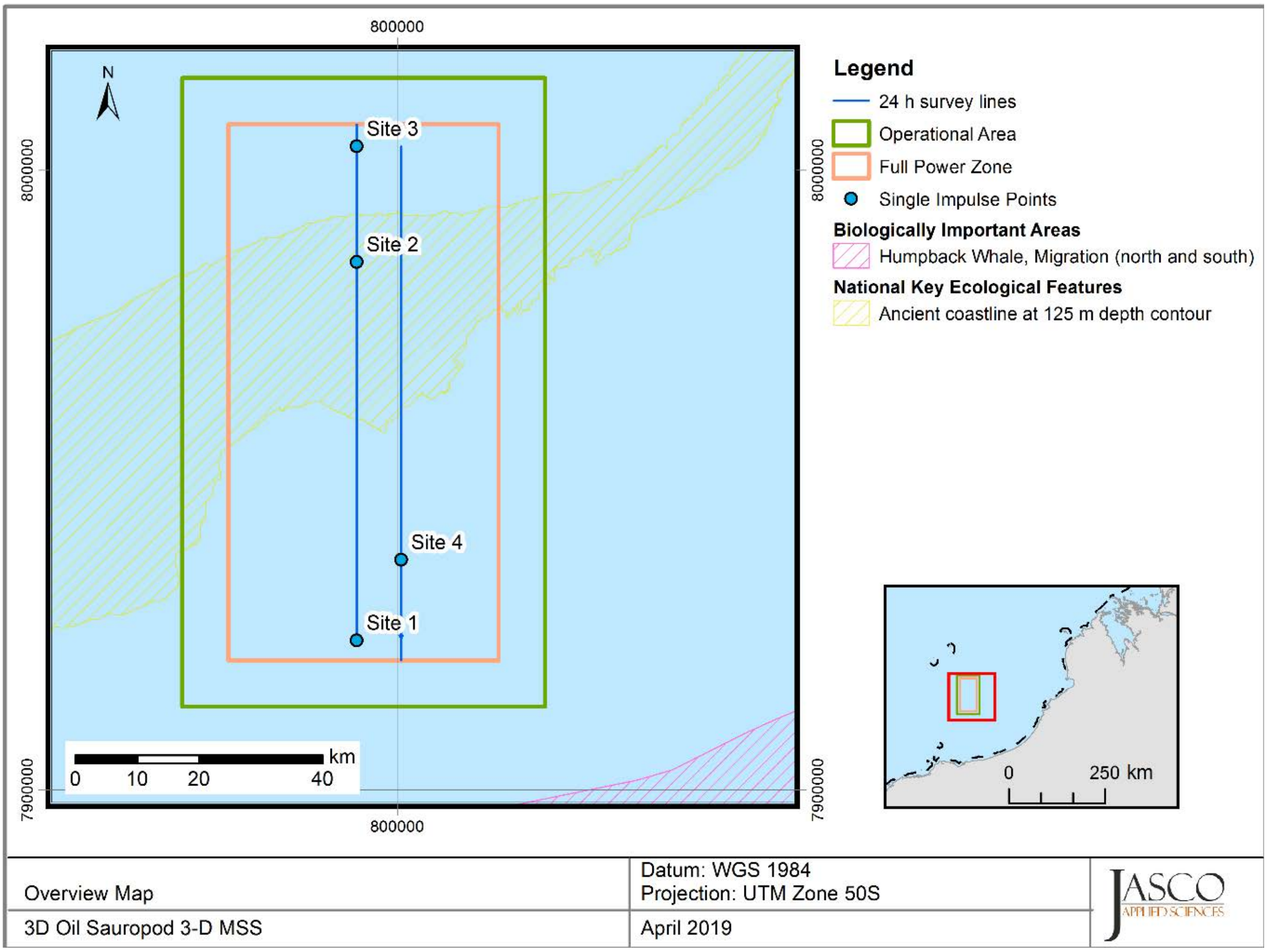


Figure 7-1 — Modelling Sites for Per-pulse Fields for Comparison Between the 3090 in^3 and 2820 in^3 Arrays.

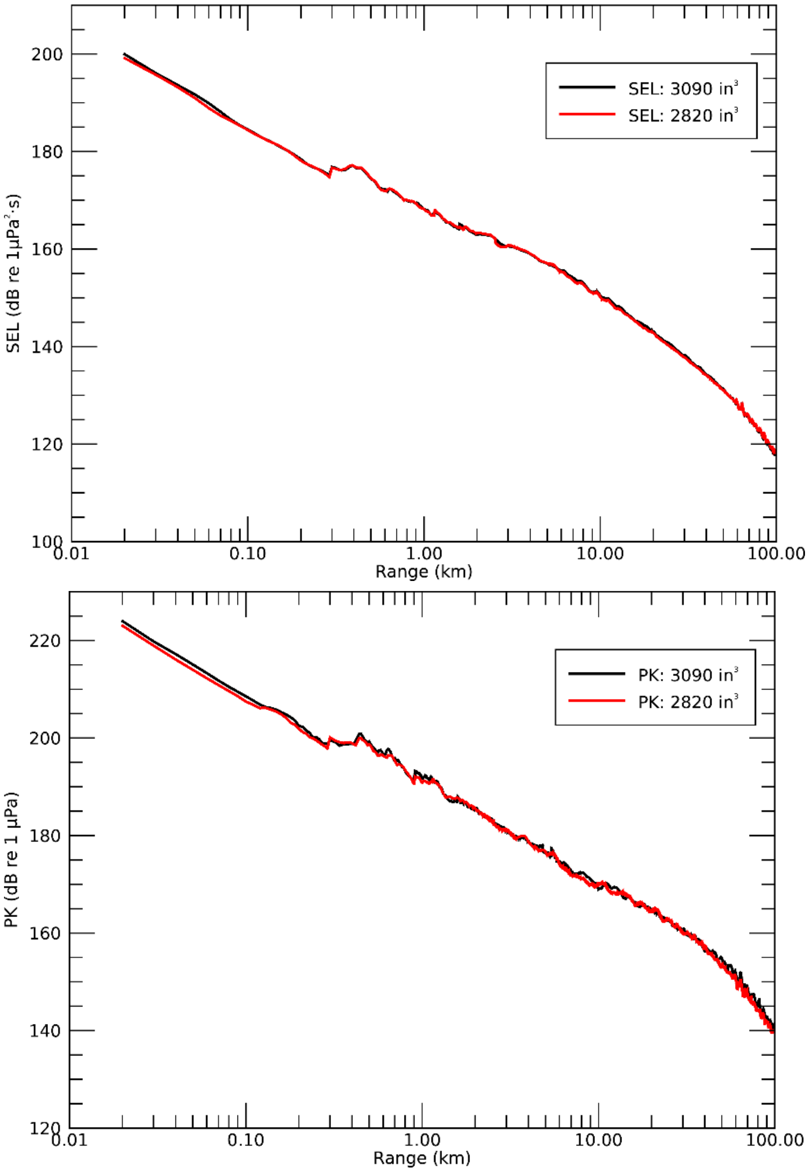


Figure 7-2 — Site 1: Maximum-over-depth SEL (top) and SPL (bottom) Predicted for the 3090 in^3 and 2820 in^3 Arrays.

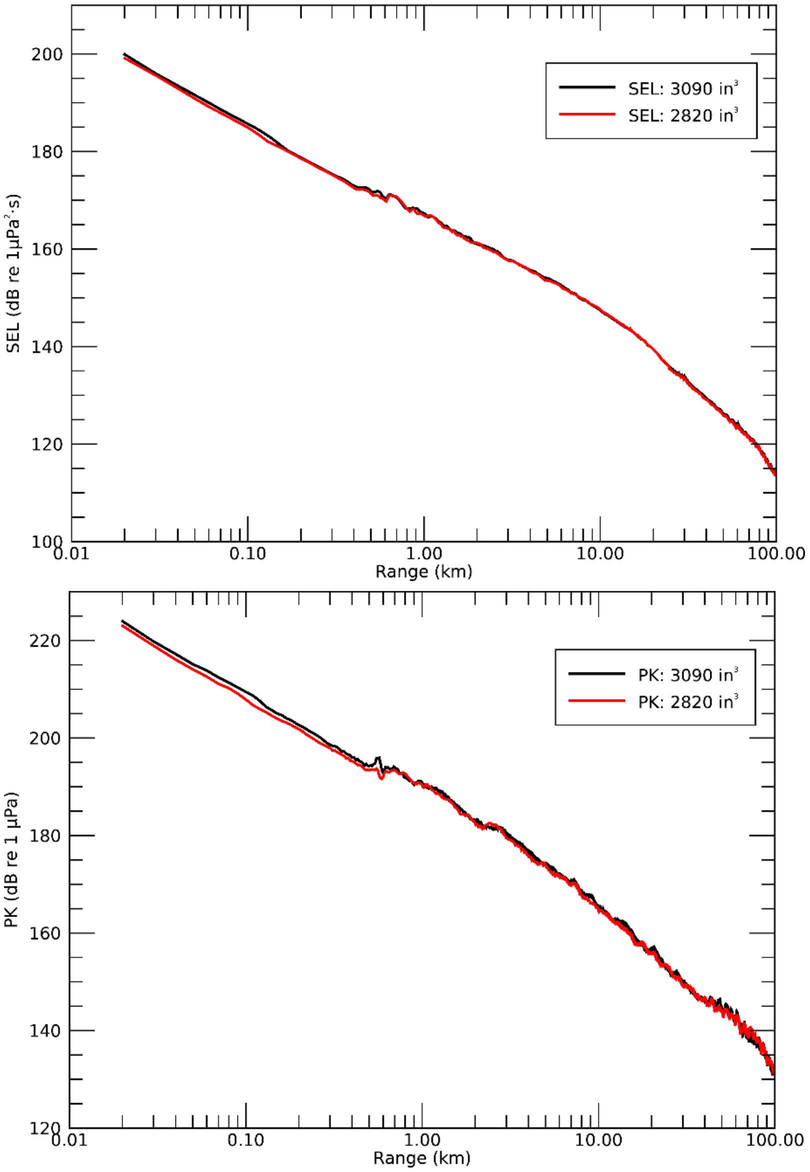


Figure 7-3 — Site 2: Maximum-over-depth SEL (top) and SPL (bottom) Predicted for the 3090 in^3 and 2820 in^3 Arrays.

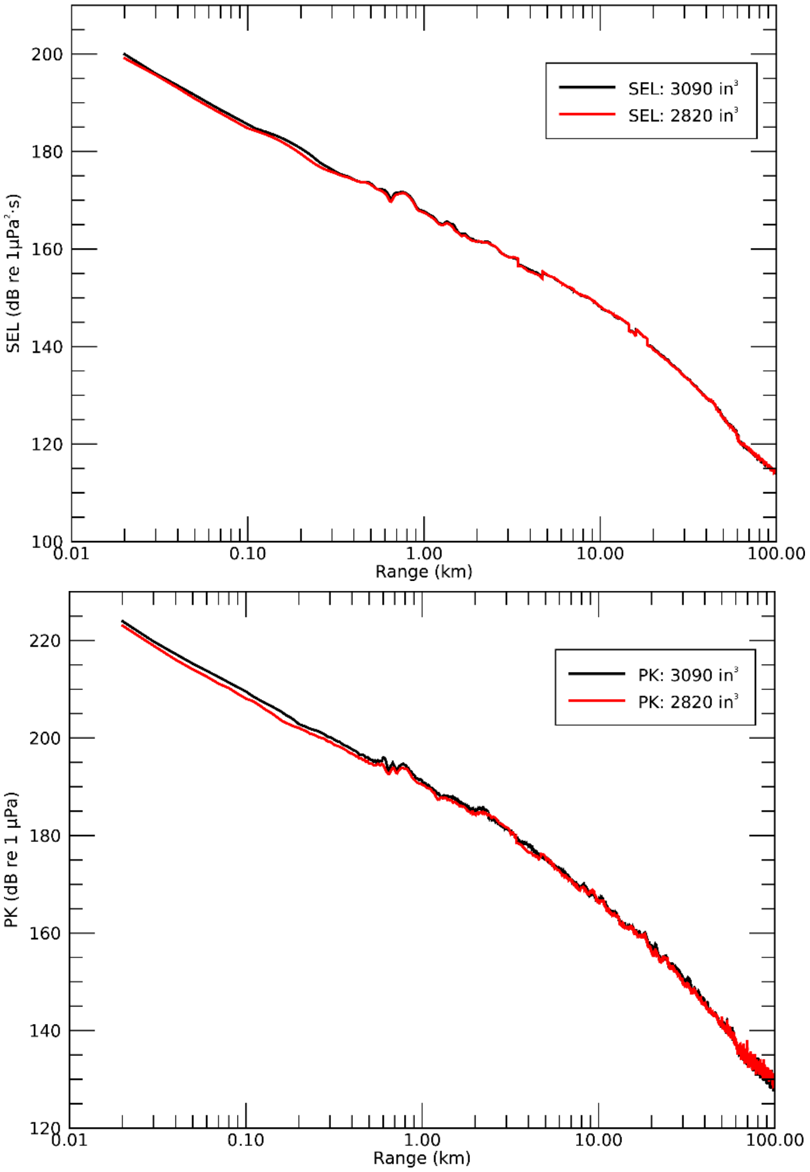


Figure 7-4 — Site 3: Maximum-over-depth SEL (top) and SPL (bottom) Predicted for the 3090 in^3 and 2820 in^3 Arrays.

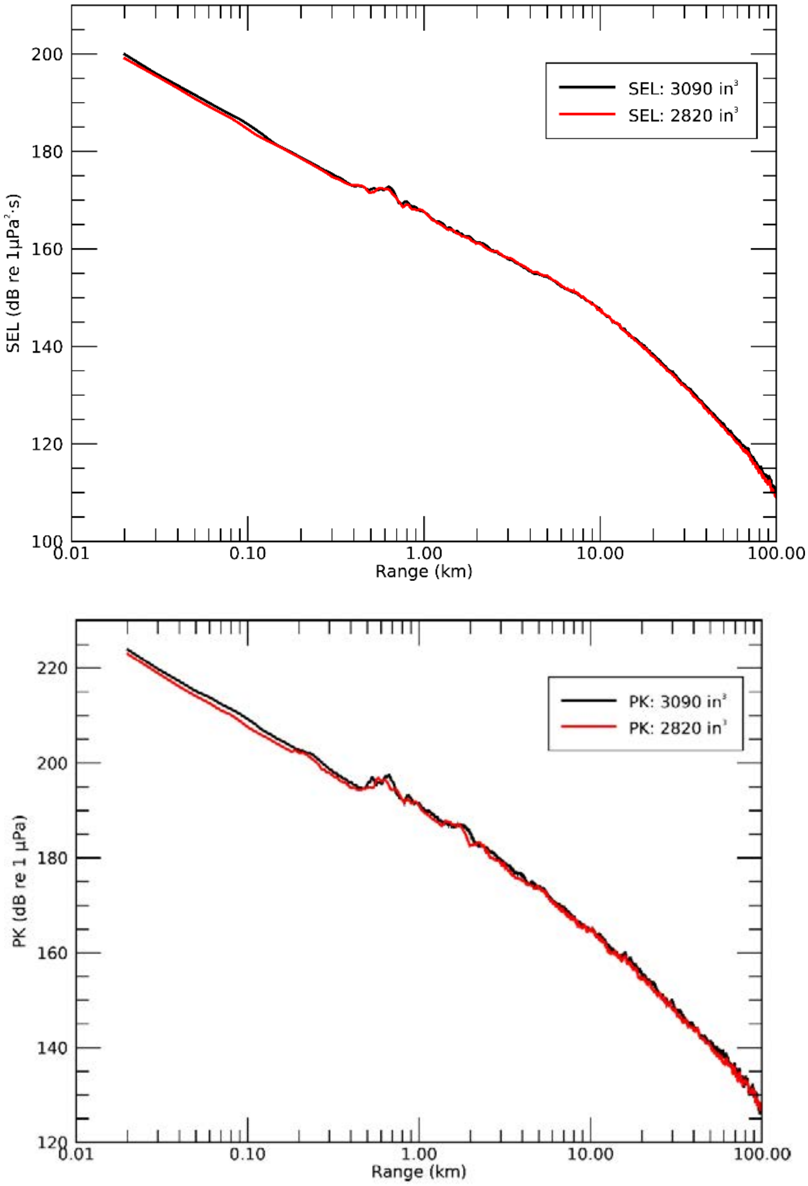


Figure 7-5 Site 4: Maximum-over-depth SEL (top) and SPL (bottom) Predicted for the 3090 and 2820 in^3 Arrays.

7.1.1 Source of Impact/Risk

Generation of noise from the seismic source has the potential to cause physical effects and behavioural disturbance to marine fauna.

This impact assessment is based on the noise emissions from an airgun array with a maximum capacity of 3,090 in^3, towed at a water depth of 5–10 m. Noise emission estimates are based on shot intervals of approximately 5.4 seconds as the vessel transits along planned survey lines within the Acquisition Area. This impact assessment is based on a theoretical seismic source that is larger and slightly louder than the source that will be used in the survey.

Underwater noise can affect marine fauna in three main ways:

- By causing direct physical effects on hearing or other organs. Hearing loss may be temporary (temporary threshold shift – TTS), or permanent (PTS), with PTS usually considered to represent a form of injury
- Through 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
- By masking or interference with other biologically important sounds (including vocal communication, echolocation, signals and sounds produced by predators or prey).

3D Oil commissioned JASCO Applied Sciences to undertake numerical acoustic modelling to predict the source levels and transmission losses from a single seismic pulse and multiple seismic pulses emitted from within the Acquisition Area. The modelling results (Quijano and McPherson 2020; Appendix D:) have been used in the following impact and risk evaluation to estimate the potential distances over which different receptors may be affected. The modelling is described in further detail below.

7.1.2 Receptors

The following receptors may potentially be impacted by noise emissions from the seismic source:

- Cetaceans
- Marine reptiles
- Seabirds
- Fishes and elasmobranchs
- Benthic invertebrates
- Zooplankton
- Fish spawning
- Commercial fisheries
- Marine protected areas
- Tourism and recreation.

7.1.3 Seismic Sound Source

Seismic sound is characterised by high energy pulses of low frequency sound. The frequency of the sound produced from each seismic pulse is primarily less than 2 kHz, with the highest levels at frequencies in the range of 10-500 Hz (McCauley 1994).

A 3,090 in^3 seismic source was modelled by JASCO Applied Sciences (JASCO) to determine acoustic source levels using their Airgun Array Source Model (Appendix D:) as the basis for the impact assessment. The modelling predicted the 3,090 in^3 seismic source to produce far-field source levels up to a maximum of 255 dB re 1 μPa.m (SPL_{pk}) and per-pulse source sound exposure levels (SEL) of 228-231 dB re 1 μPa2m^{2}s (at 0–2,000 Hz) in the vertical direction beneath the array.

The rate of sound attenuation from the seismic source is dependent on local sound propagation characteristics, including sea water temperature and salinity profiles, water depth, bathymetry and the geoacoustic properties of the seabed (McCauley 1994). While the seismic pulses are directed downwards, horizontal propagation may be detected over long distances due to the high intensity and low frequency properties of the sound source. Acoustic modelling of sound propagation from the seismic source is presented below.

7.1.3.1 Sound Source Verification

In 2018, a measurement program was conducted to validate the source signature predictions of JASCO's Airgun Array Source Model (McPherson *et al.* 2018). The validation program measured source levels for four airgun arrays including a 3,090-cui array. The measurement program was conducted in 80 m water depth off the northern coast of Australia, with an array passing directly over the recorder on the sea floor. The sound source verification process determined that the maximum measured SPL_{pk} for the 3,090-cui array was 221.7 dB re 1μPa. The measurement study results were used to validate modelled far-field source levels through a comparison between the measured received sound levels and predicted received sound levels at a real receiver point in the far-field of the source. The predictions were made using a wavenumber integral model coupled to the airgun source model. The program measured received sound levels in the endfire, broadside and vertical directions, and the results showed good agreement with the modelling results (McPherson *et al.* 2018). This study is therefore considered to provide validation of the modelled source signatures for the 3,090-cui array for this impact assessment.

7.1.4 Acoustic Modelling

3D Oil commissioned JASCO to model the source levels and sound propagation at four locations that were representative of the different water depths, bathymetry and seabed properties within the Acquisition Area (Quijano and McPherson 2020; Appendix D:). The objective of this acoustic modelling study was to evaluate the 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, marine protected areas and tourism and recreational activities. Modelling considered a 3,090 in^3 seismic source, towed at a 5–10 m depth behind the survey vessel. As described in Section 7.1 the source planned to be used for this survey is a maximum 2,820 in^3 array, however the impact assessment and subsequent management of impacts (controls) for seismic noise emissions is presented for the larger seismic array, as modelled assessed in the previously accepted 3D Oil Sauropod MSS EP (see modelling in Appendix D:).

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 defined locations within the Acquisition Area, and accumulated sound exposure fields were predicted for one representative scenario for likely survey operations over 24 hours.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL), zero-to-peak pressure levels (SPL_{pk}), peak-to-peak pressure levels ($SPL_{pk\text{-}pk}$), and either single-impulse (i.e. per-pulse) or accumulated sound exposure levels (SEL) as appropriate for different noise effect criteria. Particle motion metrics were predicted at all four modelled locations. 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 relevant effects thresholds or sound levels were reached.

Contours of the modelled underwater sound fields have been computed, sampled either as the maximum value over all modelled depths (maximum-over-depth: MOD) or at the sea floor for each of the four single-pulse locations, and for the one cumulative SEL_{24h} scenario. The modelled distances for each of the sound exposure thresholds are 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
2. R95% - the range to the given sound level after the 5% farthest points were excluded.

The difference between R_{max} and R95% 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 overestimate the area of the region exposed to such effects. In these instances R95% is considered more representative. In environments that have bathymetric features that affect sound propagation then the R95% neglects to account for these and therefore R_{max} might better represent the region of effect in specific directions. For this impact assessment the R_{max} values have been considered, in order to be conservative.

7.1.5 Sound Exposure Thresholds

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 sound exposure thresholds can be difficult. On assessment of the available science, thresholds have been defined for informing the impact assessment, and interpreting the numerical noise modelling. These sound exposure thresholds are discussed for each receptor in Section 7.1.6. The criteria have been selected on the basis that they include internationally recognised standard thresholds, thresholds suggested by the best available science, and sound levels presented in the scientific literature for species with no suggested thresholds.

Noise thresholds have been defined for both the per-pulse sound energy released, as well as the total sound energy (accumulated) that marine fauna are 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, this 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 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’s accumulated level (Gedamke *et al.* 2011). Hence, thresholds based on a 24-hour exposure period are considered to be a conservative measure of potential effect.

7.1.5.1 Particle Motion

The particle motion component of sound is also relevant to the assessment of potential impacts to marine fauna. Acoustic particle motion refers to the physical motion caused by a sound wave within the water, seabed or other medium. Unlike pressure, particle motion is directional in nature, although the actual to-and-fro particle displacements that constitute sound are extremely small, in the order of nanometres (Popper and Hawkins 2018). Particle motion can be described in terms of particle displacement (m), velocity (m/s), or acceleration (m/s2) (Popper *et al.* 2014; Carroll *et al.* 2017). Alternatively, it is sometimes expressed in dB with respect to a reference value of displacement (dB re 1 pm), velocity (dB re 1 nm/s) or acceleration (dB re 1 µm/s2) (Nedelec *et al.* 2016).

Particle motion is important because marine invertebrates and most fishes are primarily sensitive to particle motion rather than sound pressure and, therefore, particle motion is the most relevant metric for perceiving underwater sound by invertebrates and most fish species (Popper and Hawkins 2019). However, there is currently limited information available to quantify the particle motion sensitivity of fishes and invertebrates. It is complex and challenging to directly measure particle motion compared to sound pressure, hence most research is presented in the context of sound pressure or exposure levels instead of particle motion (Carroll *et al.* 2017; Popper and Hawkins 2018). Therefore, while the assessment of seismic noise impacts in this EP considers the role of particle motion and its effect on fishes and invertebrates, the acoustic modelling and impact threshold criteria are based upon sound pressure and sound exposure metrics.

It should be noted that particle motion is most relevant close to the source where it is the dominant component of a sound wave, while pressure will dominate a sound wave propagating over distance (Radford *et al.* 2012; Morley *et al.* 2014; Nedelec *et al.* 2016; Popper and Hawkins 2018). Sound pressure levels received at increasing distance from a source do not, therefore, provide a reliable representation of particle motion. Organisms that are sensitive only to particle motion have typically been found to be sensitive only at close range where these particle motions are greatest (Popper *et al.* 2014; Edmonds *et al.* 2016; Popper and Hawkins 2018).

7.1.6 Details of Impacts and Risks

7.1.6.1 Cetaceans

7.1.6.1.1 Species Sensitivity and Sound Exposure Thresholds

Physiological impacts such as physical damage to the auditory apparatus, e.g., loss of hair cells or permanently fatigued hair cell receptors, can occur in marine mammals when they are exposed to intense or moderately intense sound levels and could cause permanent or temporary loss of hearing sensitivity. While the loss of hearing sensitivity is usually strongest in the frequency range of the emitted noise, it is not limited to the frequency bands where the noise occurs but can affect a broader hearing range. This is because animals perceive sound structured by a set of auditory bandwidth filters that proportionately increase in width with frequency.

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). PTS is hearing loss from which marine fauna do not recover (permanent hair cell or receptor damage). PTS is considered injurious in marine mammals,

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 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 SPL_{pk} is needed to assess acoustic exposure injury risk.

The sound exposure thresholds applied for cetaceans in the acoustic modelling study, and in this impact assessment, are summarised in Table 7-4, and are explained in more detail in the acoustic modelling report (Appendix D:). Frequency weighting is also explained in Appendix A.3 of Appendix D:. The peak pressure levels (SPL_{pk}) and frequency-weighted accumulated sound exposure levels (SEL) presented in Table 7-4 are from the U.S. National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2018) for the onset of Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) in marine mammals. The marine mammal behavioural threshold presented in Table 7-4 is based on the current interim U.S. National Marine Fisheries Service (NMFS) (NMFS 2014) level of 160 dB re 1 µPa SPL for impulsive sound sources.

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. 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. Hence, PTS effects in marine mammals should be viewed as theoretical, as they have never actually been demonstrated in either captive or wild animals.

Table 7-4 – Unweighted SPL, SEL_{24h}, and SPL_{pk} Thresholds for Acoustic Effects on Cetaceans

Hearing Group	**NMFS (2014)**	**NMFS (2018)**			
	Behaviour	**PTS onset thresholds* (received level)**		**TTS onset thresholds* (received level)**	
	Unweighted SPL (dB re 1 µPa)	**Weighted SEL_{24h} (dB re 1 µPa2·s)**	**SPL_{pk} (dB re 1 µPa)**	**Weighted SEL_{24h} (dB re 1 µPa2·s)**	**SPL_{pk} (dB re 1 µPa)**
Low-frequency (LF) cetaceans	160	183	219	168	213
Mid-frequency (MF) cetaceans		185	230	170	224
High-frequency (HF) cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset.

7.1.6.1.2 Impact Assessment

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

As described in Section 4.3.6 the Humpback whale migration BIA is located approximately 15 km south of the Operational Area. The breeding, nursing and calving BIA for Humpback whales along the Kimberley coastline is located 255 km east of the Operational Area. However, the proposed timing for acquisition of the Sauropod 3D MSS (January to May) means that there will be no overlap with either the northbound or southbound migration of Humpback whales through the region (June to October; refer Table 4-10). The Pygmy blue whale migration and distribution BIAs pass along the shelf edge at depths between 500 m and 1,000 m. The Operational Area overlaps with the distribution BIA; however the migration BIA is located 95 km from the Operational Area. Acquisition of the survey may overlap the commencement of the northbound migration (April), but avoids the southbound migration period for Pygmy blue whales in the region (September to November; refer Table 4-10). Hence, there is a possibility of isolated individuals transiting through the Operational Area during the start of the northern migration in the region.

As summarised in Table 4-10, there is the possibility that a number of other cetacean species may be present in the Operational Area during acquisition of the survey (e.g. Bryde's, Fin, Sei, Killer and Sperm whales, Spotted bottlenose dolphin). 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.

No high-frequency (HF) cetaceans are likely to be present in the Operational Area and surrounding waters, and accordingly the impact assessment is focused on low-frequency (LF) cetaceans (baleen whales) and mid-frequency (MF) cetaceans (toothed whales and dolphins). 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. Impacts to Dugongs as a result of underwater sound from the seismic source are therefore not expected and are not addressed in this assessment.

Table 7-5 presents the results of the acoustic modelling study for maximum predicted R_{max} distances to PTS (injury), TTS and behavioural response thresholds for cetaceans, and the spatial extent (area) of these zones of potential impact (where relevant), for all modelled scenarios (four single impulse sites and one multiple pulse scenario). The results for the thresholds applied for cetacean PTS and TTS consider both single-pulse SPL_{pk} and multiple-pulse SEL_{24h}. In accordance with NMFS (2018) recommendations the longest distance associated with either metric is required to be applied for an impact assessment.

Table 7-5 – Maximum Predicted Horizontal Distances (R_{max}) To PTS (Injury), TTS and Behavioural Response Thresholds in Cetaceans, for All Modelled Scenarios

Hearing Group	Sound Exposure Threshold (Frequency Weighted)	R_{max} Distance (Km)
PTS		
LF-cetaceans	219 dB re 1 µPa (SPL_{pk})	0.03
	183 dB re 1 µPa2.s (SEL_{24h}) #	0.63
MF-cetaceans	230 dB re 1 µPa (SPL_{pk})	0.02
	185 dB re 1 µPa2.s (SEL_{24h}) #	-
TTS		
LF-cetaceans	213 dB re 1 µPa (SPL_{pk})	0.06
	168 dB re 1 µPa2.s (SEL_{24h}) #	15.4
MF-cetaceans	224 dB re 1 µPa (SPL_{pk})	0.02
	170 dB re 1 µPa2.s (SEL_{24h}) #	-
Behavioural Response		
LF-cetaceans MF-cetaceans	160 dB re 1 µPa (SPL)	8.36

The model does not account for shutdowns. A dash indicates that the threshold is not reached.

As shown in Table 7-5, considering the NMFS (2018) SEL_{24h} threshold criterion, LF-cetaceans (such as Pygmy blue whales) are predicted to experience PTS at a maximum predicted distance of 630 m from the nearest survey line, based on application of the multiple-pulse SEL_{24h} threshold across all water depths modelled (maximum-over-depth: MOD). For MF-cetaceans (such as Sperm whales and Killer whales) the maximum predicted distance to PTS effects reduces to 20 m, based on the application of the single pulse SPL_{pk} metric (the SEL_{24h} threshold was not exceeded).

The maximum predicted distance to the TTS thresholds for LF-cetaceans is 15.4 km from the nearest survey line, based on application of the multiple-pulse SEL_{24h} threshold. For MF- the maximum predicted distance to TTS effects reduces to 20 m, based on the application of the single pulse SPL_{pk} metric.

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 larger than those for peak pressure criteria, but they represent a worst-case scenario that is overly conservative and unlikely to occur. More realistically, whales would not stay in the same location or at the same range from the seismic source for 24 hours. This would particularly be the case for an animal migrating through offshore waters that do not 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 (Quijano and McPherson *et al.* 2019).

As shown in Table 7-5, predicted maximum R_{max} distances to PTS and TTS thresholds for LF-cetaceans based on the single pulse (SPL_{pk}) metric are considerably lower than those predicted using the multiple pulse SEL_{24h} thresholds. Application of the 219 dB re 1 µPa (SPL_{pk}) PTS threshold and of the 213 dB re 1 µPa (SPL_{pk}) TTS threshold indicates that predicted R_{max} radii from individual shot points are in the range of 30–60 m—i.e. a whale would have to be within a very close distance of the source (tens of metres) to be exposed to sound levels from a single pulse high enough to cause PTS or TTS effects.

The predicted maximum distance to the NMFS (2014) marine mammal behavioural threshold (single-pulse 160 dB re 1 µPa SPL), for both LF and MF-cetacean, is approximately 8.4 km, across all water depths modelled (refer Table 7-5).

PTS effects are predicted to have the potential to occur in LF-cetaceans (such as Pygmy blue whales) only within 30 m of the seismic source, based on the application of the single-pulse SPL_{pk} metric. This potential impact is highly unlikely to occur given the control measures that will be in place during acquisition of the survey. The concept of an individual whale remaining within a range of 630 m (maximum predicted distance for PTS, based on the SEL_{24h} metric) from the operating seismic source for a full 24-hour period is not credible. Furthermore, the control measures include implementation of a shut-down zone of 500 m and a low-power zone of 2 km under Part A of EPBC Policy Statement 2.1, which will further reduce the risk of injury.

TTS effects are predicted to have the potential to occur in LF-cetaceans only within 60 m of the seismic source, based on the application of the single pulse SPL_{pk} metric. Based on the $SEL_{24h}r$ metric, the maximum predicted distance for TTS is 15.4 km. However, as described above in relation to PTS, it is not credible that a whale would be consistently exposed to noise levels at a fixed position over a 24-hour period. Should an individual remain within the range for potential impact, some recoverable TTS could occur. The likelihood of TTS occurring is further reduced by the implementation of a shut-down zone of 500 m and a low-power zone of 2 km under Part A of EPBC Policy Statement 2.1.

The potential for PTS or TTS effects from single impulse or cumulative sound exposures does not extend to the Pygmy blue whale migration BIA, which is located is located 72 km to the north of the Operational Area. Therefore, no injury or hearing impairment is expected to occur to Pygmy blue whales, and sound levels received in the BIA from the seismic survey will be well below levels associated with behavioural impacts. Therefore, Pygmy blue whales will continue to utilise their migration route without injury or displacement. The proposed timing of the Sauropod 3D MSS (between January and May) also mostly avoids the Pygmy blue whale migration periods, with the exception of April/May when some Pygmy blue whales may be migrating north towards Indonesia (Table 4-10).

The potential impacts of noise emissions from the seismic source on cetaceans during acquisition of the Sauropod 3D MSS are considered to be slight and short-term, and most likely limited to temporary behavioural changes (avoidance) in individuals.

7.1.6.1.3 Summary

Based on the timing and duration of the survey, the absence of critical habitats for any species of cetacean (i.e. feeding, breeding, calving areas) or a constricted migratory pathway within the Operational Area and surrounding waters, and the control measures proposed, predicted noise levels from seismic acquisition are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for Pygmy blue whales or any other species of large whale that may be present within or adjacent to the Operational Area.

7.1.6.2 Marine Reptiles

7.1.6.2.1 Species Sensitivity and Sound Exposure Thresholds

Hearing has been studied in only a few individual marine turtles. Turtles have been shown to respond to low frequency sound, with indications that they have the highest hearing sensitivity in the frequency range 100–700 Hz.

Thresholds of 232 dB re 1 μPa (SPL_{pk}) for PTS effects and 226 dB re 1 μPa (SPL_{pk}) for TTS effects (Finneran *et al.* 2017), were applied for this impact assessment. A behavioural response threshold of 166 dB re 1 μPa SPL (NSF 2011), along with a sound level associated with an increased level of behavioural response of 175 dB re 1 μPa (SPL) (Moein *et al.* 1995; McCauley *et al.* 2000a, 2000b; NSF 2011) were also applied for this impact assessment.

Sea snake responses to seismic survey sound emissions are not well studied and thus conservatively assumed to be similar to that of turtles as described above.

7.1.6.2.2 Impact Assessment

The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017) identifies acute noise interference from anthropogenic noise sources, such as seismic surveys, as a threat to the WA stocks of Green, Flatback, Loggerhead, Hawksbill and Olive ridley turtles in the North West Shelf, Pilbara and Browse Basin regions (refer Table 4-8).

Without appropriate control measures in place, noise emissions from the seismic source have the potential to impact marine reptiles (turtles and sea snakes) 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.

As described in Section 4.3.8, there are several BIAs for turtle species in the region, including those along the coastline and around offshore islands. The closest BIA is at least 15 km from the Operational Area. No foraging, internesting, or nesting BIAs overlap with the Operational Area. The proposed timing for acquisition of the Sauropod 3D MSS (January toMay) means that there will be overlap with the nesting and breeding seasons for Green, Flatback, Loggerhead, Hawksbill and Olive ridley turtles in the region (October to March; refer Table 4-10). Hence, there is a low probability of isolated individuals transiting through the Operational Area during acquisition of the survey.

At least 20 species of sea snake occur within the region, and one threatened sea snake species (the Short-nosed sea snake) was identified in the EPBC Act Protected Matters Database search as having the potential to occur in the Operational

Area and surrounding waters. No coral reefs or shoals occur within or in close proximity to the Operational Area, and therefore sea snakes are expected to occur in very low numbers, if at all.

Table 7-6 presents the results of the acoustic modelling study for maximum predicted R_{max} distances to PTS, TTS and behavioural response thresholds in turtles for all modelled scenarios (four single impulse sites and one multiple pulse scenario).

Table 7-6 – Maximum Predicted Horizontal Distances (R_{max}) To PTS (Injury), TTS and Behavioural Response Thresholds in Turtles, for All Modelled Scenarios

Hearing Group	Sound Exposure Threshold	Distance R_{max} (Km)
PTS	232 dB re 1 µPa (SPL_{pk})	0.02
TTS	226 dB re 1 µPa (SPL_{pk})	0.02
Behavioural response	175 dB re 1 µPa (SPL)*	1.2
	166 dB re 1 µPa (SPL)#	5.1

Threshold for turtle behavioural response to impulsive noise (NSF 2011).

* Threshold for turtle behavioural response to impulsive noise (Moein *et al.* 1995).

As shown in Table 7-6, the Finneran *et al.* (2017) SPL_{pk} 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 × 8 m in the horizontal plane), the actual effect range from the edge of the array will be less than 20 m. The NMFS criterion (NSF 2011) for behavioural effects in turtles (166 dB re 1 µPa SPL) could be exceeded within a distance of approximately 5 km of the operating array, and the Moein *et al.* (1995) criterion of 175 dB re 1 µPa (SPL) could be exceeded within 1.2 km of the array.

7.1.6.2.3 Summary

As described above, at the closest point, the Operational Area is located at least 95 km from the nearest nesting BIA for turtles (Flatback turtle nesting BIA adjacent to Eighty Mile Beach), and at least 105 km from the foraging BIA for Green, Flatback and Loggerhead turtles adjacent to the Dampier Peninsula (refer Figure 4-13). At the closest point, the Operational Area is located at least 60 km from the ‘Habitat Critical’ for Flatback turtles adjacent to Eighty Mile Beach (Figure 4-14). To the north of the Operational Area there are no BIAs or ‘Habitat Critical’ for marine turtles surrounding the Rowley Shoals.

The potential impacts of noise emissions from the seismic source on marine turtles during acquisition of the Sauropod 3D MSS are considered to be slight and short-term, and restricted to temporary behavioural changes (avoidance) in any isolated individuals that may transit the area in close proximity to the operating seismic source. Based on the timing and duration of the survey, the separation distances to 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 the internesting BIA or ‘Habitat Critical’ 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 during the survey.

Sea snake responses to seismic survey sound emissions are not well studied and are thus conservatively assumed to be similar to that of turtles. Sea snakes tend to occur in shallow coastal waters or coral reef habitat and are not expected to be common in the Operational Area. Therefore, impacts are likely to be limited to occasional disturbances to transient individuals. The potential consequence to sea snake populations is considered to be not significant.

7.1.6.2.4 Seabirds

As described in Section 4.3.9, two threatened, two threatened and migratory, and 14 migratory marine birds were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the Operational Area. Seabird species that spend the majority of their lives within the region breed at locations along the coast of Australia and at offshore islands, including at the Lacepede Islands and the Rowley Shoals. The Operational Area overlaps a breeding and foraging BIA for the White-tailed tropicbird, and a breeding BIA for the Lesser frigatebird.

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. Lesser frigatebirds and White-tailed tropicbirds will not be displaced from the wider areas of the breeding and foraging BIAs.

7.1.6.3 Fishes and Elasmobranchs

7.1.6.3.1 Species Sensitivity and Sound Exposure Thresholds

The most relevant metric for perceiving underwater sound for most fish species is particle motion but, with the exception of a 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 500–1,500 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 background ambient noise. For this impact assessment, it is assumed that all fishes can detect signals below 500 Hz and so can 'hear' the seismic source.

The auditory capabilities of fishes vary depending upon the auditory structures in the inner ear (otoliths surrounded by an epithelium of hair cells) and, if present, the swim bladder (Finneran and Hastings 2000; Nedwell *et al.* 2004). Otoliths are sensitive only to particle motion, while the swim bladder may provide an indirect route for sound pressure to reach the inner ear. The other main mechano-reception system in fish is the lateral line system, which runs along the side of the body of fishes and is more pronounced in some groups of fishes than others. The lateral line system responds to particle motion produced in the near field of a sound source, as well as to tiny water currents set up by the fishes own motions (Nedwell *et al.* 2004). Therefore, all fish are sensitive to the particle motion component of sound, which is more dominant than sound pressure at close range from a sound source, while some more specialised fishes with a swim bladder involved in their hearing are sensitive to sound pressure and are capable of detecting less intense noise and a wider range of frequencies compared to less-specialised groups of fish (Popper *et al.* 2014; Hawkins and Popper 2017; Carroll *et al.* 2017).

In marine fishes, the connection with the swim bladder and ability to detect sound pressure is understood to be present to some varying degree in the families Clupeidae (e.g. herrings, sardines, pilchards and shads), Gadidae (e.g. true cods such as Atlantic cod and Whiting), and some nearshore / reef species relevant to tropical Australia, including some species in the families Pomacentridae (e.g. Damsel fishes and Clown fishes), Holocentridae (Soldierfishes and Squirrelfishes) and Haemulidae (e.g. Grunters and Sweetlips) (Nedwell *et al.* 2004; Braun and Grande 2008; Popper *et al.* 2014; Salgado-Kent *et al.* 2016; Popper and Hawkins 2018, 2019). However, the vast majority of marine fish species do not have this hearing specialisation.

A great many fish species possess a swim bladder or other gas-filled cavity but do not have a connection with their hearing. This is true of the various demersal snapper, emperor, cod and grouper species that occur in the Operational Area that are targeted by the demersal scalefish fisheries.

Fish species that lack a gas-filled cavity altogether, include elasmobranchs (e.g. sharks and rays), some flat fishes, some tunas, and mackerels (Casper *et al.* 2012; Popper *et al.* 2014). This is true of the sharks, mackerel species and some tuna species that may occur in the Operational Area, including Spanish mackerels and other mackerel species targeted by the Mackerel Managed Fishery.

Therefore, the modelling study (Quijano and McPherson 2020; Appendix D:) assesses the ranges for quantitative threshold criteria for potential mortality/injury and hearing impairment based on the Popper *et al.* (2014) guidelines, and considered both SPL_{pk} and SEL_{24h} metrics for both water column and sea floor associated with mortality/PMI and impairment in the following groups:

- I - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
- II - Fish with a swim bladder that do not use it for hearing
- III - Fish that use their swim bladders for hearing
- Fish eggs and fish larvae.

The sound exposure thresholds applied for fishes and elasmobranchs (sharks and rays) in the acoustic modelling study, and in this impact assessment, are summarised in Table 7-7, and explained in more detail in the acoustic modelling report (Appendix D:).

Note that the following assessment focusses primarily on impacts to fishes. The assessment of impacts to fish eggs and larvae is addressed in more detail in the assessment of impacts to zooplankton in Section 7.1.6.5. The assessment of impacts to fish spawning and recruitment success as a result of behavioural effects in fishes and impacts to eggs and larvae is subsequently assessed in Section 7.1.6.6.

Table 7-7 – Sound Thresholds for Seismic Sound Exposure for Fish, Fish Eggs and Larvae, 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 SPL_{pk}	216 dB SEL_{24h} or 213 dB SPL_{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 SPL_{pk}	203 dB SEL_{24h} or 207 dB SPL_{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 SPL_{pk}	203 dB SEL_{24h} or 207 dB SPL_{pk}	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate (I) High (F) Moderate	(N) High
Fish eggs and fish larvae	210 dB SEL_{24h} or 207 dB SPL_{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

Peak sound level (SPL_{pk}) dB re 1 µPa; SEL_{24h} dB re 1µPa2·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).

Mortality / Injury

It is noted that while thresholds for fish mortality have been included for consideration in this assessment based on the Popper *et al.* (2014) guidelines, 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; Popper *et al.* 2016; Carroll *et al.* 2017). Although some fish deaths have been reported during cage experiments, these were more likely caused by experimental artefacts of handling or confinement stress (Hassel *et al.* 2004, as cited in NSW DPI 2014). For free-swimming fish that are able to move away from seismic sources as they approach, the potential for lethal physical damage from airgun emissions is even further nullified. However, reef or bottom-dwelling fish that show greater site attachment may be less inclined to flee from a seismic sound source and experience greater effects as a consequence.

Despite mortality being a possibility for fish exposed to airgun sounds, Popper *et al.* (2014) do not reference an actual occurrence of this effect. In Popper *et al.* (2014) pile driving data was used as a proxy as the research to date had not identified a threshold level where mortality has been observed. Since the publication of that report, 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 (Pallid sturgeon and Paddlefish), with body masses in the range 200–400 g, exposed to a single shot of a maximum received level of either 231 dB re 1 µPa (SPL_{pk}) or 205 dB re 1 µPa2·s (SEL), remained alive for seven days after exposure and that the probability of mortal injury did not differ between exposed and control fish. They also found no difference in injuries between fish exposed closest to the source compared to those further away. Thus, this study, using an actual seismic source, did not show mortality at a level higher than the mortality, potential mortal injury and recoverable injury to the threshold of 207 dB re 1 µPa (SPL_{pk}) applied in this impact assessment.

ERM (2017) conducted a detailed literature review of potential fish mortality and physical injury as a result of exposure to seismic sources. Only three studies of the 23 reviewed observed direct mortality of exposed fish:

- Booman *et al.* (1996) – at received levels (RL) of 241-231 dB SPL_{pk}
- Weinhold and Weaver (1972) – at RL of 234 dB SPL_{pk}
- Matishov (1992) – at RL of 220 dB SPL_{pk}.

In each case mortalities occurred to caged fish that were constrained within very close proximity to the airguns (2 m). The results of the Matishov (1992) study should be treated with some caution, given the lack of detail provided for this experiment.

Eleven other studies did not observe mortality effects or injury likely to result in mortality, at RL levels ranging from 246-220 dB SPL_{pk}. Fanta (2004) found no mortality or physical damage in coral reef fishes exposed in cages to RL ranging from 235-215 dB SPL_{pk}. The relevance of the findings of this study are regarded as high, given that the RL were measured and that the experiment involved exposure of 15 different fish species to a full commercial seismic array (3,090 cui) at a minimum exposure distance of 45 m. Wardle *et al.* (2001) did not observe any mortality or physical damage in free-ranging temperate reef fish exposed to RL of 218 dB SPL_{pk}, at a minimum exposure distance of 5.3 m. Again, the relevance of the results of this experiment is regarded as high, in that the RL were measured rather than estimated.

Based on the above studies, the Popper *et al.* (2014) thresholds of 207 and 213 dB re 1 µPa (SPL_{pk}) applied in this impact assessment for mortality, mortal injury and recoverable injury in fishes are potentially conservative.

TTS

Temporary hearing impairment (TTS) can occur due to fatigue and temporary changes to the epithelium (hair cells) of the inner ear and/or damage to auditory nerves innervating the ear, which has the potential to occur in some fishes exposed to intense sound pressures for prolonged periods of time (Smith *et al.* 2006; Popper *et al.* 2014; Liberman 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 Yan 2001; Amoser and Ladich 2003; Smith *et al.* 2004a; 2004b; 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."

The impact threshold of 186 dB re 1 µPa2·s proposed by Popper *et al.* (2014) in Table 7-7 is based on exposure of a freshwater fish species with a connection between the swim bladder and inner ear (more specialised hearing than the demersal and pelagic fish species likely to occur in the Sauropod 3D MSS Operational Area). Fish that showed TTS recovered to normal hearing levels within 18–24 hours. Given that reliable auditory frequency weightings have not been defined for the three categories of fish in the way they have been for cetaceans (Section 7.1.6.1), the 186 dB re 1 µPa2·s SEL_{24h} criteria in Table 7-7 includes a level of conservatism as:

- The types of fish that are likely to occur in the Sauropod 3D MSS Operational Area do not possess a direct connection between the swim bladder and the inner ear; they are therefore sensitive primarily to particle motion rather than sound pressure and may be less sensitive than the types of fish upon which the 186 dB re 1 µPa2·s threshold is derived
- Modelled SELs are based on broadband sounds and may therefore account for more sound energy associated with frequencies that are not within the auditory ranges of the fish species likely to occur in the Sauropod 3D MSS Operational Area.
- The main contribution of sound energy to the onset of TTS will occur over just a few hours when the source is at the closest point of approach; the 24-hour modelled accumulation period accounts for additional sound energy accumulated while the seismic source is at greater distances and potentially not audible to fishes.

It is also noted that many of the available studies on TTS are based on captive fish, whereas free-swimming fishes in the wild are likely to make some effort to avoid the intense sound pressures that contribute the most to the onset of TTS. If TTS does occur, the effects are temporary and will recover.

Behavioural Effects

Behavioural effects of noise on fish will vary depending on the circumstances of the fish, hearing sensitivity, the activities in which it is engaged, its motivation, and the context in which it is exposed to sounds (Hawkins and Popper 2017). Responses may include avoidance behaviours, startle reactions, increased swimming speed, change in orientation, change in position in the water column, changes to schooling behaviour (e.g. tightening of school structure), and temporary avoidance of an area (Simmonds and MacLennan 2005; McCauley *et al.* 2000a; Fewtrell and McCauley 2012; Popper *et al.* 2014; Carroll *et al.* 2017). Changes in movement patterns may also temporarily divert efforts away from feeding, egg production and spawning success (Hawkins and Popper 2017). The potential extent and duration of behavioural effects based on studies of seismic exposure are summarised below.

A degree of caution should be given when interpreting behavioural studies, given that many are conducted on captive fish, which may not provide an accurate representation of responses in free-swimming fish in the wild (Popper *et al.* 2014; Salgado Kent *et al.* 2016; Carroll *et al.* 2017). Behavioural studies are also highly subjective. Extrapolation of observed effects on fishes should also be undertaken with caution (Carroll *et al.* 2017). This is particularly the case given that many exposure experiments report received sound pressure levels or sound exposure levels, even though the most relevant metric for most fish species is particle motion (Popper and Hawkins 2018; Popper *et al.* 2019). Many exposure experiments are undertaken using a single airgun and it is not clear how transferrable the behaviours and received SPL/SEL levels are to a full commercial-sized seismic array, particularly if observed behaviours are in response to particle motion close to the sound source rather than to sound pressure.

Pearson *et al.* (1992) exposed captive demersal rockfish to multiple 10-minute periods of seismic sound from a seismic source towed at distances of less than 215 m, which is not representative of real-life exposures to a seismic survey. Schools of rockfish were observed to exhibit a ‘startle’ response (shudders, flexions of the body followed by rapid swimming) at sound levels above 200–205 dB re 1µPa SPL. An ‘alarm’ response (change in vertical position in the water column to be closer to the seabed, short-term post-exposure behavioural changes) was found to occur above approximately 180 dB re 1 µPa SPL, although it was suggested that some individuals may begin to exhibit subtle changes in behaviour and position in the water column at sound levels above 161 dB re 1µPa SPL. Changes in behaviour were found to return to normal before the end of the sound exposure or within just minutes of the sound ceasing, indicating only very short-term, transient effects and potential habituation to the disturbance.

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.

The Scott Reef Study associated with the Woodside Maxima 3D survey reported in McCauley *et al.* (2008) and Miller and Cripps (2013) and summarised in Salgado-Kent *et al.* (2016) included a component that examined how the behaviour of caged fish exposed to seismic signals changed. The study examined the effects to fish species in the Holocentridae family, which have adaptations linking the swim bladder to the otolith system of the inner ear, as well as to Bluestripe snapper, a demersal species without such a hearing adaptation, similar to the demersal species that are most likely to occur within the Sauropod 3D MSS Operational Area. Fish were exposed to either one or two passes of the active source at three distance categories (45–74 m, 105–131 m, 475–807 m). Alarm responses (including the startle response and behavioural avoidance) occurred within less than 200 m either side of the pass by, but responses were too infrequent to include in analyses. Less significant agitation levels (defined by changing swim direction) in Holocentridae increased with increasing received sound level above 155–165 dB re 1 uPa2.s SEL, but agitation levels did not seem to increase with increasing received sound levels for the less sensitive Bluestripe snapper (McCauley *et al.* 2008). Fish began to feed and behave normally again within 20 minutes after the passage of the seismic source (McCauley *et al.* 2008; Miller and Cripps 2013).

McCauley *et al.* (2000a, 2003) reported that trials involving captive fishes (of various species, including snappers, emperors, groupers, trevally, bream, herring and others) exposed to seismic sound showed a common ‘startle’ response (C-turns), 'alarm' responses (e.g. swimming faster, darting movements and sudden changes in school structure), or less obvious changes such as moving closer to the seabed or huddling closer together. Subtle responses such as moving closer to the seabed or changes in schooling behaviour were suggested to commence when sound levels exceeded approximately 147–151 dB re 1 µPa2.s SEL. Similar behaviours in pink snapper and trevally were noted by Fewtrell and McCauley (2012) in response to comparable sound levels. These are minimal reactions that are likely to be an indication of awareness and perception of the sound rather than a response that could result in significant ecological impacts. More obvious startle and alarm responses were apparent in trials when received sound levels were in the order of 159–172 dB re 1 µPa2.s SEL. In situations where a behavioural response was observed, fishes were considered to have resumed normal behaviour within 4–31 minutes after cessation of the seismic activity (McCauley *et al.* 2000, 2003). Startle and alarm responses reduced with time, indicating some habituation to the sound. No statistically clear trends in physiological stress response were observed following exposure (McCauley *et al.* 2000, 2003).

Behavioural observations of two tropical snapper species and another coral reef fish species, Spadefish, in field enclosures before, during and after exposure to seismic sound showed that repeated exposure resulted in increasingly less obvious startle responses (Boeger *et al.* 2006). This is consistent with the potential habituation suggested by McCauley *et al.* (2000) and by Fewtrell and McCauley (2012).

McCauley and Salgado Kent (2007, cited in Santos Ltd 2018) observed the behaviour of Goldband snapper in fish traps in the Timor Sea using cameras placed inside the fish traps. A seismic vessel towed two 3,090 cubic inch seismic sources. Maximum signals reached at the closest trap to each seismic pass-by were 200, 202 and 212 dB re 1 µPa SPL_{pk-pk} (equivalent to approximately 194, 196 and 206 dB re 1 µPa SPL_{pk}). No dramatic behavioural responses of fish to the passing seismic source were observed. Fish generally displayed increased activity immediately after entering a trap presumably as they searched for a way out, with this activity reducing with time. Fish which had been in a trap for some time showed increased activity levels as the operating seismic source approached but were ‘quiet’ when the array passed at the point of closest approach.

The Australian Institute of Marine Science (AIMS), as part of the North West Shoals to Shore Research Program, have undertaken a study of the potential behavioural effects of seismic sound exposure on red emperor, another key demersal species that occurs in the Operational Area and in the wider region. The results from this study show that there were no short-term (days) or long-term (months) effects of exposure on the composition, abundance, size structure, behaviour, or movement of key fisheries species (Meekan *et al.* 2021).

Bruce *et al.* (2018) tagged Tiger flathead and two shark species, which were monitored during a seismic survey undertaken in Australian waters. Sharks moved freely in and out of the study area and exposed sharks did not show any indication of differences in behaviour or distribution compared with control areas. Minor behavioural effects were observed in exposed Tiger flathead, which increased their swimming speed during the seismic survey and changed daily movement patterns after the survey but showed no significant displacement. Overall, there was little evidence for consistent behavioural responses (Bruce *et al.* 2018).

Paxton *et al.* (2017) observed temperate reef fish, including snapper and grouper species, in 33 m water depths located 7.9 km from a seismic survey line using video recordings. The authors observed fish abundance and habitat use during the evening hours for three days prior to a seismic survey and then during the evening of the day when seismic activity occurred. The authors attempted to measure sound at two other reefs in closer proximity to the survey, but the hydrophones malfunctioned. No video recordings were made at the other reefs where hydrophone measurements were attempted. No hydrophone measurements were made at the reef where video recordings took place, but maximum sound levels were estimated to be in excess of 170 dB re 1 μPa SPL. Despite no clear visual evidence of behavioural responses in fishes during the seismic survey, the authors noted a 78% decline in abundance in the evening following the survey. No further recordings were made to assess when fish abundance returned to pre-exposure levels or how far they may have moved. Therefore, with limited data, it is not clear from this study if reduced abundance is attributed to the seismic sound or other natural factors such as tidal influence or food availability. However, the study may indicate a possible avoidance response and change in local abundance and distribution.

Some other studies looking at the behavioural response of sound pressure sensitive Gadidae and Clupeidae species, such as Whiting, Atlantic cod and Herring, have reported changes in vertical position in the water column, potential avoidance responses and short-term changes in distribution. Chapman and Hawkins (1969) observed that the depth distribution of free-ranging Whiting changed in response to an intermittently discharging stationary seismic source, which resulted in fish being exposed to an estimated SPL of 178 dB re 1 μPa. The fish school responded to the sound by shifting downward, forming a more compact layer at greater depth although temporary habituation was observed after one hour of continual sound exposure (Chapman and Hawkins 1969).

Hawkins *et al.* (2014) exposed free-swimming Sprat (a sound pressure sensitive Clupeidae species with a swim bladder connected to the inner ear) and Atlantic mackerel (a particle motion detecting species without a swim bladder) to playback of impulsive sound. Sprat schools were more likely to disperse laterally in response to received sound levels of approximately 135 dB re 1 μPa2.s SEL. Mackerel schools were more likely to alter their depth in the water column in response to approximately 142 dB re 1 μPa2.s SEL. Hawkins *et al.* (2014) note how the two different species seemed to respond to the sound playback at similar sound levels despite the differences in sound sensitivity of the two species, but suggested that Mackerel were simply more “flighty” than Sprat and therefore more likely to react. The tests were also undertaken using low sound level playback in very close proximity to the schools of fish and it is not clear how relevant the sound pressure and SEL levels are in relation to Mackerel given that their response was likely driven by particle motion. The study location in a very small, enclosed, quiet, coastal sea lough, where fish were not accustomed to heavy disturbance from shipping and other intense sound sources is also very different from an open ocean location.

Slotte *et al.* (2004) monitored the effects of a 3,090 cubic inch seismic array on migrating Herring (Clupeidae) and Whiting (Gadidae), mapping their distribution and abundance in relation to the seismic survey lines. There was no significant evidence of immediate, near-field scaring reactions on the horizontal scale in response to acquiring survey lines, but there was some evidence that fish changed position in the water column, moving closer to the seabed. Some short-term changes in distribution were observed but were not statistically significant; fish consistently remained within the immediate vicinity of the survey area, but in a limited number of measurements there was an indication that fish abundance was lower near to the survey area and increased with distance out to a maximum range of 37 km. However, results were inconsistent and clear trends were not observed in all cases. Slotte *et al.* (2004) concluded that it was not possible to determine how much abundance and distribution were attributed to the seismic survey or to the fishes’ natural migration patterns, food availability or other natural factors. Herring and Whiting were found to be abundant in the survey area again after a pause in seismic acquisition and monitoring of fishes for three to four days, indicating that if any displacement did occur as a result of seismic sound exposure, the displacement was temporary (i.e. less than 3–4 days) (Slotte *et al.* 2004). In similar studies, Engås *et al.* (1996) and Engås and Løkkeborg (2002) reported on the effects of seismic surveys on Atlantic cod and Haddock (Gadidae) and found that the abundance of fish was lower in the survey area compared with areas outside of the survey area, which the authors hypothesize may be the result of an avoidance response. Some differences in abundance were still detectable within the survey area five days after the survey was completed (Engås *et al.* 1996; Engås and Løkkeborg 2002).

Conversely, Peña *et al.* (2013) described the real-time behaviour of Herring schools exposed to a full-scale 3D seismic survey, observed using sonar. No changes were observed in swimming speed, swimming direction, or school size that could be attributed to a transmitting seismic vessel as it approached from a distance of 27 km to 2 km, over a six-hour period. The unexpected lack of a response to the seismic survey was interpreted as a combination of a strong motivation for feeding by the fish, a lack of suddenness of the onset of sound, and an increased level of tolerance to seismic pulses.

The following conclusions are made regarding behavioural effects to fishes, based on the literature above:

- Different fish may exhibit different behavioural responses when exposed to seismic survey noise, depending on their activities, motivation and the context in which they receive sound.
- Fishes may change position in the water column (i.e. move closer to the seabed) as a response to becoming aware of approaching seismic sound (generally observed in response to sound levels greater than 150 dB re 1 µPa2.s SEL or 160 dB re 1 µPa SPL, but this varies depending on hearing sensitivity and context) (e.g. Pearson *et al.* 1992; McCauley *et al.* 2000, 2003; Slotte *et al.* 2004; Fewtrell and McCauley 2012; Miller and Cripps 2013).
- Exposure to higher sound levels at close range to a seismic source may begin to result in more noticeable startle or alarm responses, such as changes in school structure, increased swimming speed and avoidance of the sound source (typically observed within hundreds of metres of the seismic source or in response to sound levels of approximately 150 dB re 1 µPa2.s SEL or 168–190 dB re 1 µPa SPL and varying depending on hearing sensitivity and context) (e.g. Simmonds and MacLennan 2005; McCauley *et al.* 2000, 2003; Fewtrell and McCauley 2012; Popper *et al.* 2014; Carroll *et al.* 2017).
- Many exposure experiments are undertaken using a single airgun and it is not clear how transferrable the behaviours and received SPL/SEL levels are to a full commercial-sized seismic array, particularly if observed behaviours are in response to particle motion close to the sound source rather than to sound pressure.
- Many studies indicate that fishes resume normal behaviour shortly after cessation of the acoustic disturbance (within minutes / less than an hour), with no evidence of long-term changes (e.g. Wardle *et al.* 2001; Pearson *et al.* 1992; Santulli *et al.* 1999; McCauley *et al.* 2000, 2003; Fewtrell and McCauley 2012; Miller and Cripps 2013; Meekan et al 2021).
- There is some evidence that fish may also tolerate gradual increases in sound levels and habituate to repeated sound exposures (Chapman and Hawkins 1969; McCauley *et al.* 2000; Boeger *et al.* 2006; Fewtrell and McCauley 2012; Peña *et al.* 2013).
- In other studies, there is some evidence that changes in distribution may persist for longer than the initial change in behaviour, i.e. position in the water column, schooling behaviours and swim speeds may return to normal relatively quickly within minutes or hours, but their distribution may not return to normal for hours or days. Potential changes in distribution of fishes have been observed in some studies for approximately 5 days following sound exposure, although 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). These studies also acknowledge that it is difficult to attribute these changes in distribution directly to the seismic survey or to natural migration patterns, food availability or other natural factors (Slotte *et al.* 2004; Engås *et al.* 1996; Engås and Løkkeborg 2002).

Given the limited convergence in results from the available studies, the subjective nature of many assessments and the context under which fish received sound, the Popper *et al.* (2014) ANSI-Accredited Standards Committee Sound Exposure Guidelines for Fishes and Turtles determined that it is not possible to define exact sound level thresholds for changes in fish behaviours. Instead, Popper *et al.* (2014) applies relative risk criteria (Table 7-7). The criteria reflect the potential for substantial changes in behaviour for a large proportion of the animals exposed to a sound, which may alter distribution and moving from preferred sites for feeding and reproduction. These criteria do not include effects on single animals or small changes in behaviour such as a startle response or minor movements. As such, Popper *et al.* (2014) indicate that fish without a swim bladder or with no connection between the swim bladder and the inner ear may experience substantial changes in behaviour within tens or hundreds of metres of a seismic source. These peer-reviewed and accredited sound exposure criteria are reflected in CGG's risk assessment. It is acknowledged that some fishes with swim bladders may show varying levels of awareness of sound pressure at greater distances from the seismic source, but it is important to recognise changes in behaviour that may be of ecological significance from those that are not.

7.1.6.3.2 Impact Assessment

As described in Section 4.3, the Operational Area and surrounding waters represent habitat for a range of bony fishes (teleosts) and elasmobranchs (sharks and rays), including pelagic, demersal and benthic assemblages. These fish assemblages include species and stocks that are targeted by commercial fisheries in the region (e.g. Goldband snapper, Rankin cod, Red emperor, Spanish mackerel and Blue-spotted emperor). The Operational Area overlaps the Whale shark foraging BIA that extends northwards from North West Cape along the 200 m isobath.

The EPBC Protected Matters Search (refer Section 4.3) identified 31 pipefish, six seahorse, four pipehorse and one seadragon species within the Operational Area, which are listed marine species. Pipefish and seahorses occur in nearshore and coastal waters comprising suitable habitat, such as seagrass, mangrove, coral reef and sandy habitats around coastal islands and shallow reef areas. Due to the water depth range within the Operational Area (95–172 m) and absence of suitable habitat, pipefish and seahorses are unlikely to occur within the Operational Area and surrounding waters. Consequently, these listed marine species are not considered in this impact assessment.

The Operational Area also overlaps the ancient coastline at 125 m depth contour key ecological feature (KEF). Parts of this KEF, represented as rocky escarpment, are considered to provide biologically important habitat in an area predominantly made up of soft sediment. These areas of hard substrate may represent habitat for both demersal and benthic fish assemblages.

Without appropriate control measures in place, noise emissions from the seismic source have the potential to impact fishes and elasmobranchs by causing mortality / potential mortal injury (PMI), recoverable injury and hearing impairment (TTS and masking) as a result of high sound levels at close range to the seismic source, or behavioural disturbance impacts at greater distances.

Table 7-8 presents the results of the acoustic modelling study for maximum predicted R_{max} distances to mortality/potential mortal injury, recoverable injury and TTS thresholds in fishes in the Operational Area. Data are presented for both the water column (maximum over depth) and at the sea floor.

The following fish types have been identified for this assessment:

- Demersal fish species, including key commercial indicator species such as tropical snappers and emperors (families Lutjanidae and Lethrinidae)
- Pelagic fish species, including key commercial indicator species such as Spanish mackerel
- Whale sharks
- Fish assemblages associated with the ancient coastline at 125 m depth contour.

Table 7-8 – Maximum Predicted Distances (R_{max}) to Mortality/Potential Mortal Injury, Injury and TTS Thresholds for Fish, Fish Eggs and Larvae for Single-Pulse and SEL_{24h} Modelled Scenarios, For Both Water Column and at The Sea floor

Marine Fauna Group	Potential Impact	Sound Exposure Threshold	Water Column (Maximum-Over-Depth)		Sea floor	
			R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
I - Fish: No swim bladder (incl. sharks)	Mortality/ potential mortal injury	219 dB re 1 µPa2·s (SEL_{24h})	0.03	9.75	-	-
		213 dB re 1 µPa (SPL_{pk})	0.06	NR*	0.08	NR*
	Recoverable injury	216 dB re 1 µPa2·s (SEL_{24h})	0.03	12.00	-	-
		213 dB re 1 µPa (SPL_{pk})	0.06	NR*	0.08	NR*
	TTS	186 dB re 1 µPa2·s (SEL_{24h})	2.81	720.12	2.79	715.75
II - Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality/ potential mortal injury	210 dB re 1 µPa2·s (SEL_{24h})	0.03	12.44	-	-
		207 dB re 1 µPa (SPL_{pk})	0.13	NR*	0.19	NR*
	Recoverable injury	203 dB re 1 µPa2·s (SEL_{24h})	0.04	13.28	-	-
		207 dB re 1 µPa (SPL_{pk})	0.13	NR*	0.19	NR*
	TTS	186 dB re 1 µPa2·s (SEL_{24h})	2.81	720.12	2.79	715.75
III - Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality/ potential mortal injury	207 dB re 1 µPa2·s (SEL_{24h})	0.04	13.28	-	-
		207 dB re 1 µPa (SPL_{pk})	0.13	NR*	0.19	NR*
	Recoverable injury	203 dB re 1 µPa2·s (SEL_{24h})	0.04	13.28	-	-
		207 dB re 1 µPa (SPL_{pk})	0.13	NR*	0.19	NR*
	TTS	186 dB re 1 µPa2·s (SEL_{24h})	2.81	720.12	2.79	715.75
Fish eggs and larvae	Mortality/ potential mortal injury	210 dB re 1 µPa2·s (SEL_{24h})	0.03	12.44	-	-
		207 dB re 1 µPa (SPL_{pk})	0.13	NR*	0.19	NR*
	Injury	Popper *et al.* (2014) relative risk criteria#	(N) Moderate; (I) Low; (F) Low			
	TTS		N) Moderate; (I) Low; (F) Low			

A dash indicates that the threshold is not reached. * Not relevant. # 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).

Demersal Fish Species

The various species of demersal snappers (Lutjanidae), emperors (Lethrinidae), rock cods and groupers (Serranidae) that are characteristic of the Operational Area do not possess a mechanical connection between the swim bladder and the ears and can be said to have mid to poor hearing ability (Tavolga and Wodinsky 1963; Higgs *et al.* 2006; Braun and Grande 2008; Engineering-Environmental Management, Inc. 2008; United States Department of the Navy 2008; Popper 2012; Caiger *et al.* 2012). Note that commercially targeted Rankin cod and other 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 in Table 7-7).

As shown in Table 7-8, the maximum predicted R_{max} distance to the injury threshold at the sea floor for the hearing group of fishes with swim bladders not involved in hearing (Group II, which would represent most demersal fish), is 190 m. The maximum predicted R_{max} distances to the injury thresholds for adult fish (with swim bladder), and fish eggs and larvae, in the water column is 130 m. Therefore, injury effects have the potential to occur to demersal fishes at or close to the sea floor within or adjacent to the Acquisition Area. However, as discussed above, the thresholds for mortality and injury are considered highly conservative. While injury or mortality to fishes in the immediate proximity of the seismic source is theoretically possible, free-swimming fishes such as the demersal species that are characteristic of the Operational Area are expected to be able to avoid the seismic source as it approaches their position or ramps up during soft starts. For example, the demersal fish assemblages that are typical of the habitats in the Operational Area (predominantly snappers, emperors, cods and groupers), despite exhibiting particular habitat preferences and some fidelity to an area, can be found across a variety of habitats and are typically mobile with home ranges in the order of kilometres or tens of kilometres (Ovenden *et al.* 2004; Moran *et al.* 2004; Newman *et al.* 2008; Parsons *et al.* 2011; Harasti *et al.* 2015). Impacts to demersal fishes are, therefore, considered more likely to be limited to behavioural and TTS effects, with injury/mortality being highly unlikely to occur.

Based on the maximum predicted R_{max} distances to the TTS threshold (approximately 2.8 km in the water column and at the sea floor; refer Table 7-8) individuals in demersal fish communities at or close to the sea floor within the Acquisition Area could experience TTS effects. The radii that correspond to SEL_{24h}r typically represent an unlikely worst-case scenario for SEL-based exposure since, more realistically, fishes would not stay in the same location or at the same range for 24 hours. Therefore, this method is highly conservative and a reported radius of SEL_{24h}r criteria does not necessarily mean that animals travelling within this radius of the source will suffer hearing impairment.

Popper (2018) in his review of TTS for the Santos Bethany 3D MSS, which considered similar demersal fish species as present in the Sauropod 3D MSS Operational Area, 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, this also applies for the North West Shelf region), being species that do not have hearing specialisations, are not likely to have much (if any) TTS as a result of the Bethany 3D survey.
- 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.
- Little 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 and survival is very low.

Therefore, it is possible that some demersal fishes may not avoid the approaching seismic source completely and some level of TTS is possible, but the effects are temporary and recoverable, and the potential for such effects to have significant implications on fish fitness and survival is low.

The majority of studies relevant to behavioural responses in demersal fish species (e.g. Pearson *et al.* 1992; Santulli *et al.* 1999; McCauley *et al.* 2000a; 2003; McCauley and Salgado Kent 2007, cited in Santos Ltd 2018; Woodside 2011; Fewtrell and McCauley 2012; Miller and Cripps 2013; Bruce *et al.* 2018), indicate that exposure to a mobile seismic source and significant changes in behaviour are likely to be limited to durations of minutes or hours and occur within hundreds of metres of the seismic source as it passes.

Popper *et al.* (2014) suggest that the potential for significant behavioural impacts in the Group II 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, 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 startle or avoidance responses are more likely to be limited to a shorter period (less than an hour) when the seismic source passes close by. Consistent with the studies reviewed earlier in this section, behaviours may return to normal within less than an hour (sometimes just minutes) of the survey vessel passing.

Further, the implications for demersal fishes at a population level are expected to be limited. McCauley (1994) suggests that behavioural changes in fishes may only be localised and temporary, without significant repercussions at a population level. Hawkins and Popper (2016) highlight that some responses to artificial sound may have minimal or no consequences for populations. For example, short-term startle responses to sounds that rapidly diminish with repeated presentation, or that do not change the overall behaviour of fishes are unlikely to affect key life functions. In addition, anthropogenic sound events that are transient in nature, such as a seismic survey, and result in short-term impacts do not necessarily translate into long-term consequences to populations (Hawkins and Popper 2016). Most recently, Meekan et al (2021) demonstrated there were no short-term (days) or long-term (months) effects of exposure on the composition, abundance, size structure, behaviour, or movement of several demersal fish species in the survey area.

Pelagic Fish Species

Most pelagic fishes likely to be present in the region would belong to the Suborder Scombroidei, (which includes all of the large, pelagic, fast-swimming fish species): Family Sphyraenidae (barracudas); Family Gempylidae (snake mackerels);

Family Trichiuridae (cutlassfishes) Family Scombridae (mackerels and tunas); Family Xiphiidae (swordfishes); and Family Istiophoridae (billfishes).

Scombridae species are hearing generalists (narrower frequency range with higher auditory thresholds), in that some species, such as mackerels, do not possess a swim bladder (Group I fishes) while some species possess a swim bladder, but lack the mechanical connection to the inner ear and the otoliths (Group II fishes). As a group, they seem able to detect mid-range frequencies (~300-1,000 Hz).

As shown in Table 7-8, the maximum predicted R_{max} distance to the injury threshold in the water column for the hearing groups of fishes with swim bladders not involved in hearing (Groups II) and no swim bladder (Group I)), is 130 m and 60 m respectively (refer Table 7-8). The maximum predicted R_{max} distance to the TTS threshold for all fish hearing groups is ~2.8 km.

Large, pelagic, fast-swimming fish species such as mackerel, billfishes and tunas are highly unlikely to experience TTS effects as they can swim away from a seismic source. Individuals would have to remain within ranges of approximately 2.8 km of the operating seismic source for a full 24-hour period to be exposed to sound levels that could cause TTS. Pelagic fishes are most likely to exhibit a significant behavioural response (avoidance) by moving away from an operating seismic source that approaches within a few tens or hundreds of metres of them (Wardle *et al.* 2001).

Whale Sharks

The Operational Area overlaps the foraging BIA for Whale sharks that extends northeast from North West Cape across the North West Shelf (refer Figure 4-12). This BIA is centred on the 200 m isobath and Whale sharks are most likely to be present in the months of July to November. Therefore, given that the proposed timing of the survey does not coincide with this period, Whale sharks are not expected to be encountered frequently, although it is possible that occasional Whale sharks may be present in the Acquisition Area during the Sauropod 3D MSS. Given that there is no temporal overlap, no displacement of Whale sharks from foraging activities within the BIA is expected.

No sound exposure thresholds currently exist for acoustic impacts from seismic sources to sharks. As a conservative and precautionary approach, the Popper *et al.* (2014) exposure guidelines for fish with no swim bladder for injury (213 dB re 1 µPa (SPL_{pk}) and 219 dB re 1 µPa2·s (SEL_{24h})); and TTS (186 dB re 1 µPa2·s (SEL_{24h})), have been used for this assessment.

As shown in Table 7-8, the maximum predicted R_{max} distance to the injury threshold in the water column for the hearing group of fishes without swim bladders, is 60 m (refer Table 7-8). The maximum predicted R_{max} distance to the TTS threshold for this fish hearing group is ~2.8 km. Again, it is important to appreciate that individual whale sharks would have to remain within a range of approximately 2.8 km of the operating seismic source (which is also moving) for a full 24-hour period to be exposed to sound levels that could cause TTS.

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

Seismic noise has not been identified as a threat to Whale sharks (or other shark species identified that may be present in the region) in either the Approved Conservation Advice (TSCC 2015) or previously in force Whale Shark Recovery Plan 2005 – 2010 (DEH 2005). Noise pollution is not identified as a pressure to Whale sharks in the Marine Bioregional Plan for the NWMR (DSEWPaC 2012), or in the Ningaloo Coast: World Heritage nomination report (Commonwealth of Australia 2010).

Ancient Coastline At 125 M Depth Contour KEF

As shown in Table 7-8, the maximum predicted R_{max} distances to the mortality/injury thresholds of 213 dB re 1 µPa (SPL_{pk}) and 207 dB re 1 µPa (SPL_{pk}) at the sea floor for all hearing groups of fishes, and for fish eggs and larvae, range from 80-190 m. The maximum predicted R_{max} distance to the TTS threshold of 186 dB re 1 µPa2·s (SEL_{24h}) at the sea floor for all hearing groups of fishes, and for fish eggs and larvae, is 2.8 km.

The area of overlap between the ancient coastline at 125 m depth contour KEF and the Acquisition Area for the Sauropod 3D MSS is approximately 1,272 km^2, which represents approximately 8% of the designated area of the KEF. Given the maximum predicted R_{max} distances for mortality/injury and TTS effects of 190 m and 2.8 km, respectively, there is the potential for some fishes at the sea floor to experience mortality/injury and TTS effects. However, as discussed above, the thresholds for mortality and injury are considered highly conservative. While injury or mortality to fishes in the immediate proximity of the seismic source is theoretically possible, free-swimming fishes such as the demersal species associated with the KEF are expected to be able to avoid the seismic source as it gradually approaches their position or ramps up during soft starts. For example, the demersal and pelagic fish assemblages that are expected to be present in the Acquisition Area are generally wide-ranging, free-swimming species. The demersal fish assemblages that are typical of the habitats in the Operational Area, including the KEF (predominantly snappers, emperors, cods and groupers), despite exhibiting particular habitat preferences and some fidelity to an area, can be found across a variety of habitats and are typically mobile with home ranges in the order of kilometres or tens of kilometres (Ovenden *et al.* 2004; Moran *et al.* 2004; Newman *et al.* 2008; Parsons *et al.* 2011; Harasti *et al.* 2015). Pelagic species of trevally as well as sharks and rays are also noted as occurring in the KEF, and these types of fishes are also highly mobile. Impacts to fishes associated with the ancient coastline at 125 m depth contour KEF are, therefore, considered more likely to be limited to behavioural and TTS effects, with injury/mortality being highly unlikely to occur.

Any potential injury or TTS effects to Group I, II and Group III fishes, and to fish eggs and larvae, within the ancient coastline KEF are not likely to be ecologically significant at a population level for the following reasons:

- Limited spatial and temporal overlap with the KEF – approximately 8% of the total area of the KEF, and 60 days of seismic acquisition.
- The sound exposure thresholds applied are highly conservative and the criteria predicting the largest impact ranges (across all of the modelled sites and scenarios) have been utilised, providing further conservatism in the impact assessment.
- The area of potential impact assumes that the area will receive the same sound levels at the same time for the period of a survey, which is not the case. The received sound levels at a location will reduce and increase as the seismic vessel moves through the area during a survey.
- The area of potential impact for the assessed species is a low proportion of the area they are likely to inhabit. Thus, population effects are not likely as there is a significant proportion of the population that remains unaffected.
- 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. Popper *et al.* (2005) reports that fish that showed TTS recovered to normal hearing levels within 18–24 hours.

As described above, the area of overlap between the Sauropod 3D MSS Acquisition Areas and the KEF is small (1,272 km^2, ~8%). The SPRAT profile for the ancient coastline at 125 m KEF states "Little is known about fauna associated with the hard substrate of the escarpment, but it is likely to include sponges, corals, crinoids, molluscs, echinoderms and other benthic invertebrates". There is little published information on the fish communities associated with the KEF but due to the presence of epibenthic communities associated with hard substrate, it was considered that some demersal and site-attached fish species may be present. A study by Santos for the portion of the KEF within the Keraudren 3D MSS area indicated that a consistent structurally complex seabed feature that may provide unique habitat for demersal and site-attached fish was not evident (Santos 2019). However, an area of high relief and greater demersal fish abundance and diversity was described in the 95 to 115 m depth range outside of the Keraudren survey area.

Based on the qualitative approach applied in Popper *et al.* (2014) the likelihood of behavioural effects occurring is assessed as high to moderate within tens or hundreds of metres of the seismic source. Fish communities at 125 m depth may therefore exhibit some temporary behavioural responses to noise emissions from the seismic source. The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered.

7.1.6.3.3 Summary

The potential impacts of noise emissions from the seismic source on fishes and elasmobranchs during the Sauropod 3D MSS are considered to be localised and have no lasting effects on populations. Impacts are primarily expected to be restricted to temporary changes, such as to fish behaviours and local distribution (e.g. avoidance). Such changes are recoverable and normal behaviours and distributions may return to normal within minutes, hours or days of exposure to the operating seismic source, based on available studies. Predicted noise levels from seismic acquisition are unlikely to cause mortality or injury to the mobile demersal and pelagic species that are likely to be present in the Operational Area. There is the potential for TTS effects in some fishes exposed in close proximity to the seismic acquisition, however, if TTS does occur the effects are temporary and will recover. Overall, the Sauropod 3D MSS is not expected to result in any ecologically significant impacts at a population level for any species of fishes that may be present within or adjacent to the Sauropod 3D MSS.

7.1.6.4 Benthic Invertebrates

7.1.6.4.1 Species Sensitivity and Sound Exposure Thresholds

Research is ongoing into the relationship between sound and its effects on benthic invertebrates, including the relevant metrics for both effect and impact. Marine invertebrates lack a gas-filled bladder and are unable to detect the pressure component of sound waves (Parry and Gason 2006; Carroll *et al.* 2017) or “hear” sound in the way that mammals and fish are able to. Instead, invertebrates detect sound by sensing the particle motion component of sound in water and seabed sediments through physiological structures such as sensory hairs, statocysts and muscles, and therefore detect sound at close range (McCauley 1994; Parry and Gason 2006; André *et al.* 2016; Roberts *et al.* 2016; Edmonds *et al.* 2016; Carroll *et al.* 2017; Popper and Hawkins 2018). Statocysts, found in a wide range of invertebrates, 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. Although directly sensitive to particle motion and not to sound pressure, most available research on seismic impacts to invertebrates characterises received sound levels in terms of the sound pressure. Therefore, available literature suggests particle motion, rather than sound pressure, is a more important factor for benthic invertebrates such as crustacean and molluscs. Water depth and seismic source size are related to the particle motion levels at the sea floor, with larger arrays and shallower water being related to higher particle motion levels, thus more relevant to effects on crustaceans and molluscs (including bivalves) (Quijano and McPherson 2020).

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 tens or a few hundred metres from the sound source or have been from repeated exposure at the same sound levels, which is not typical of an actual seismic survey (Carroll *et al.* 2017; Edmonds *et al.* 2016; Salgado Kent *et al.* 2016; Webster *et al.* 2018).

Studies by Christian *et al.* (2003), DFO (2004) and Payne *et al.* (2007, 2008) have exposed crustaceans to seismic sound levels of approximately 197–237 dB re 1 µPa SPL_{pk-pk}. No acute or chronic lethal or sub-lethal effects were observed in the weeks to months following exposure, with the exception of Payne *et al.* (2007, 2008) who noted 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.

Research undertaken by Day *et al.* (2016a, 2016b) over three years in Australian waters, exposed captive southern rock lobster *Jasus edwardsii* to multiple passes of a seismic source element in 10-12 m water depths. Maximum received sound exposures were 209-212 dB re 1µPa SPL_{pk-pk}, 186 to 190 dB re 1 µPa2.s per-pulse SEL, and SELcum of 192 to 199 dB re 1 µPa2.s. Exposed lobsters and control lobsters were sampled up to a year after exposure. The findings of the study are as follows:

- Exposure to seismic sound did not result in any mortalities to adult lobsters.
- The condition or development of eggs carried by female lobsters at the time of exposure, even at close proximity directly beneath the seismic source, were not affected.
- Some potential sub-lethal changes in adult lobsters were observed, including some long-term impairment to lobsters’ statocysts, which was also linked to a short delay in the lobsters’ ability to right themselves when upturned.
- Haemocyte count (indicative of immune response function) also showed some evidence of decline over time.

The significance of the seismic exposures and whether the sub-lethal effects may have wider ecological implications (e.g. ability to feed, avoid predators and resist disease) warrants further consideration. Day *et al.* (2016a, 2016b) reported that some of the control lobsters used in the experiments were collected from a marine reserve and were found to have a high level of pre-existing impairment to statocysts similar to that induced by the seismic exposure experiments. This statocyst impairment was considered to be the result of long-term exposure to shipping noise. Some experiments showed no significant differences in righting times between control and exposed lobsters, while in some instances the control lobsters demonstrated slower righting times than exposed lobsters. Lobsters with pre-existing statocyst impairment demonstrated the fastest righting times of all experiments, which Day *et al.* (2016a, 2016b) suggested may indicate that lobsters are able to adapt or compensate for long-term statocyst impairment. Therefore, the level of statocyst impairment resulting from seismic exposure is not clear. Monitoring of the lobster population at the same reserve where the lobsters with pre-existing statocyst impairment were taken from showed that the rock lobster population within the reserve was thriving and at carrying capacity (Green and Gardner 2009; Kordjazi *et al.* 2015). Therefore, the levels of statocyst impairment reported in the Day *et al.* (2016a, 2016b) study appear not to be impacting on the survival of the lobster population. Therefore, any population-level survivability effects from statocyst impairment are not significant and wider ecological implications are likely to be negligible.

Kosheleva (1992; cited in Parry and Gason 2006) identified no detectable effects to marine bivalves and gastropods (mussels and periwinkles) after exposure to a single seismic source element of source level 233 dB re 1 µPa at a distance of 0.5 m or greater from the source. Conversely, 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 would not occur during the Sauropod 3D seismic survey.

Recent Australian studies (Przeslawski *et al.* 2016, 2018; Day *et al.* 2016b, 2017) have focussed on commercial scallops (*Pecten fumatus*). Przeslawski *et al.* (2016, 2018) examined the short-term impacts on scallops and other marine invertebrates from a 2,530 cubic inch seismic array and found no evidence of mortality or change in condition following exposure to a seismic survey. Analysis of images and samples revealed some site-specific differences in scallop abundance, size, condition and assemblages, but these were not related to seismic operations.

Day *et al.* (2016b, 2017) exposed scallops to maximum received sound exposures of up to 213 dB re 1µPa SPL_{pk-pk}, 181 to 188 dB re 1 µPa2.s per-pulse SEL, and SELcum of 188 to 198 dB re 1µPa2.s. The study also predicted ground acceleration of up to 37.57 m/s2. Day *et al.* (2016b, 2017) concluded that exposures did not result in any immediate mass mortalities, however, repeated exposures resulted in a chronic increase in mortality over timeframes of approximately four months post-exposure, though not beyond naturally occurring rates of mortality. Separate experiments undertaken in 2013 and 2014 yielded mortalities of 3.6–3.8% in control scallops (no seismic exposure), 9.4–11.3% mortality in scallops exposed to a single pass of the seismic source, 11.3–16.1% mortality in scallops exposed to two passes of the seismic source, and 14.8–17.5% mortality in scallops exposed to four passes of the seismic source. The mortality rates were at the low end of the range of naturally occurring mortality rates documented in the wild, which range from 11–51% with a six-year mean of 38% (Day *et al.* 2017). A third experiment in 2015 resulted in 100% mortality to both control scallops and exposed scallops, and accordingly was attributed to other causes and not to seismic exposure (Day *et al.* 2016b, 2017).

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) time-scales after 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).

Published sound exposure criteria do not currently exist for acoustic impacts to invertebrates but the available literature above provides an indication of the sound levels and distances within which some impacts may occur. A range of sound levels, from 202 dB re 1 µPa SPL_{pk-pk} to 212 dB re 1 µPa SPL_{pk-pk}, based on the findings of the Payne *et al.* (2008) and Day *et al.* (2016) studies, were applied in the acoustic modelling study and this risk assessment. The Payne *et al.* (2008) 202 dB re 1 µPa SPL_{pk-pk} is considered to be associated with no impacts to benthic crustaceans (such as prawns, scampi and lobsters), whereas the 209-212 re 1 µPa SPL_{pk-pk} thresholds could be associated with some level of sub-lethal effects in these animals (Quijano and McPherson 2020). A 213 dB re 1 µPa SPL_{pk-pk} level is considered as representative of levels that may result in sublethal effects and chronic mortality in molluscs and some other invertebrates based on Day *et al.* (2016b, 2017).

A sound level of 226 dB re 1 µPa SPL_{pk} was applied for sponges and corals, based on a study where corals received maximum sound pressure levels of 226-232 dB re 1µPa SPL_{pk-pk}, but no mortality, damage to soft tissue or skeletal integrity, visible signs of stress, change in abundance or community structure were detected immediately after, and up to four months following exposure (Heyward *et al.* 2018).

7.1.6.4.2 Impact Assessment

Whilst the Silver-lipped pearl oyster (*Pinctada maxima*) has been recorded at maximum water depths of 100 m, adults are mostly found in shallow waters (10–15 m) in inshore, coastal areas, and the species is targeted in the Pearl Oyster Managed Fishery out to water depths of approximately 30–40 m. Previous consultation with the Pearl Producers Association (PPA) has confirmed that there may be pearl oyster brood stock out to a depth of approximately 50 m, but any seismic survey activity in water depths in excess of 70 m was of no concern to the PPA with regards to potential impacts on adult shell (Santos 2019). Minimum water depths in the Acquisition Area for the Sauropod 3D MSS are approximately 95 m, and therefore all seismic acquisition will take place in water depths well outside the normal range for pearl oyster broodstock. Potential impacts to adult pearl oyster have, therefore, not been considered as part of this impact assessment for benthic invertebrates.

Accordingly, the following benthic invertebrates have been identified for this assessment:

- Benthic invertebrate communities, including sponges and soft corals associated with the ancient coastline at 125 m depth contour KEF.

7.1.6.4.3 Sound Pressure

As described above, a range of sound exposure thresholds, from 202 dB re 1 µPa SPL_{pk-pk} to 212 dB re 1 µPa SPL_{pk-pk}, were applied in the acoustic modelling study for benthic crustaceans. Sound levels of 209-212 re 1 µPa SPL_{pk-pk} thresholds are potentially associated with some level of sub-lethal effects. As shown in Table 7-9, at a sound exposure threshold of 209 dB re 1 µPa SPL_{pk-pk}, maximum predicted R_{max} distance was 260 m. The maximum predicted R_{max} distance associated with the 213 dB re 1 µPa SPL_{pk-pk} level for sublethal effects and chronic mortality (Day *et al.* 2016b, 2017) is 156 m.

The sound level at the sea floor directly underneath the seismic source was estimated at all four modelling sites and compared to the sound level of 226 dB re 1 µPa SPL_{pk} for sponges and corals (Heyward *et al.* 2018). It was found that the level was not reached at any of the four sites.

Table 7-9 – Maximum Predicted Distances (R_{max}) to Effect Thresholds for Crustaceans at the Sea Floor

Sound Exposure Threshold (SPL_{pk-pk})	**R_{max} (m)**
213 dB re 1 µPa	156
212 dB re 1 µPa	179
211 dB re 1 µPa	204
210 dB re 1 µPa	234
209 dB re 1 µPa	260
202 dB re 1 µPa	709

As described above, the area of overlap between the ancient coastline at 125 m depth contour KEF and the Acquisition Area is 1,272 km^2, which represents ~8% of the designated area of the KEF. Given the maximum predicted R_{max} distance for impacts to invertebrates of 260 m, there is the potential for some invertebrates on the sea floor, including within the KEF, to experience sound levels that could result in some low-level, sub-lethal effects (e.g. impairment of reflexes, damage to statocysts and reduction in numbers of haemocytes). These sub-lethal effects could result in a reduction in fitness to some individuals. Chronic mortality may also occur in a small number of organisms within a maximum distance of 156 m from the source within the weeks and months following exposure.

At received noise levels of 209 dB re µPa (SPL_{pk-pk}) (Day *et al.* 2016a) did not observe any impacts to embryonic development, with hatched larvae found to be unaffected in terms of egg development, the number of hatched larvae, larval dry mass and energy content and larval competency (i.e. survival in adverse conditions); thus recruitment should be unaffected. Therefore, impacts at a population level due to reduced recruitment would be unlikely to occur.

7.1.6.4.4 Particle Motion

The acoustic modelling study included predictions of particle motion metrics at all four modelled locations, along the broadside directions, which were associated with the highest levels.

At the sea floor interface, crustaceans and bivalves are subject to particle motion stimuli from several acoustic or acoustically induced waves. These include the particle motion associated with an impinging sound pressure wave in the water column (the incident, reflected, and transmitted portions), substrate acoustic waves, and interface waves of the Scholte type. However, it is unclear which aspect(s) of these waves is/are most relevant to the animals, either when they normally sense the environment or their physiological responses to loud sounds so there is not enough information to establish similar criteria and thresholds as done for marine mammals and fish. Including recent research, such as Day *et al.* (2016a), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes the consideration of what particle motion levels lead to a behavioural response, or mortality. Therefore, at this stage, we cannot propose authoritative thresholds to inform the impact assessment. However, levels can be determined for pressure metrics presented in literature to assist the assessment (Quijano and McPherson 2020).

As described above, for crustaceans, a SPL_{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 SPL_{pk-pk} sound levels determined for crustaceans in Day *et al.* (2016), 209–212 dB re 1 µPa, are also included.

For bivalves, literature does not present a sound level associated with no impact, and as particle motion is the more relevant metric, particle acceleration from the seismic source has been modelled for comparison with the results of Day *et al.* (2016). The maximum particle acceleration assessed for scallops was 37.57 ms-2 (Quijano and McPherson 2020).

The maximum particle acceleration and velocity for each of the four sites, as a function of horizontal range from the centre of the array in broadside directions (which generate the higher amplitude results) were modelled. The maximum distance to a particle acceleration of 37.57 ms-2 is 9.1 m, which occurs at the shallowest site (Site 1, 66 m water depth) (refer Figure 7-1).

Particle acceleration decays rapidly away from the source location within the distance equal to half the water depth. It is then influenced by constructive interference, resulting in an increase in levels at a distance equal to the water depth (66 m at Site

1) before again rapidly decaying by 10 ms–2 out to approximately two water depths. Beyond this distance, it exhibits an almost linear decay, apart from constructive interactions at multiples of water depth, with a low point at approximately 10 times the modelling site water depth (Figure 7-1) (Quijano and McPherson 2020).

Particle motion traces generated during the modelling show that vertical particle motion is larger than horizontal particle motion for receivers directly underneath or at short ranges from the array, but at longer ranges the horizontal particle motion dominates. The duration of particle motion also increases with distance as critically reflected multipath propagation becomes important.

Day *et al.* (2016) included a regression of particle acceleration versus range for the single 150 in^3 airgun used in their study (minimum range of 6 m) and showed that acceleration at 10 and 100 m range was typically 26 and 5 ms-2, respectively. Day *et al.* (2016) also referenced an unpublished maximum particle acceleration measurement of 6.2 ms-2 from a 3,130 in^3 airgun array at 477 m range in 36 m of water. In the acoustic modelling study for the Sauropod 3D MSS, modelled peak acceleration at 10 m range was predicted to be between 35 and 19 ms-2 depending on the site; corresponding values at 100 m range are between 21 and 12 ms-2. At ~477 m, the modelling predicts an acceleration of between 8.5 and 5.8 ms-2 in both the port and starboard broadside directions. This result aligns reasonably with the measurements reported in Day *et al.* (2016) and thus represents what is likely to occur (Quijano and McPherson 2020).

The maximum distance to a particle acceleration of 37.57 ms-2 of 9.1 m is less than that predicted for other studies in the region (Quijano and McPherson 2020), however the difference is likely due to the different airgun array configuration and tow depth, as well as the geology for the respective studies. The seabed geology used for this study, silty carbonate sand to calcarenites, are generally less reflective than seabeds which have thin layers of sand over calcarenite substrate.

Based on the above body of research and risk assessment, some benthic invertebrate species may experience sub-lethal effects or a small increase in mortality rates in the weeks or months following seismic exposure within tens or hundreds of metres from the seismic source. Should this occur, the continuous natural cycle of death, recovery and recruitment of invertebrates from adjacent sediments will occur in parallel over these 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.

The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered.

7.1.6.4.5 Summary

The potential impacts of noise emissions from the seismic source on benthic invertebrates during the Sauropod 3D MSS are considered to be slight and short-term, as the activity is not likely to result in any ecologically significant impacts at a population level for any species of invertebrate that may be present on the sea floor within or adjacent to the Acquisition Area. While some sub-lethal impacts and chronic mortality are possible in some sessile organisms exposed in very close proximity to the seismic source, not all organisms are expected to be affected. Benthic communities are expected to recover in the weeks or months following exposure and changes in community structure and composition are not expected to be detectable from natural variability.

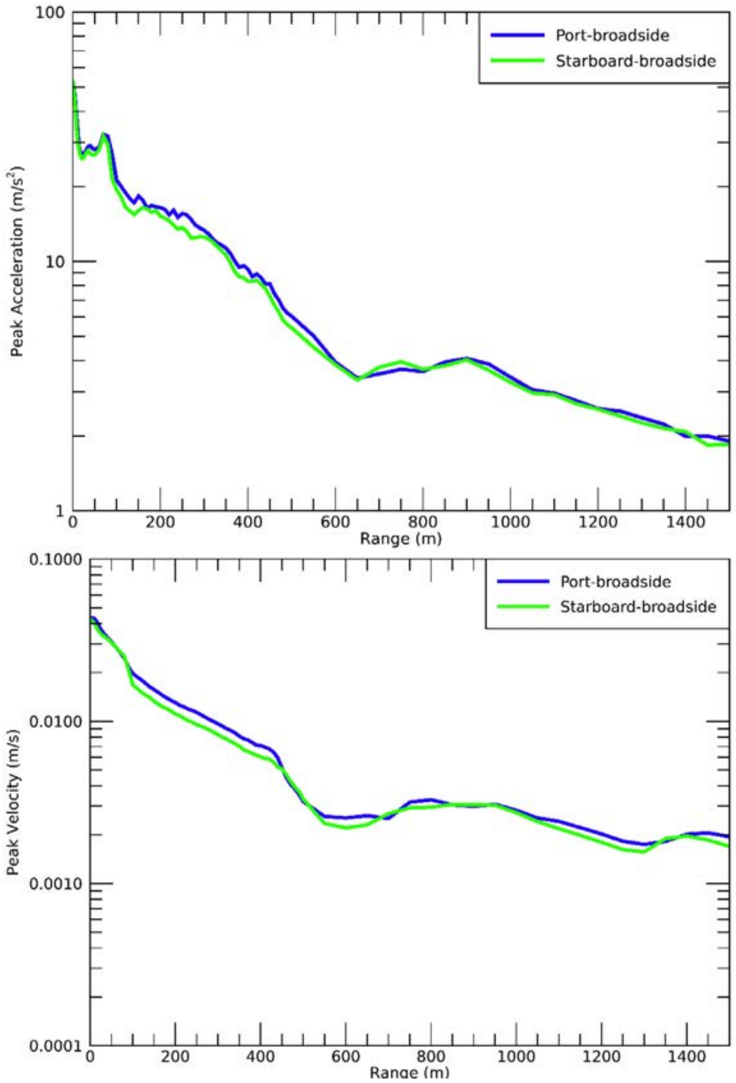


Figure 7-6 – Site 1: Maximum Particle Acceleration (top) and Velocity (bottom) at the Sea Floor as a Function of Horizontal Range from the Centre of the 3,090 in^3 Array Along the Broadband Directions

7.1.6.5 Zooplankton

7.1.6.5.1 Species Sensitivity and Sound Exposure Thresholds

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.

Zooplankton includes fish eggs and larvae that are transported by currents and winds and hence cannot take evasive behaviour to avoid seismic sources. With respect to the Sauropod 3D MSS, key spawning areas for commercially targeted fish species (assessed under "Fish spawning" below) have been identified as areas where zooplankton populations may be more important.

Larval fish species studied appear to have hearing frequency ranges similar to those of adults and similar acoustic startle thresholds (Popper *et al.* 2014). Swim bladders may develop during the larval stage and may render larvae susceptible to pressure-related injuries such as barotrauma. Effects of sound upon eggs, and larvae containing gas bubbles, is focused on barotrauma rather than hearing (Popper *et al.* 2014). Larval stages are often considered more sensitive to stressors than adult stages, but exposure to seismic sound reveals no differences in larval mortality or abundance for fish, crabs or scallops (Carroll *et al.* 2017).

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 at a population-level. Other studies have also noted limited negative impacts on zooplankton, fish eggs, larvae or fry, and most have reported that impacts occur within a few metres or tens of metres from the source (Kostyuchenko 1973; Dalen and Knutsen 1987; Holliday *et al.* 1987; Kosheleva 1992 cited in Parry *et al.* 2002; Pearson *et al.* 1994; Turnpenny and Nedwell 1994; Booman *et al.* 1996; Payne 2004; Payne *et al.* 2009). These studies included exposures to sound pressures up to approximately 242 dB re 1 µPa, comparable to those predicted in close range to the Sauropod 3D MSS seismic source.

Day *et al.* (2016b) 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 that early life stage crustaceans may be more resilient to seismic air gun exposure than other marine organisms (Pearson *et al.* 1994). Received levels were ~211 dB re 1 µPa (SPL_{pk-pk}; approximately 205 dB re 1 µPa SPL_{pk}) and as such are similar to those proposed by Popper *et al.* (2014).

For this impact assessment the sound exposure thresholds for mortality/PMI to fish eggs and larvae from Popper *et al.* (2014) have been applied (as described above in the impact assessment for fish and outlined below in Table 7-10).

In addition, a highly conservative threshold of 178 dB re 1 µPa SPL_{pk-pk} derived from the McCauley *et al.* (2017) study has also been considered, as described below.

McCauley *et al.* (2017) found that after exposure to airgun sounds generated with a single airgun (150 cui) zooplankton abundance decreased and mortality in adult and larval zooplankton increased two to three-fold when compared with controls. In this 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, and a maximum effect-range of horizontal 1.2 km was determined. The findings contradicted the conventional idea of limited and very localised impact of intense sound in general, and seismic airgun signals in particular, on zooplankton, with the results indicating that there may be noise-induced effects on these taxa and that these effects may even be negatively affecting ocean ecosystem function and productivity.

This study measured zooplankton abundance and the proportion of the population that was dead at three distances from a single 150 cui airgun – 0, 200 and 800 m. The experiment estimated the proportion of the zooplankton that was dead, both before and after exposure to airgun noise, using net samples to measure zooplankton abundance, and bioacoustics to identify the distribution of zooplankton. In this study, copepods dominated the mesozooplankton (0.2–20 mm), and impacts were not assessed on microzooplankton (0.02–0.2 mm) or macrozooplankton (20 mm). There was movement of water through the experimental area, which made interpreting their results more difficult (Richardson *et al.* 2017).

McCauley *et al.* (2017) provide three findings from the experiment to show that zooplankton were affected by the seismic source, the:

- Proportion of the mesozooplankton community that was dead increased two to three-fold
- Abundance of zooplankton estimated by net samples declined by 64%
- Opening of a "hole" in the zooplankton backscatter observed via acoustics.

They found that exposure to airgun noise significantly decreased zooplankton abundance and increased the mortality rate from a natural level of 19% per day to 45% per day (on the day of exposure), and that these impacts were observed out to the maximum range assessed (1.2 km) (Richardson *et al.* 2017).

Scientists from CSIRO's Oceans and Atmosphere Business Units were contracted by APPEA to undertake a desktop study that: a) critically reviewed the methodologies and findings of the McCauley *et al.* (2017) experiment; and b) simulated the large-scale impact of a seismic survey on zooplankton in the North West Shelf region, based on the mortality rate associated with airgun noise exposure reported by McCauley *et al.* (2017).

The CSIRO review of the McCauley *et al.* (2017) study found that there were three primary questions raised by the results of the experiment, all of which warrant further investigation (Richardson *et al.* 2017):

1. Why was there no attenuation of the impact with distance?

   There is no consistent decline in the proportion of zooplankton that are dead with increasing distance away from the airgun. The energy of the sound waves at a distance of 1.2 km is substantially lower than at the source.

2. Why was there an immediate decline in abundance?

   It is unclear why there would be a near immediate drop in zooplankton abundance as measured by net samples and acoustic data. If zooplankton were killed, they would not immediately sink from the surface layers, or be rapidly eaten. A drop in abundance would be more likely once the dead zooplankton either sunk to the bottom or were removed by predation. Richardson *et al.* (2017) conclude it is difficult to explain this immediate decline in zooplankton abundance.

3. Was there sufficient replication to be confident in the study findings?

The conclusions were based on a relatively small number of zooplankton samples. A total of 24 samples were collected – two tows each sampling time × three distances from the gun (0 m, 200 m, 800 m) × two levels (Control, Exposed) × two replicate experiments (Day 1, Day 2). This means that there were only 12 samples collected under conditions exposed to the airgun, six on each day of the two experiments. The main potential confounding explanation in the study would be that a different water mass entered the area on each day of the experiment and had lower abundance and higher quantities of dead zooplankton. Richardson *et al.* (2017) conclude that: "although this is relatively unlikely it cannot be discounted because of the relatively few samples collected and only two replicate experiments conducted."

Independently of the APPEA/CSIRO study, the International Association of Geophysical Contractors (IAGC) conducted its own review of the McCauley *et al.* (2017) paper. This review came to the following conclusion:

> While we found the study interesting, we are also troubled by the small sample sizes, the large day-to-day variability in both the baseline and experimental data, and the large number of speculative conclusions that appear inconsistent with the data collected over a two-day period. Both statistically and methodologically, this project falls short of what would be needed to provide a convincing case for adverse effects from geophysical survey operations.

(IAGC 2017).

The second component of the CSIRO study was to estimate the spatial and temporal impact of seismic activity on zooplankton on the North West Shelf from a large-scale seismic survey, considering mortality estimates of McCauley *et al.* (2017), and accounting for typical growth rates, natural mortality rates, and the ocean circulation in the region. The approach modelled a hypothetical 3D survey (2,900 km^2 in size, over a 35-day period, in water depths of 300–800 m) on the edge of the North West Shelf during summer. To simulate the movement of zooplankton by currents, the researchers used a hydrodynamic model that seeded 0.5 million particles into CSIRO's Ocean Forecast Australia Model. Zooplankton particles could be hit multiple times by airgun pulses if they were carried by currents into the future survey path. The greatest limitation in this approach was accurate knowledge of the natural growth and mortality rates of zooplankton, and to address this the CSIRO researchers tested the sensitivity of the model to different recovery (growth-mortality) rates, and also the sensitivity of the results to ocean circulation by undertaking simulations with and without water motion (Richardson *et al.* 2017).

The results of the simulations that included ocean circulation showed that the impact of the seismic survey on zooplankton biomass was greatest in the Survey Region (defined as the survey acquisition area with a 2.5 km impact zone around it) (22% of the zooplankton biomass was removed) and declines as one moves beyond it to the Survey Region + 15 km (14% of biomass removed), and the Survey Region + 150 km (2% of biomass removed). The time to recovery (to 95% of the original level) for the Survey Region and Survey Region + 15 km recovery was 39 days (38–42 days) after the start of the survey and three days (2–6 days) after the end of the survey (Richardson *et al.* 2017).

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. Additionally, 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). The CSIRO modelling was carried out for the North West Shelf IMCRA Mesoscale Bioregion and the findings of this study are therefore applicable in determining the potential impacts of the Sauropod 3D MSS on zooplankton communities.

A recent study by Fields *et al.* (2019) exposed zooplankton (copepods) to seismic pulses at various distances up to 25 m from a seismic source. The source levels produced were estimated to be 221 dB re 1 µPa2.s and comparable to the far-field source levels predicted for the Sauropod 3D MSS seismic source. 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 are consistent with numerous other field studies, as referenced previously, indicating that the potential effects of seismic pulses to zooplankton are limited to within approximately 10 m from the seismic source. Fields *et al.* (2019) note that the findings of the McCauley *et al.* (2017) study are difficult to reconcile with the body of further available research. The findings of the McCauley *et al.* (2017) study may, therefore, provide an overly conservative estimate of the potential effects of seismic pulses to zooplankton.

7.1.6.5.2 Impact Assessment

As described above, the sound exposure thresholds used in this assessment for mortality/PMI to fish eggs and larvae from Popper *et al.* (2014), have been applied, as well as the 178 dB re 1 µPa SPL_{pk-pk} threshold derived from the McCauley *et al.* (2017) study (refer to Table 7-10).

Table 7-10 – Maximum Predicted Distances (R_{max}) to Mortality/PMI Thresholds in the Water Column for Fish Eggs and Larvae, and Zooplankton

Sound Exposure Threshold	R_{max} (Km)
210 dB re 1 µPa2·s (SEL_{24h})	0.03
207 dB re 1 µPa (SPL_{pk})	0.13
178 dB re 1 µPa (SPL_{pk-pk})	7.93

As shown in Table 7-10, the maximum predicted R_{max} distance for mortality/PMI effects in fish eggs and larvae, based on application of the Popper *et al.* (2014) single-pulse 207 dB re 1 µPa (SPL_{pk}) threshold is 130 m. Based on the application of the McCauley *et al.* (2017) threshold of 178 dB re 1 µPa SPL_{pk-pk}, the maximum predicted R_{max} distance increases to ~8 km.

Any potential mortality/PMI impacts to zooplankton communities have to be assessed in the context of natural mortality in these populations. Any mortality or mortal injury effects to zooplankton (including fish eggs and larvae) resulting from seismic noise emissions are likely to be inconsequential compared to natural mortality rates, which are very high; exceeding 50% per day in some species and commonly exceeding 10% per day (Tang *et al.* 2014). For example, in a review of mortality estimates (Houde and Zastrow 1993), the mean mortality rate for marine fish larvae was M = 0.24, a rate equivalent to a loss of 21.3% per day. In the experiment undertaken by McCauley *et al.* (2017) zooplankton mortality rate background levels were 19%. 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.

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 in the NWMR. In particular, phytoplankton and zooplankton biomass in the oceans can vary significantly at spatial scales ranging from hundreds of metres to hundreds of kilometres and temporal scales of hours, days, seasons and inter-annually, due to tidal and large-scale currents, bathymetry, temperature, salinity, water chemistry parameters and other environmental factors (Gibbons and Hutchings 1996; Holliday *et al.* 2011; McKinnon *et al.* 2008; Pearce *et al.* 2000; Sutton and Beckley 2017). Therefore, changes in zooplankton abundance are likely to be replenished and indistinguishable from natural levels and distributions within hours of a seismic survey vessel passing.

7.1.6.5.3 Summary

The potential impacts of noise emissions from the seismic source on plankton during the Sauropod 3D MSS are considered to be slight and short-term, as the activity is not likely to result in any ecologically significant impacts at a population level for any fish eggs and larvae, or zooplankton that may be present in the water column within or adjacent to the Acquisition Area.

7.1.6.6 Fish Spawning

7.1.6.6.1 Impact Assessment

High intensity impulsive sound emitted from the seismic source has the potential to result in behavioural changes in fish or masking of fish vocalisations, which may temporarily divert efforts away from spawning aggregations, egg production and recruitment success (Hawkins and Popper 2017). This impact assessment is focused on fish spawning and recruitment for key indicator commercial fish species, which commercial fisheries stakeholders have raised as a concern during consultation.

Section 4.3.4 describes the key indicator species that are relevant to the Sauropod 3D MSS. Recent information obtained from DPIRD (DPIRD 2019c) has defined the depth ranges and key spawning periods for a range of key indicator species for the north coast scalefish resource. The reproductive biology of the key indicator fish species results in a very broad distribution of eggs and larvae, and consequently genetic connectivity over a wide geographic range. Multiple batches of pelagic eggs are released during multiple, frequent spawning events and throughout extended spawning periods (Gaughan *et al.* 2018).

The following impact 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:

1. Spatial-temporal analysis – to understand the proportion of the spawning areas and spawning areas that may be exposed during the Sauropod 3D MSS
2. Consideration of the natural variability in fish distribution, spawning biomass and recruitment
3. Consideration of the sustainability status of the fish stocks.

While the focus of the assessment is on the key indicator species, DPIRD (2017) note that 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 exploited in the region.

7.1.6.6.2 Spatial-Temporal Analysis

A spatial-temporal analysis has been conducted to determine the overlap between the Acquisition Area and the principal spawning ranges and seasons 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 Sauropod 3D MSS at some point during the survey.

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

- Red emperor
- Rankin cod
- Goldband snapper
- Blue-spotted emperor
- Giant ruby snapper.

It is understood from DPIRD (2019c) that all of these species undergo group spawning throughout their range, rather than aggregating at specific locations.

Spanish mackerel, the key indicator species for the Mackerel Managed Fishery, has been excluded from the assessment, given that the principal depth range for the spawning of this species is considered to be in water depths less than 50 m (DPIRD 2019c) and the depths within the Sauropod 3D MSS Acquisition Area are greater than 95 m. The spawning period for this species (September to December) is also outside the proposed acquisition window of the survey. Therefore, the Sauropod 3D MSS is not expected to impact the spawning of Spanish mackerel.

It is important to note that a number of assumptions are applied to the analysis in order to provide a highly conservative estimate of the proportion of spawning fish stocks that may be exposed and affected during the survey:

1. Spatial overlap is based upon the entire Acquisition Area and the temporal overlap is based upon the entire 60-day survey duration. 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 likely to be limited to within tens or hundreds of metres of the seismic source (Popper *et al.* 2014), the actual area of disturbance to fishes will be significantly smaller and likely to be within hundreds of metres from the seismic source as it moves across the acquisition area. Some awareness of sound and some level of disturbance may be possible over distances of kilometres for some fish species, but the potential for this is considered low by Popper *et al.* (2014). Therefore, the spatial-temporal analysis is simply an indication of the total area that may be ensonified. Within any 24-hour period the actual area that may be ensonified may be hundreds of square kilometres, rather than thousands of square kilometres. Hence, there will be large areas within the survey area unaffected by sound or with sound below levels that might disturb fish.
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 2019c) and the Pilbara fishery management area. As described in Section 4.3.4, 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 from around the Gascoyne region of WA to the NT or even as far as south-east 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 Sauropod 3D MSS 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 Pilbara fishery management unit, but potentially not across the entire biological stock area. Therefore, to address any potential uncertainty in the biological stock ranges, the Pilbara fishery management area has been selected by CGG 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.

3. The spatial-temporal analysis is a simplistic approach that assumes that fish spawning in the area and period of exposure will 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 the fish stocks that may be exposed. This provides useful context for the impact assessment, but the extent and duration of actual impacts will be significantly smaller.

It is noted that the Sauropod 3D MSS Operational Area also overlaps with the edge of the Kimberley fisheries management unit (less than 0.01% of the fishery management unit). The Acquisition Area does not overlap with the Kimberley fishery management unit. Given that seismic acquisition will not occur in this area and that operation of the seismic source in this area will be limited (e.g. very occasional source testing), the potential for disturbance to the fish populations within the Kimberley fisheries management unit is considered to be negligible and significantly smaller than in the Pilbara fisheries management unit. Therefore, the focus of the analysis is on the Pilbara fisheries management unit, and the Kimberley fisheries management unit is not considered further.

Table 7-11 presents the spatial overlap of the Sauropod 3D MSS Acquisition Area with the spawning areas of key indicator species based on each species' principal depth range and the Pilbara fisheries management unit. The spatial overlap ranges from 0.7% (Ruby snapper) to 5.1% (Goldband snapper). A temporal (duration) analysis has been conducted to determine the maximum overlap between the timing of the Sauropod 3D MSS and the spawning times of key commercial indicator fish species (refer to

Table 7-12).

Table 7-11 – Spatial Overlap with Spawning Areas of Key Indicator Fish Species in the Pilbara

Fish Species	Depth Range (m)	Spawning Area (km^2) *	Acquisition Area (3,512 km^2)	
			Overlap (km^2)	%
Red emperor	10–180	99,349	3,505	3.5%
Rankin cod	10–150	92,575	3,205	3.5%
Goldband snapper	50–200	68,748	3,505	5.1%
Bluespotted emperor	5–110	77,912	1,001	1.3%
Giant ruby snapper	150–480	43,566	300	0.7%

* Spawning areas have been estimated based on each species' depth range and the Pilbara fishery management area. It is important to note that genetic connectivity and the biological stocks have been confirmed across significantly larger areas, however, the Pilbara fishery management area is 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.

Table 7-12 – Temporal Overlap with Spawning Periods of Key Indicator Fish Species

Fish Species	Spawning Period	Maximum Temporal Overlap from the Sauropod 3D MSS *	
		Days	%
Red emperor	September–June (303 days)	60	19.8%
Rankin cod	June–December, March (245 days)	31	12.7%
Goldband snapper	October–May (243 days)	60	24.7%
Bluespotted emperor	July–March (274 days)	60	21.9%
Giant ruby snapper	December–April (151 days)	60	39.7%

*Temporal overlap is based on the maximum number of days that the survey may coincide with the days that each species is known to spawn.

As shown in Table 7-12, the temporal overlap with key indicator species spawning periods, ranges from 12.7% (Rankin cod) to 39.7% (Ruby snapper). It is again stressed that the temporal overlap may also over-represent what will likely, in reality, be a disturbance to one out of many spawning events for a very small proportion of fish affected by the passing seismic source at the time of a spawning event. For example, the above demersal fish species are serial/multiple batch broadcast spawners, releasing multiple batches of eggs into the water column over a wide area, and spawn multiple times throughout the spawning period (Newman *et al.* 2008; Gaughan *et al.* 2018).

A combined spatial-temporal analysis has also been conducted to determine the maximum spatial and temporal overlap of the Sauropod 3D MSS with the spawning area and period of each fish species (refer to Table 7-13). As shown in Table 7-13, the maximum spatial-temporal overlap (1.3%) is with Goldband snapper spawning area in the Pilbara management unit and spawning period. The spatial-temporal overlap for other key indicator species ranges from 0.27% (Ruby snapper) to 0.7% (Red emperor).

Table 7-13 – Combined Spatial – Temporal Overlap with Spawning Periods and Ranges of Key Indicator Fish Species

Fish Species	Spatial Overlap (%)	Temporal Overlap (%)	Spatial-Temporal Overlap (%)
Red Emperor	3.5%	19.8%	0.70%
Rankin Cod	3.5%	12.7%	0.44%
Goldband Snapper	5.1%	24.7%	1.26%
Bluespotted Emperor	1.3%	21.9%	0.28%
Giant Ruby Snapper	0.7%	39.7%	0.27%

As noted above, a number of assumptions have been applied that make the spatial-temporal analysis results highly conservative. Noting again that not all of the Acquisition Area will be ensonified for the full duration of the survey, it is important to consider how a more realistic scenario and area of disturbance may affect the spatial-temporal overlap and the magnitude and extent of the potential impacts to spawning fishes.

For example, within any 24-hour period, the seismic vessel (travelling at a speed of approximately 4.5 knots [8.3 km/hr]) will cover a distance of around 200 km. The Sauropod 3D MSS sail lines will be approximately 83 km in length and take ten hours to acquire, with approximately five hours for the vessel to turn (with the seismic source turned off) and then acquire a parallel line in the opposite direction, offset at least 7.5 km from the previous line. Therefore, in a single 24-hour period, the seismic vessel will cover nearly both sides of a racetrack. Applying a 500 m buffer to either side of the acquisition lines (representative of behavioural effects to fishes within tens or hundreds of metres from the seismic source [Popper *et al.* 2014]) would suggest a very small area of disturbance of approximately 166 km^2, which would be negligible in the context of the large spawning areas and protracted spawning seasons.

It is noted that the same groups of demersal fishes may be exposed to the seismic source again during the following 24-hour period when the seismic vessel returns to acquire the adjacent line offset approximately 450 m from the first line. Therefore, it may be more appropriate to consider a week of acquisition lines in the racetrack; the seismic vessel will gradually move across the survey area and the sound levels will reduce, after which the same groups of demersal fishes will not be exposed again. To apply an additional level of conservatism and account for possible uncertainty about the range over which fish may be disturbed, a 5 km buffer can be applied to the racetrack formation to broadly represent where some fishes may have some awareness of sound pressure changes. Overall, this scenario would result in an area of disturbance of approximately 1,450 km^2. Therefore, at any point during the 60-day duration of the survey, up to 1,450 km^2 may be disturbed (approximately 60% less than the scenario that considers the total Acquisition Area (3,512 km^2). The spatial-temporal overlaps associated with this exposure scenario are between approximately 0.12% (Ruby snapper) and 0.52% (Goldband snapper) of the available spawning area and spawning period, depending on the species.

7.1.6.6.3 Natural Variability in Fish Distribution, Spawning Biomass and Recruitment

In addition to the above spatial-temporal analyses, it is important to note that fishes may not be evenly distributed throughout their range. As is evident from historic catch-per-unit-effort (CPUE) data for the PFTIMF, Gaughan *et al.* (2018) note that species distribution and abundance may vary, for example, Bluespotted emperor is most abundant in the western part of the Pilbara region. Figure 7-7 presents CPUE data for the PFTIMF for Red emperor, Rankin cod, Blue-spotted emperor and Goldband snapper. The red and black dashed polygons indicate the location of the Sauropod 3D MSS Acquisition Area and Operational Area. The CPUE data indicates that these indicator species are potentially less abundant in the Sauropod 3D MSS Acquisition Area than they are in other parts of the Pilbara region and, therefore, the proportion of the fish stocks that may be affected may be significantly less than that inferred by the spatial-temporal analyses above.

Therefore, while it is acknowledged that some temporary and localised disturbances may occur to spawning groups of fishes, the proportion of fishes affected will be very small and there is unlikely to be a significant population level impact.

To provide further context, CGG 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 number of effective spawnings (Newman *et al.* 2003). For example, between 1980 and 2013, Red emperor spawning biomass in the adjacent 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 7-8). 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 7-9). 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 1.26% or less of the spawning biomass of each species in the Pilbara management unit to be disturbed is expected to have a negligible effect. The effects of the Sauropod 3D MSS 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, offset 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.

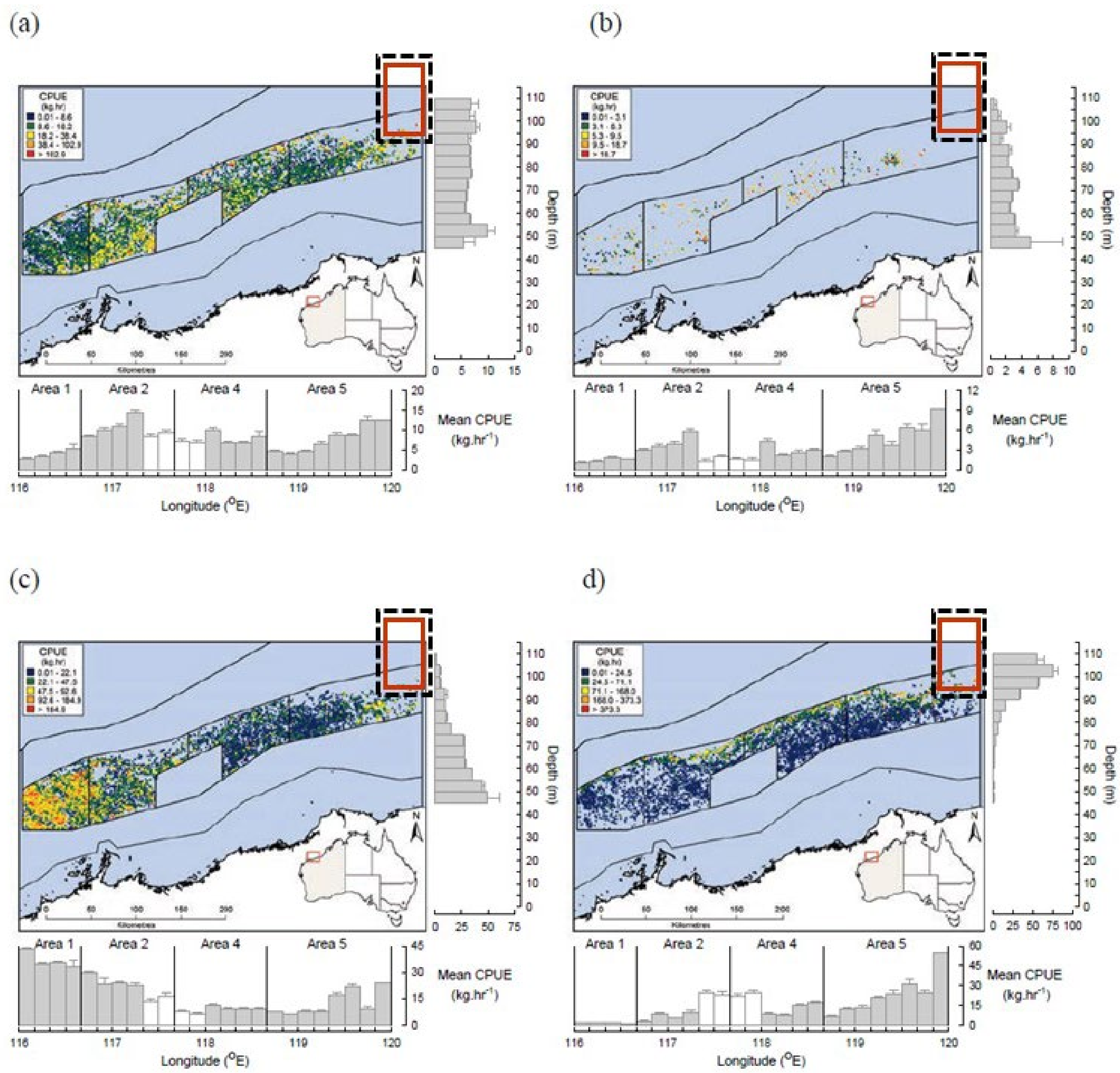


Figure 7-7 – Spatial Distribution of Catch per Unit Effort (CPUE) for the PFTIMF from 2004-2008 for Four Indicator Species, Including (a) Red emperor, (b) Rankin cod, (c) Blue-spotted emperor and (d) Goldband snapper (Gaughan *et al.* 2018). The Red and Black Dashed Polygons Indicate the Location of the Sauropod 3D MSS Acquisition Area and Operational Area Respectively

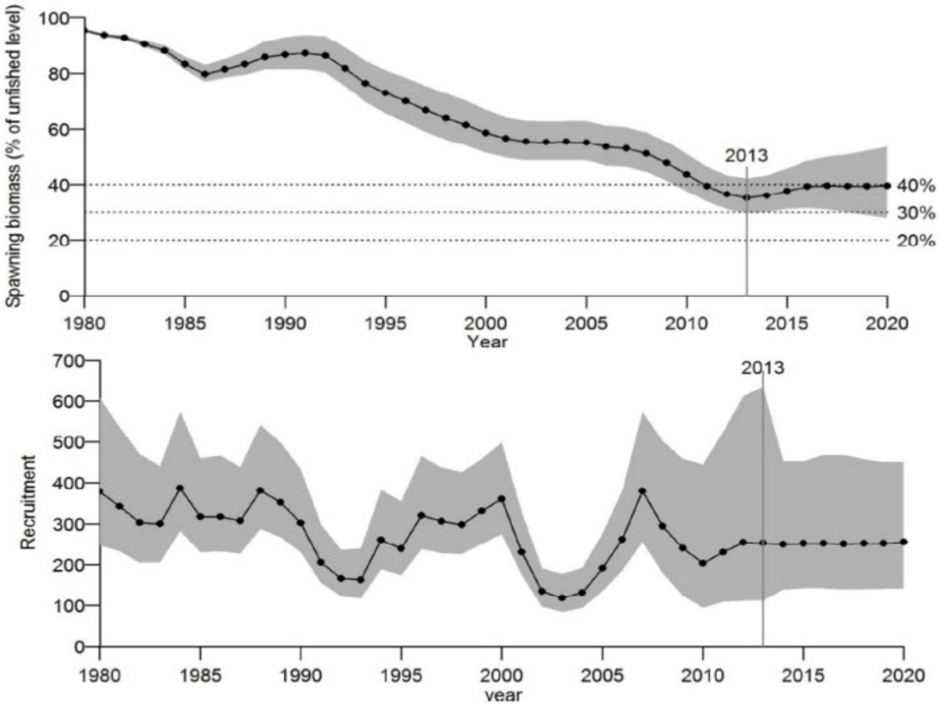


Figure 7-8 – Red emperor Spawning Biomass (Expressed as a Percentage of Unfished Levels) (Top) and Recruitment (Millions of Fish) (Bottom) (source: Department of Fisheries 2015). Levels After 2015 are Predictions Made in 2015 Based on Different Fishing and Stock Scenarios, and do not Represent Real Levels.

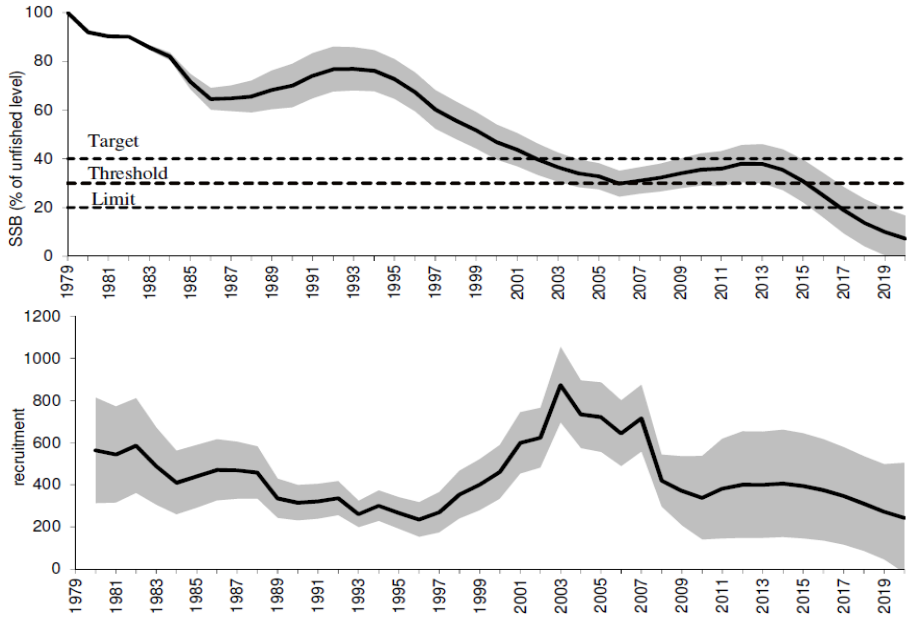


Figure 7-9 – Goldband snapper Spawning Biomass (Expressed as a Percentage of Unfished Levels) (Top) and Recruitment (Thousands of Fish) (bottom) (Source: Department of Fisheries 2015). Levels After 2015 are Predictions Made in 2015 Based on Different Fishing and Stock Scenarios, and do not Represent Real Levels.

7.1.6.6.4 Fish Stock Assessments and Sustainability Status

Assessment and management of the north coast demersal scalefish resource is undertaken by DPIRD for the two separate Pilbara and Kimberley fisheries management units. 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 three to five 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.

The stock assessment process and objectives are consistent with the principles of ecologically sustainable development as they aim to maintain spawning stock biomass, high productivity and recruitment, as well as to ensure that fishing impacts do not result in serious or irreversible environmental harm (DPIRD 2017). 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).

Table 7-14 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. Assessments of the overall demersal fish resource in the Pilbara region undertaken between 2008 and 2017 also found that the levels of fishing mortality on the key indicator species (Goldband snapper, Red emperor, Rankin cod and Bluespotted emperor) either achieved the target level or were between the target and the threshold level (Newman *et al.* 2018). This indicates that the level of fishing and mortality rate is not having an unacceptable level of impact on the population and the stocks are sustainable (Saunders *et al.* 2018).

The most recent DPIRD Status of the Fisheries report (Newman *et al.* 2019) further notes that total annual trawl catches reduced between 2008 and 2015 in direct response to effort reductions imposed on the PFTIMF by the Department since 2008. Total catch, however, has since increased despite having the same annual effort allocations, with catches in 2017–2018 exceeding the Department's defined acceptable catch range. Given that the effort allocations are the same, Newman *et al.* (2019) suggest that the increased catch rates indicate that fishing effort reductions since 2008 have been effective and have resulted in increased fish abundance and stock rebuilding. The fish stocks continue to be monitored and the biomass continues to be classed as sustainable despite ongoing fishing and seismic operations in the region in past years (refer to Section 0 for further evaluation of the cumulative effects of past seismic surveys on the commercial fish stocks).

Table 7-14 –Stock Assessment of Key Indicator Fish Species

Fish Species	Stock Assessment*
Red emperor (Newman *et al.* 2018c)	The spawning biomass level of Red emperor overall (across all management areas) was estimated to be above the threshold level in the Pilbara management unit in 2015 (the last integrated assessment was undertaken in 2015) (Newman *et al.* 2018). The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. The stability in the adjusted fish trawl catch rates since 1998 indicates that stock abundance has remained stable during this period, with some indication of recent increasing abundance in the western area of the fishery. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. Therefore, Red emperor in the Pilbara management unit have been classified as a sustainable stock.
Rankin cod (Newman *et al.* 2018d)	The spawning biomass level of Rankin cod overall (across all management areas) was greater than 40% in the Pilbara management unit in 2015 (the last integrated assessment was undertaken in 2015). The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. The fishing mortality levels of Rankin cod in 2015 were mainly between the target and threshold levels in all management areas. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. Therefore, Rankin cod in the Pilbara management unit have been classified as a sustainable stock.

Fish Species	Stock Assessment*
Goldband snapper (Saunders *et al.* 2018)	Goldband snapper catches from the Pilbara management unit over the last ten years (2008–2017) have ranged from 113–208 t. The catch of Goldband snapper in the unit has been consistent and stable for the past five years (2013–2017), ranging from 143–208 t, with a mean annual catch of 187 t. The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. Therefore, Goldband snapper in the Pilbara management unit have been classified as a sustainable stock.
Bluespotted emperor (Newman *et al.* 2018e)	The spawning biomass level of Bluespotted emperor overall (across all management areas) was greater than 40% of the unfished biomass in the Pilbara management unit in 2015 (the last integrated assessment was undertaken in 2015). The above evidence indicates that the biomass of this stock is unlikely to be depleted and that recruitment is unlikely to be impaired. The current level of fishing mortality is unlikely to cause the stock to become recruitment impaired. Therefore, Bluespotted emperor in the Pilbara management unit have been classified as a sustainable stock.

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

In comparison with the fishing mortalities (which DPIRD considers to be acceptable and sustainable), the Sauropod 3D MSS is not expected to result in any direct reduction in the available spawning biomass / allocated stock through fish mortalities as fish are unlikely to be killed as a result of the seismic survey, as noted in Section 7.1.6.3 above).

7.1.6.6.5 Summary

The potential spatial-temporal overlap of the survey with the spawning fish stocks (≤1.26%) will be minor. The effects of the seismic survey on the spawning biomass of the various stocks are expected to comprise occasional localised behavioural disturbances to spawning groups of fish, but the level of impact to the populations (spawning biomass and recruitment) is predicted to negligible, particularly in the context of normal variability in the fish biomass and recruitment levels (250–350%) indicated above.

Potential impacts to spawning and recruitment within commercially significant fish stocks are, therefore, expected to be within an acceptable level based on:

- The seismic 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 7-8 (130 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 Sauropod 3D MSS with the spawning areas in the Pilbara management unit and spawning periods of key indicator fish species (maximum spatial-temporal overlap of 1.26%, based on highly conservative spatial-temporal analyses)
- 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 1.26%) with the key fish stocks is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250–350%)
- CPUE data indicates that fish abundance is relatively low within the Sauropod 3D MSS Acquisition Area compared with other parts of the region, therefore, there may be a lower likelihood of disturbing significant numbers of fish
- Key indicator species in the Pilbara 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. 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
- DPIRD Status of the Fisheries reports also consider other activities in the region, including oil and gas activities and seismic surveys. DPIRD considers 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.

Therefore, the survey is not expected to result in a serious or irreversible impact to the recruitment or sustainability of key indicator commercial fish stocks.

Based on the timing and duration (up to 60 days) of seismic acquisition, the potential impacts of noise emissions from the seismic source on spawning of key indicator commercial fish species during the Sauropod 3D MSS are considered to be slight and short-term, as the activity is not likely to result in any ecologically significant impacts at a population level for any key indicator species that may be spawning within or adjacent to the Acquisition Area during acquisition activities.

7.1.6.7 Commercial Fisheries

7.1.6.7.1 Impact Assessment

Increased sound levels associated with seismic acquisition may modify the behaviour, local abundance and distribution of fish species and therefore affect commercial fisheries catch rates in proximity to the Operational Area.

Additionally, seismic acquisition has the potential to affect commercial fisheries via displacement or exclusion of fishers from areas where they normally operate for all or part of the period during which the survey is being acquired. This potential impact is assessed separately in Section 7.4.

As described in Section 4.4.4, there are a number of commercial fisheries that have historic fishing effort within the Operational Area, as follows:

- Pilbara Trap Managed Fishery (PTMF)
- Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)
- Northern Demersal Scalefish Managed Fishery (NDSMF)
- Mackerel Managed Fishery (MMF).

The Pilbara Line Fishery also has fishing rights (the fishery licence areas) that extend into the same waters as the Operational Area; however, fishing effort is not reported here and so they are not assessed further.

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

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 vessel as it approached from a distance of 27 km to 2 km, over a six-hour period (Peña *et al.* 2013). As fishing areas are large and commercial fish species are free-swimming, if fish are 'scared' temporarily from an area, based on evidence presented, it is likely they will be displaced temporarily to another area still within the fishing zone and so able to be caught.

There is little research undertaken on what effect seismic surveys have on fish catchability. Salgado Kent *et al.* (2016) 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 fin fish catch rates with seismic surveys have yielded results of any meaning. The Gippsland Marine Environmental Monitoring (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.* 2016a): "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 and School whiting) in the Bass Strait 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.* 2016b). Przeslawki *et al.* (2016b) 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 returned to pre-survey levels after seismic activity had ceased (Carroll *et al.* 2017). As noted by Przeslawski *et al.* (2016b), 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.

Effects will be temporary as the seismic vessel traverses each survey line, and fish may move away as the airgun array approaches. As described above, significant behavioural responses in the key indicator demersal fish species (Red emperor, Rankin cod, Goldband snapper, Blue-spotted emperor and Ruby snapper) will be limited to distances of a few tens or hundreds of metres from the operating seismic source.

An analysis has been conducted to determine the area of overlap of historic fishing activity (effort) and the Acquisition Area (refer to Table 7-15).

Table 7-15 – Spatial Overlap of the Acquisition Area with Fishing Effort for Relevant Commercial Fisheries

Relevant Commercial Fisheries	Average area of Fishing Effort (km²)*	Maximum Potential Spatial Overlap	
		Overlap (km²)	%
Pilbara Fish Trawl (Interim) Managed Fishery	25,922	1,047	4.04%
Pilbara Trap Managed Fishery	197,722	3,506	1.77%
Northern Demersal Scalefish Managed Fishery	133,229	0	0%

*The area of fishing effort for WA managed fisheries is based on historic FishCube data from 2016 to 2020.

As shown in Table 7-15, the spatial overlap between the Acquisition Area and historic fishing effort in the Pilbara region ranges from 1.77% (Pilbara Trap Managed Fishery) to 4.04% (Pilbara Fish Trawl Interim Managed Fishery). These fisheries operate throughout the year. The Sauropod 3D MSS is expected to take 60 days to acquire, therefore the temporal overlap is approximately 16%, indicating a total spatial-temporal overlap with the Pilbara demersal scalefish fisheries of ≤0.66%. In addition, as noted in Section 4.4.4, fishing effort is highest in western areas of the fisheries compared to the eastern areas of the fisheries (where the Sauropod 3D MSS is located). FishCube data reports that less than three vessels have typically operated in the Operational Area each year for the last five years (2016 - 2020), compared with greater fishing effort located to the south-west of the Operational Area, between Exmouth and Dampier (up to five vessels operating). Therefore, interactions and the potential for disturbances to commercial catch rates may be infrequent or may not occur at all. The distribution of fishing effort (Section 4.4.4) as well as catch-per-unit-effort (CPUE) of key indicator fish species (Section 7.1.6.7) indicates that target fish populations may be more abundant elsewhere.

The Acquisition Area does not overlap with the area of historic fishing activity for the Northern Demersal Scalefish Managed Fishery. Although sound will propagate into the waters accessible to the NDSMF, historically fishing activity only occurs at the eastern edge of the Operational Area where the effort is undertaken by less than three vessels during the entire five-year period from 2016 to 2020 (refer to Section 4.4.4). Therefore, it is considered highly unlikely that disturbances to catch rates in the NDSMF will occur.

In addition to the limited overlap between the Acquisition Area and commercial fishing effort, it is important to note that the spatial overlaps in Table 7-15 are conservative as they assume that disturbance occurs across the entire Operational Area (6,000 km²). In reality, the area that may be exposed to seismic sound at any one time during the survey will be significantly less. For example, as described in Section 7.1.6.7, in a single 24-hour period, the area of disturbance (based on the distance travelled by the seismic vessel and a 500 m buffer to either side of the acquisition lines to be representative of behavioural effects to fishes within tens or hundreds of metres from the seismic source [Popper *et al.* 2014]) would be approximately 166 km^2. Even considering the area exposed during a week of racetrack acquisition with a highly conservative 5 km buffer applied, the total area exposed would be approximately 1,450 km^2, approximately 60% less than the total Acquisition Area (3,512 km^2).

It is also important to note that, despite ongoing fishing and seismic surveys across the fisheries in previous years, the demersal scalefish catch in the Pilbara remained stable and within catch tolerance levels between 2012 and 2017, with the PFTIMF averaging approximately 1,200 tonnes per year during this period (DPIRD 2017). Subsequently, the most recent DPIRD Status of the Fisheries report (Newman *et al.* 2019) notes that total annual trawl catches have since increased despite having the same annual effort allocations, with catches in 2017–2018 exceeding the Department's defined acceptable catch range. Given that the effort allocations are the same, Newman *et al.* (2019) suggest that the increased catch rates indicate that fishing effort reductions since 2008 have been effective and have resulted in increased fish abundance.

It was understood through consultation with DPIRD and MMF fishers that there has been a moderate depletion of the mackerel stock as evident from the decline in catch rates in recent years (FRDC 2021). Whilst short-term movement by mobile pelagic species away from a marine seismic survey area is not unexpected, coincident changes in mackerel catches reflect the long-term trajectory of the fishery and cannot be attributed to a seismic activity. The behaviour and distribution of mackerel is affected by various environmental factors such as water temperature (Mackie *et al.* 2003) and the fishery experiences regular intrinsic fluctuations. There was a decline in effort and catch rates in the MMF over the 2011/12 year, which may have been due to the 2011 marine heatwave causing changes in biomass and availability of mackerel (DOF 2012). Declining catches were seen again following the 2016 marine heatwave (which occurred over the spawning period) in all three areas of the MMF (DPIRD 2020). DPIRD has considered this an 'acceptable moderate depletion of stock' (FRDC 2021).

The low catches in Western Australia are attributed to 'widespread environmental changes' and the status report notes that other Australian states have also recorded declining catches (DPIRD 2020). Whilst considered three distinct stocks, declines in CPUE have also been observed across the Queensland and Torres Strait fisheries in recent years (ABARES 2020, DAF 2021). The Gulf of Carpentaria fishery is currently considered a depleting stock (FRDC 2021) which is in part attributed to "extreme climatic conditions observed in 2015-2016 (that) may have exacerbated declines in biomass post 2017, once fish spawned in those years became vulnerable to fishing". The decline in catches described could be the result of these factors.

Pelagic fishes are most likely to exhibit a significant behavioural response (avoidance) by moving away from an operating seismic source that approaches within hundreds of metres of them (Wardle *et al.* 2001). Research shows that mackerel in this region don't move more than 100 km along the coast (DOF 2013), and whilst it is possible that fish may be displaced from a survey footprint to adjacent areas, the total number of fish within the fishery stock remains unchanged and survey-induced mortality is highly unlikely. Apart from temporary avoidance behaviour around the source and vessel, mackerel behaviour and catchability will also be unaffected by the survey. It is noted that the majority of the survey area is more distant from the actively fished areas than the southern edge where there may be some behavioural disturbance when the vessel is at its closest and therefore, for most of the survey duration noise levels in actively fished areas will be significantly lower than the behavioural effect threshold. Refer to Section 7.2 for further evaluation of the cumulative effects of past seismic surveys on the commercial fisheries.

Impacts to commercial fish stocks and fishing catch rates due to the survey are likely to be negligible for the following reasons:

- As noted in Section 7.1.6.7, mortality of 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).
- Large proportions of the PFTIMF, PTMF, MMF and NDSMF fished areas (95%) are located outside of the Sauropod 3D MSS.
- Fishing catch and effort within the Sauropod 3D MSS Acquisition Area is relatively low (refer to Section 4.4.4). Historic catch effort indicates effort is more focussed in other areas than it is in the Sauropod 3D MSS Operational Area.
- Despite ongoing fishing and seismic surveys across the fisheries in previous years, the demersal scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017–2018 exceeding the acceptable catch tolerance range, indicating an increased level of fish abundance, as well as increased catch rates (CPUE).

- As noted in Section 7.1.6.7, the stock assessment for all key indicator commercial fish species (Red emperor, Blue-spotted emperor, Goldband snapper and Rankin cod) indicates adequate stock status, breeding stock and fishery catch levels (Gaughan and Santoro 2018).
- As noted in Section 7.1.6.7, fish recovery from TTS or behavioural effects is expected in days to weeks. No population level effects are predicted to target fish species hence no lasting effects on their catchability, and consequently to commercial catch rates, are expected.
- There are no effects predicted to the ecosystems or habitats of the North Coast fishing bioregion, therefore the proposed seismic activities do not threaten the sustainability of the fisheries that cover significantly smaller areas than the overall distribution of fish in the North Coast fishing bioregion.
- The area of potential impact for the assessed species is a low proportion of the area that they are likely to inhabit and where they are targeted by commercial fishers.

7.1.6.7.2 Summary

Based on the timing and duration (up to 60 days) of seismic acquisition, the potential impacts of underwater noise emissions from the seismic source on commercial catch rates during the Sauropod 3D MSS are considered to be slight and short-term. The activity is not likely to result in any ecologically significant impacts at a population level for any key indicator commercial fish species targeted by commercial fisheries within or adjacent to the Operational Area.

7.1.6.8 Marine Protected Areas

7.1.6.8.1 Impact Assessment

As shown in Figure 4-15, the northern boundary of the Operational Area is located approximately 21 km from the southern boundary of the Multiple Use Zone (MUZ) of the Argo-Rowley Terrace Marine Park (an AMP) and approximately 60 km from the boundary of the Rowley Shoals Marine Park (State waters) at Imperieuse and Clerke reefs. The Operational Area is located approximately 80 km from the boundary of the Mermaid Reef Australian Marine Park.

As described in Section 4.4.1.1, the Argo-Rowley Terrace AMP was established to protect a range of natural, cultural and heritage values, including the canyons linking the Argo Abyssal Plain with the Scott Plateau and the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEFs. The latter KEF overlaps the MUZ of the Argo-Rowley Terrace AMP.

Based on the sound level isopleths for modelling Site 3, maximum predicted received sound levels in the water column at the boundaries of these marine protected areas (MPAs) are as follows:

- MUZ of the Argo-Rowley Terrace Marine Park - approximately 134 dB re 1 μPa (SPL)
- Rowley Shoals Marine Park (at Clerke Reef) - approximately 125 dB re 1 μPa (SPL)
- Mermaid Reef Marine Park – approximately 122 dB re 1 μPa (SPL).

Maximum predicted received sound levels at the boundary of the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF closest to the Operational Area are approximately 127 dB re 1 μPa (SPL).

Consequently, received sound levels in the water column or at the sea floor within the areas of these MPAs closet to the Operational Area will not exceed any of the sound exposure thresholds for injury, TTS or behavioural disturbance in cetaceans, marine reptiles, fishes/elasmobranchs, benthic invertebrates or zooplankton that may be present within the MPAs during acquisition of the Sauropod 3D MSS.

7.1.6.8.2 Summary

Based on the timing and duration (up to 60 days) of the Sauropod 3D MSS and the control measures that will be implemented, predicted noise levels from seismic acquisition are not considered likely to cause any impacts to the natural or cultural heritage values of the any AMP in the region, or to the values of the Rowley Shoals Marine Park (State waters) (Section 4.4.1).

7.1.6.9 Tourism and Recreation

7.1.6.9.1 Impact Assessment

As described in Section 4.4, a range of recreational activities take place at Imperieuse and Clerke reefs, within the Rowley Shoals Marine Park (State waters), including scuba diving, snorkelling and fishing charter trips.

The separation minimum distances from the Operational Area and Imperieuse and Clerke reefs are 67 km and 63 km, respectively. At these ranges, received sound levels at the reefs will be well below levels that would result in any effects, including TTS and behavioural disturbance, in fish targeted by recreational fishers. Therefore, acquisition of the Sauropod 3D MSS will not result in any impact to recreational fishing charter trips to the Rowley Shoals.

To assess the potential impacts from operation of the seismic source in the Acquisition Area on divers and snorkellers in the water at Imperieuse and Clerke reefs, a single-impulse sound exposure threshold of 145 dB re 1 µPa (SPL) was applied, which represents a human health assessment threshold for sound exposure to divers and swimmers, derived from Ainslie (2008) and Parvin (2005). This does not imply that this level is associated with the onset of injury. Based on a number of studies examining the potential effects of underwater noise emissions on both military and recreational divers Parvin (2005) suggested 145 dB re 1 µPa (SPL) as a safety criterion for recreational divers and swimmers, within a frequency range between 100 and 500 Hz. Seismic airgun sources are broadband sources and therefore, for this assessment, the most precautionary and conservative diver acoustic impact threshold has been used.

For modelling Site 3, which is the closest of the four single impulse modelling sites to the Rowley Shoals, the maximum predicted R_{max} distance to the 145 dB re 1 µPa (SPL) threshold was 15.8 km, in the endfire direction (i.e. north towards the reefs). Received levels at Imperieuse and Clerke reefs are predicted to be at or below 120 dB re 1 µPa (SPL), which is approaching ambient background noise levels in these offshore atoll environments where SPLs are consistently between 85–110 dB increasing at times to in excess of 120 dB re 1 µPa as a result of biological noise, waves and tidal currents.

On this basis, divers and snorkelers at Imperieuse and Clerke reefs will not be exposed to sound levels anywhere close to the 145 dB re 1 µPa (SPL) threshold. If diving and snorkelling activities in these areas were to coincide with acquisition of the Sauropod 3D MSS, it is highly unlikely that individuals in the water would be able to hear individual shots from the seismic source above background ambient noise levels.

7.1.6.9.2 Summary

On the basis of the information provided above there will be no impacts from seismic noise emissions during the Sauropod 3D MSS on diving and snorkelling activities at the Rowley Shoals.

7.1.7 Decision Context

The decision context for underwater sound emissions from the seismic source has been assessed as ‘Type B’ due to stakeholder concerns raised in relation to potential impacts to commercial fisheries, including fish spawning. As described in Section 6.7.1, further analysis is required in addition to using the tools for a Decision Type A, including assessing the results of probabilistic analyses such as modelling, quantitative risk assessment and/or cost benefit analysis to support the selection of control measures.

7.1.8 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Operation of the seismic source within the Operational Area for the Sauropod 3D MSS will be compliant with EPBC Act Policy Statement 2.1 Part A Standard Management Measures	Yes	Consistent with Part A of EPBC Policy Statement 2.1, the following precaution zones will be applied: • Observation zone: 3+ km horizontal radius from the seismic source • Low power zone: 2 km horizontal radius from the seismic source • Shut-down zone: 500 m horizontal radius from the seismic source. • Part A of EPBC Policy Statement 2.1 provides standard management procedures and will be implemented during the Sauropod 3D MSS. • Precaution zones will be implemented around the seismic source to allow whale observations to be undertaken and the seismic source to be powered or shut down to reduce the potential for PTS and TTS in the event a whale is observed within the precaution zones. Consistent with Part A of EPBC Policy Statement 2.1, the following procedures will be applied: • Pre-Start-up Visual Observations (30 minutes) • Start-up Delay Procedures (if sighting) • Soft-start Procedures (30 minutes) • Operational Shut-down and Low-power Procedures • Night-time and Low Visibility Procedures • Seismic survey vessel crew will be briefed in marine fauna observations, distance estimation and procedures • Cetacean sighting and compliance reports to be submitted to DAWE within 2 months of survey completion.	1.1
Operation of the seismic source within the Operational Area for the Sauropod 3D MSS will be compliant with EPBC Act Policy Statement 2.1 Part B.1 – Additional Management Measures: Marine Mammal Observers	Yes	Two trained and experienced marine fauna observers (MFOs) will be aboard the seismic survey vessel. The two MFOs (in addition to briefed crew members) will alternate shifts during daylight hours in order to manage fatigue and provide some redundancy in the event one MFO is unavailable. The MFOs will have adequate training and will have 12 months experience in Australian waters.	1.2
Operation of the seismic source within the Operational Area for the Sauropod 3D MSS will be compliant with EPBC Act Policy Statement 2.1 Part B.4 - Increased precaution zones and buffer zones.	Yes	In accordance with criteria outlined in EPBC Policy Statement 2.1, acoustic modelling confirmed that the received sound exposure level from a single seismic pulse will exceed 160 dB re 1μPa2.s for 95% of pulses at 1 km range. Therefore, instead of a 1 km low power zone, a larger 2 km low power zone will be implemented.	1.3
Good Industry Practice			
The seismic source will not be discharged outside the Operational Area. The seismic source will only be discharged outside of the Acquisition Area for the purpose of run-outs, source testing and soft starts.	Yes	The seismic source will not be discharged outside the Operational Area and will only be discharged outside the Acquisition Area for the purpose of run-outs, source testing and soft starts. Good industry practice, environmental benefit outweighs additional cost.	1.4
CGG will engage with proponents identified as having potential concurrent MSS activities prior to commencing the Sauropod 3D MSS and develop a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area	Yes	Engagement with titleholders for potential concurrent MSS activities prior to acquisition commencing, and development of a concurrent operations plan, which will include the following aspects: • Communications protocols • SIMOPS and work programming • Hazard management • Emergency response. Good industry practice, environmental benefit outweighs additional cost.	1.5

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Alternatives/Substitutes Considered			
The source volume used during acquisition of the survey will be equal to or less than the source volume used for the acoustic modelling and impact assessment	Yes	CGG has assessed the minimum size source required to fulfil survey data objectives. A maximum source volume of 3,090 in^3 will be used to acquire the survey. This provides confidence in the impact assessment conducted, which was based on modelling results for a 3,090 in^3 array. Good industry practice, no additional cost.	1.6
Additional Controls Considered			
Survey acquisition timed to avoid the migration periods for Humpback whales (June to October).	Yes	The survey will be acquired in the period January to May, which will avoid the northbound and southbound migration season for Humpback whales in the region (June to October). Good industry practice, environmental benefit outweighs additional cost.	1.7
Survey acquisition timed to avoid the migration periods for Pygmy blue whales	No	Not justified. Acquisition of the survey may overlap the commencement of the northbound migration (April/May), but avoids most of the northbound migration and the entire southbound migration period for Pygmy blue whales in the region (September to November). While the Operational Area overlaps with the Pygmy blue whale distribution BIA, the migration BIA is located 95 km from the Operational Area. Only occasional, transient individuals are therefore expected in the area during the proposed acquisition period. The costs of limiting the acquisition window further to avoid the Pygmy blue whale migration entirely are grossly disproportionate to any potential environmental benefit gained.	N/A
Survey acquisition timed to avoid turtle internesting periods	No	Not justified. Acquisition of the survey may overlap the nesting and breeding season for a number of turtle species in the region, however the Operational Area is located at least 15 km from the closest BIA or 'Habitat Critical' boundary. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
EPBC Act Policy Statement 2.1 Part B.2 – Night-time/ Poor Visibility	No	Not justified. These control measures will not be implemented 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. Additionally, survey acquisition is timed to avoid the Humpback whale migration season. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
EPBC Act Policy Statement 2.1 Part B.3 - Use of spotter aircraft and vessels to detect presence of cetaceans	No	Not justified. These control measures will not be implemented 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. Additionally, survey acquisition is timed to avoid the Humpback whale migration season. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
EPBC Act Policy Statement 2.1 Part B.5 - Passive Acoustic Monitoring (PAM) to detect presence of vocalising cetaceans	No	Not justified. These control measures will not be implemented 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. Additionally, survey acquisition is timed to avoid the Humpback whale migration season. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
EPBC Act Policy Statement 2.1 Part B.6 - Adaptive Management Measures	No	Not justified. These control measures will not be implemented 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. Additionally, survey acquisition is timed to avoid the Humpback whale migration season. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
Application of a 200 m shut-down zone for Whale sharks	Yes	Whale sharks are most likely to be present in the Operational Area from July to November and so are not expected to occur in high numbers during the January to May period of the survey. However, they may occur in low numbers. Acoustic modelling indicates that the maximum predicted distance to the injury threshold for Whale sharks (categorised in the hearing group of fishes without swim bladders) is 60 m. A shut-down zone with a horizontal radius of 200 m from the seismic source is therefore considered to reduce the potential for PTS and TTS to occur.	1.8
Application of a 100 m shut-down zone for marine turtles	Yes	The Operational Area is located at least 15 km from the closest BIA or 'Habitat Critical' boundary for turtles; however, occasional turtles may be present in the Operational Area. Acoustic modelling indicates that injury (PTS) and TTS effects will only occur within very close ranges (tens of metres) to the operating source. A shut-down zone with a horizontal radius of 100 m from the seismic source is therefore considered to reduce the potential for PTS and TTS to occur.	1.9
Survey acquisition timed to avoid or limit temporal overlap with the spawning periods for key indicator species for commercial fisheries	No	Not justified. The maximum spatial-temporal overlap of the survey with the spawning areas and periods of commercial fish species is approximately 1.26%. However, the spatial overlap is simply an indication of the area that may be ensonified and where potential spawning aggregations may be influenced. At any one time and during any single spawning event, the area of disturbance will be significantly smaller and will represent a very small proportion of the spawning stock. Therefore, this assessment is conservative. In addition, CPUE data indicates that fish abundance within the Operational Area is relatively low. The level of impact to the populations (spawning biomass and recruitment) is predicted to be negligible, particularly in the context of normal variability. Further limiting the temporal overlap with the spawning periods has been considered. The proposed schedule and temporal window for the Sauropod 3D MSS (January to May) was determined considering the:	N/A

Control Measure	Control Adopted	Justification	Performance Standard Ref.
		• Timing of key environmental and socio-economic receptors • Hearing ability and sensitivity of those receptors to sound from the seismic survey • Proximity of sensitive habitat areas to seismic survey areas • Species distribution and range • Level of overlap (in space and time) by the survey with important habitats and life stages of sensitive species • Species vulnerability / conservation status • Potential for impacts to species at both an individual level and at a population level. The optimum window of opportunity was determined to be from January to May (inclusive). The proposed survey timing was selected primarily to avoid the Humpback whale migration through the region (June to October), as well as reduce exposure to Pygmy blue whales during their migrations to the north of the Operational Area (April – August and October to December). Both of these species are low-frequency cetaceans and sensitive to seismic sound over several kilometres. The defined survey period, therefore, limits the potential for impacts to these protected species, including preventing injury/hearing impairment (PTS/TTS) or significant behavioural effects during their migrations. It is noted that the Pygmy blue whale migration BIA is located sufficiently far from the Operational Area for impacts to be avoided but the timing had also originally taken into account Pygmy blue whale distribution outside of the main migration BIA. Fish spawning periods were also considered in detail, noting the importance of spawning and recruitment of fish stocks, but also noting fishes' sensitivity to seismic sound is significantly less than that of cetaceans. Significant disturbance to groups of spawning fishes may occur for short periods when the seismic source is passing within hundreds of metres of their location. The spawning periods of the many different key indicator fish species for the commercial fisheries in the region extend throughout the majority of the year but can vary significantly between species. It is noted that most key indicator species spawn between October and March, April or May. In order to avoid or reduce the survey's overlap with this period, the survey window would extend into both the Humpback whale and more of the Pygmy blue whale migration periods. As noted in the above risk assessment, occasional localised disturbances of groups of spawning fishes may occur, but this is not expected to have a significant impact on the stocks, due to their high fecundity, protracted spawning periods, biological connectivity through recruitment from across the region, as well as large natural variability in the spawning biomass and recruitment levels. Avoidance of fish spawning periods would provide limited additional environmental benefit at a disproportionate cost (in terms of potential impacts to more sensitive marine fauna and costs associated with additional measures that would likely be required for whales such as additional shutdowns, adaptive management, etc. Therefore, this option is not considered practicable. Further constraining the survey window and limiting the overlap of the survey with fish spawning periods may mean that the proposed seismic survey could not be completed, potentially equivalent to a cost in the order of millions of dollars of lost seismic survey effort time and data. Given the limited predicted risk to fish spawning and fish stocks, the costs are grossly disproportionate to any potential environmental benefit gained.	
Survey acquisition timed to reduce temporal overlap with commercial fishing operations	No	The Sauropod 3D MSS primarily overlaps with the Pilbara Demersal Scalefish Fisheries, specifically the fished areas of the PFTIMF and the PTMF. The survey does not overlap with the fished area of the PLF or the Mackerel Managed Fishery. Overlap between the Operational Area and the NDSMF is negligible (as explained in the above risk assessment). The PFTIMF, PTMF and NDSMF operate throughout the year. Analysis of FishCube data for the fisheries monthly catch and effort does not provide sufficient information to indicate any clear seasonal trends. Therefore, it is not practicable to alter the timing of the survey in a way that would reduce the temporal overlap with these fisheries.	N/A
No acquisition overlapping the ancient coastline at 125 m depth contour KEF	No	Not justified. Would result in removal of 1,272 km^2 from the Acquisition Area and CGG would not be able to obtain data for all hydrocarbon prospects being targeted. The area of the KEF potential impact by the survey is small (8%), and the KEF is not expected to support large numbers of site-attached species. Any impacts to individuals are not expected to lead to population or ecosystem level impacts. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
Implementation of a management of change process that includes a specific trigger to review new evidence in relation to impacts and risks to commercial fishing from the survey, and the review of the need to enhance existing controls	Yes	CGG is cognisant of the concerns raised by commercial MMF fishers over the potential impacts of noise emissions from the survey on mackerel catches. These concerns are based on declines in catches during the past few years. However it is not reasonable to assume that this data reflects a future impact from the proposed seismic survey; firstly because there is no overlap of MMF historical fishing effort within the Acquisition Area and the ensonified area (as supported by acoustic modelling described in Section 7.1 of the EP), and also because the survey period (January to May) avoids the majority of the peak mackerel fishing season in the Pilbara (May-August). In addition, it is noted that recent declines in mackerel catches and catch rates in the Kimberley and Pilbara fishery management areas, as reported by DPIRD (2020), may 'indicate a decline in the spawning stock [of mackerel] after the influence of the 2016 northern heat pulse [marine heatwave] during the spawning period'. Nevertheless, whilst the above evidence supports the assessment that potential impacts from the seismic survey on mackerel fishers will be Negligible, it is appreciated that MMF fishers have ongoing concerns over impacts due to the survey. As such CGG will implement an environmental management process for the activity (Section 9.1) that includes a specific trigger to review new evidence in relation to impacts and risks to commercial fishing from the survey. If a change in impacts and risks to commercial fishing is confirmed a practical, evidence-based process for reasonable monetary adjustment will be provided to commercial fishers for loss of catch, displacement, or fishing gear loss or damage in the form of a Fishery Impacts Mitigation Plan. Good practice principles that will be incorporated into the Fishery Impacts Mitigation Plan include: • Mitigation will be made available during the acquisition phase of the seismic survey and up to two months after the conclusion of the acquisition of the seismic survey.	1.10

Control Measure	Control Adopted	Justification	Performance Standard Ref.
		• Mitigation will be available to a commercial fisher who fishes as a normal part of their commercial fishing activity within the Adjustment Area (an area extending 10 km around the perimeter of the acquired survey area [where guns are fired at full power for the purpose of data acquisition], noting this may be smaller than the defined Acquisition Area of the survey as defined in the EP). A commercial fisher must be able to demonstrate that they would have received the revenue from the landed catch that is the subject of a claim and adjustment is dependent on a commercial fisher continuing to carry out their fishing activities to the best of their ability and to mitigate and limit financial loss despite the occurrence of a seismic survey, i.e. adjustment would not be available where a fisher chooses to move away from a survey and makes no attempt to fish within the survey Adjustment Area. • The mitigation process will apply to historical fishing activity over established fishing grounds, and not to speculative fishing activity • Mitigation claims may be lodged up to 4 months after the conclusion of the acquisition of the seismic survey • If a commercial fisher is unable to fish in their historical fishing area within the Adjustment Area during the seismic survey and incurs costs over and above the normal running costs for a fishing trip while relocating to another historical fishing area, then costs associated with increased distance/transit time, fuel and crewing will be considered for monetary adjustment.	

Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)

No practicable improvements have been identified

ALARP Statement

CGG considers the adopted control measures appropriate to manage the impacts and risks of underwater sound emissions from the seismic source. As no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.

Receptor	Consequence	Likelihood	Residual Risk Ranking
Cetaceans	Moderate (2)	Unlikely (B)	Medium
Marine reptiles	Moderate (2)	Rare (A)	Low
Seabirds	Minor (1)	Rare (A)	Low
Fishes and elasmobranchs	Minor (1)	Possible (C)	Medium
Benthic invertebrates	Minor (1)	Unlikely (B)	Low
Zooplankton	Minor (1)	Possible (C)	Medium
Fish spawning	Moderate (2)	Unlikely (B)	Medium
Commercial fisheries	Moderate (2)	Unlikely (B)	Medium
Marine protected areas	Minor (1)	Rare (A)	Low
Tourism and recreation	Minor (1)	Rare (A)	Low

7.1.9 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The impact/risk associated with underwater noise emissions from the seismic source will be managed in accordance with CGG's HSE Policy. The risk management strategy for managing underwater noise impacts is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	The impact/risk associated with underwater noise emissions from the seismic source will be managed in accordance with CGG's Management System. Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management • Notification and Reporting.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk associated with underwater noise emissions from the seismic source has been assessed as Medium and will not have a 'significant impact' upon Protected Matters in accordance with EPBC Policy Statement 1.1. – Significant Impact Guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** The activity will be undertaken in a manner consistent with the applicable objectives and actions of the following marine reserve management plans, species conservation or recovery plans, threat abatement plans, and conservation advice: • Conservation Management Plan for the Blue whale – 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

Context	Factor	Demonstration
		• Approved Conservation Advice for *Megaptera novaeangliae* (Humpback whale) – Consistent with the Conservation advice for Humpback whales, acoustic modelling has been undertaken to assess the potential impacts on Humpback whales. The seismic survey will also be undertaken consistent with the EPBC Act Policy Statement 2.1 • Conservation advice for Sei and Fin whales – The Conservation Advice for both species do not specify required standards for managing noise impacts from seismic surveys, but they do recognise anthropogenic noise as a potential threat to the species. No significant or long-term disturbance, or injury, to Sei or Fin whales from noise emissions is expected as a result of the seismic survey • Recovery Plan for Marine Turtles in Australia – 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. The Recovery Plan also 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 • Conservation Advice for *Rhincodon typus* (Whale Shark) - This Conservation Advice identifies habitat disruption from mineral exploration, production and transportation as a threat to Whale sharks. It does not specifically outline management actions in relation to seismic noise emissions, however, given the control measures to be implemented for the seismic survey, which include soft-start procedures, as well as shut-down procedures for Whale sharks, no injury is expected and the potential for significant disturbance is limited. **Conservation values and objectives of the North-west Marine Parks Management Plan** No impacts are predicted to occur to the natural or cultural heritage values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs as a result of underwater noise from the seismic source.
	Socio-economic Environment – Commercial Fisheries	The assessment of impacts to commercial fisheries and key indicator fish stocks has been undertaken based on relevant external context, including the following data and publications: • North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017), which describes the stock assessment and management approach (consistent with the principles of ESD), including annual fishing effort allocations and catch tolerance levels • Spatial and temporal patterns in fisheries catch and effort distribution (based on DPIRD 2016-2020 FishCube data) • DPIRD (2019c) key indicator fish species' spawning information • DPIRD and FRDC publications and summaries (various, as referenced in this EP) that describe the extent of the biological stocks and fisheries management units. CGG has considered the mitigation recommended in the Department of Fisheries (2013) Guidance statement on undertaking seismic surveys in Western Australian waters: • Avoid key times of year – CGG has considered reducing the temporal overlap of the survey with fish spawning periods, but found this not to be practicable • 'Soft starts' for every event – Soft-starts will be implemented • Avoid restricting movement of fish away from the source of seismic sounds – Fish movements will not be restricted • Minimise the sound intensity and exposure time of surveys - CGG has assessed the minimum size source required to fulfil survey data objectives • Address specific advice from WAFIC, Recfishwest and individual fishers – Consultation has been undertaken. Key indicator fish species' stock status and annual performance reviews, as determined annually by DPIRD and outlined in the annual DPIRD Status of the Fisheries reports. In relation to impacts to commercially targeted fishes and invertebrates, CGG also considered 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). However, the report states that the assessment is only applicable to individual fish, assumes they do not move away from the seismic source and only considers mortality. Therefore, the report is not suitable for application to larger scale impacts such as regional aggregations and population level impacts.
	Relevant Persons Expectations	Stakeholder concerns have been assessed, responded to and controls adopted for objections and claims which hold merit.
Legislation and Other Requirements	Legislation and Conventions	The proposed control measures meet or exceed the required standards and control measures set out in Part A of EPBC Policy Statement 2.1.
Industry Standards	Industry Standards and Best Practices	The activity will comply with the following applicable industry standards and best practice guidance: • EPBC Policy Statement 2.1. Part A Standard Management Measures • IOGP Recommended monitoring and mitigation measures for cetaceans during marine seismic survey geophysical operations (March 2017) • IAGC Mitigation Measures for Cetaceans during Geophysical Operations (February 2015).
Ecological Sustainability Development (ESD)	ESD Application	CGG has reduced the impact/risk of underwater noise emissions from the seismic source to prevent serious or irreversible ecological damage. Impacts are expected to be have a Negligible or Minor consequence, with likelihoods ranging from Very Unlikely to Possible. The aspect and potential interactions are well understood and managed in accordance with EPBC Policy Statement 2.1 and applicable industry standards and best practice guidance.

7.1.9.1 Defined Acceptable Levels of Impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
Marine Fauna or Ecological Communities Listed as Threatened or Migratory under the EPBC Act (Matters of NES)	EPBC Act Part 3 (18A and 20A) EPBC Act Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013).	Seismic survey activities are undertaken in alignment with: • the EPBC Act Part 3 (18A and 20A) and Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013), whereby activities do not have a significant impact on a listed threatened or migratory species population or a listed threatened ecological community • do not result in the mortality or physical injury of an individual of an EPBC listed (marine fauna) species.	The predicted level of impact from underwater noise emissions from the seismic source, as assessed above, does not exceed the defined acceptable level of impact to marine fauna given the controls adopted will: • Prevent mortality or physical injury to EPBC listed marine fauna species • Prevent a significant impact on a listed threatened or migratory species population or a listed threatened ecological community.
	Conservation Management Plan for the Blue Whale	Seismic survey activities are undertaken in a manner consistent with the requirements of the Conservation Management Plan for the Blue Whale, specifically: • 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.	No injury/hearing impairment (PTS/TTS) or significant behavioural impacts are expected to occur to Pygmy blue whales within the migration BIA, which is located is located 72 km to the north of the Operational Area. The proposed timing of the Sauropod 3D MSS (between January andMay) has also been selected to limit overlap with the Pygmy blue whale migration periods (April to August and October to December) and therefore reduce the risk of impacts to migrating Pygmy blue whales outside of the migration BIA.
	Conservation Advice for *Megaptera novaeangliae* (Humpback whale)	Seismic survey activities are undertaken in a manner consistent with the requirements of Conservation Advice for *Megaptera novaeangliae* (Humpback whale), specifically: • 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 consistently with 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.	Consistent with the Conservation advice for Humpback whales, acoustic modelling has been undertaken to assess the potential single pulse and cumulative sound exposure impacts on Humpback whales. The seismic survey will also be undertaken consistent with Part A of EPBC Act Policy Statement 2.1, although the survey will not take place near a calving, resting or foraging area. The proposed timing of the Sauropod 3D MSS (between January andMay) has been selected to avoid the Humpback whale migration through the region, therefore, no impacts to Humpback whales are expected.
	Recovery Plan for Marine Turtles in Australia 2017-2027.	Seismic survey activities are undertaken in a manner consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017-2027, specifically: • Seismic surveys should not occur inside important internesting habitat during the nesting season. • Consistent 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	The Sauropod 3D MSS seismic source will not be operated within any important internesting habitats. The Operational Area is located at least 15 km from the closest BIA or 'Habitat Critical' for marine turtles and no significant impacts to marine turtle populations are expected. Soft-starts (as well as shut-down procedures for turtles, which exceed this requirement) will be implemented during the seismic survey.
Marine Fauna or Ecological Communities not listed as threatened or migratory (not matters of NES) under the EPBC Act	Principles of ESD, specifically no serious or irreversible damage.	No serious* or irreversible damage to a population of any marine fauna species or ecological community not listed as threatened or migratory (matters of NES) under the EPBC Act, including: • Marine fauna species not listed under the EPBC Act as threatened or migratory • Benthic invertebrate communities, including those associated with KEFs • Fish communities, including those associated with KEFs • Planktonic communities.	The predicted level of impact from underwater noise emissions from the seismic source, as assessed above, does not exceed the defined acceptable level of impact to non-listed marine fauna given that: Non-listed marine fauna – The controls adopted to reduce risks to marine fauna such as cetaceans and turtles, apply to all species in these groups irrespective of their status under the EPBC Act. No injury or mortality to such marine fauna is expected to occur given the controls proposed consistent with EPBC Policy Statement 2.1 (e.g. marine fauna observers, precaution zones, soft-starts, shut-down procedures). No species is expected to be displaced from an area of significant habitat; no significant areas for non-listed species are identified in the Operational Area and no serious (i.e. population level) or irreversible impacts are predicted to occur. The structure and ecological function of the ancient coastline at 125 m depth contour KEF will not be impacted. Benthic communities – Impacts to benthic communities are expected to be recoverable. While some benthic invertebrate organisms may experience sub-lethal or effects or chronic mortality, benthic communities are expected to recover in the weeks or months following exposure and changes in community structure and composition are not expected to be detectable from natural variability. No serious (i.e. community

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
		* In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, CGG considers a serious impact to be impacts with the potential to result in a threat to population or community viability, consistent with a consequence ranking of 'Significant' or greater.	level) or irreversible impacts are predicted to occur. The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered Fish communities – Consistent with fisheries management principles, key indicator species have been considered as representative of the full suite of fishes that occur in the Operational Area. The effects of the seismic survey on the spawning biomass of the various stocks are expected to comprise occasional localised behavioural disturbances to spawning groups of fish, but the level of impact to the populations (spawning biomass and recruitment) is predicted to negligible, particularly in the context of normal variability in the fish biomass and recruitment levels (250-350%). Injury or mortality to the types of fish found in the Operational Area is highly unlikely. No serious (i.e. population level) or irreversible impacts are predicted to occur. The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered. Planktonic communities – Zooplankton may be injured or killed in close proximity to the seismic source, however, 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. No serious (i.e. community level) or irreversible impacts are predicted to occur.
Marine Protected Areas	Conservation objectives and zone rules/requirements of the North-west Marine Parks Management Plan and other marine protected area management plans	Seismic activities are undertaken in a manner consistent with a management plan that is in force for AMPs or State Marine Parks in the region (i.e. Eighty Mile Beach AMP, Argo-Rowley Terrace AMP, Rowley Shoals Marine Park and Mermaid Reef Marine Park).	The predicted level of impact from underwater noise emissions from the seismic source, as assessed above, does not exceed the defined acceptable level of impact to marine protected areas given the activity will be managed in a manner that is consistent with management objectives for relevant AMPs and State Marine Parks.
Commercial Fisheries and Commercial Fish Stocks	Commercial fisheries stakeholder objections, claims and concerns regarding: • effects of seismic sound on key indicator commercially targeted finfish and invertebrate stocks, and • effects of seismic sound on fish behaviour and commercial catch levels.	Commercial fish stocks: Seismic activities are undertaken in a manner that does not result in serious* or irreversible impacts to key indicator commercial fish populations, such that sufficient spawning fish biomass and recruitment of the stocks may be maintained, and the stocks continue to be assessed by DPIRD as Sustainable. * In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, CGG considers a serious impact to be impacts with the potential to result in a threat to population or community viability, consistent with a consequence ranking of 'Significant' or greater. Commercial fisheries: Seismic activities are undertaken in a manner that: • Does not interfere with commercial fishing to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities. • Does not prevent each of the licenced commercial fisheries that overlap with the survey area from a catch that meets (or exceeds) the acceptable annual catch tolerance ranges for the fishery, as defined in the relevant harvest strategy (where catch below these tolerance levels cannot be attributed to other factors, such as changes in annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts). Note - It is a legislated function of DPIRD to annually report the status of the fisheries and fish stocks to WA Parliament and so the status and trends can be considered over time.	CGG considers the level of impact to commercial fish stocks to be of an acceptable level given that: • The seismic 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 Section 7.1.6.6 (130 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 Sauropod 3D MSS with the spawning areas in the Pilbara management unit and spawning periods of key indicator fish species • The approach to assessing the spatial-temporal overlap of the survey includes a significant level of conservatism due to the assumptions outlined in the assessment • The level of disturbance and spatial-temporal overlap (maximum of 1.26%) with the key fish stocks is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250-350%) • CPUE data indicates that fish abundance is relatively low within the Sauropod 3D MSS Acquisition Area compared with other parts of the region, therefore, there may be a lower likelihood of disturbing significant numbers of fish • Key indicator species in the Pilbara 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 • All indicator fish stocks are assessed as Sustainable, and no additional actions are implemented or proposed by DPIRD to further protect or manage the stocks • The sustainable status of the stocks indicates that the spawning biomass of key indicator species has remained within an acceptable range, consistent with DPIRD's management objectives for sustainability and 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

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
			• The DPIRD Status of the Fisheries reports indicate that in general 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. • The DPIRD Status of the Fisheries Report 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'. Therefore, the survey is not expected to result in a serious or irreversible impact to the sustainability of key indicator commercial fish stocks. CGG acknowledges that localised and temporary disturbances to fishing activities from seismic survey activities may occur. CGG recognises that clear and regular communication with fisheries stakeholders is required in order to facilitate planning and resource sharing. However, the level of impact from the Sauropod 3D MSS to commercial fisheries is considered to be Acceptable due to the following reasons: • Based on DPIRD FishCube data and CPUE data, the Sauropod 3D MSS Acquisition Area only overlaps with areas fished by the PFTIMF and the PTMF, however, fishing catch and effort as well as the CPUE (indicative of fish abundance) for these fisheries are relatively low. • The level of interference CGG may have on commercial fisheries is no greater than is necessary to exercise of right conferred by the titles granted to carry out exploration activities. • Despite ongoing fishing and significant areas of seismic surveys across the fisheries in previous years, the demersal and pelagic scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017–2018 exceeding the Department's defined acceptable catch range for the PFTIMF, indicating an increased level of fish abundance, as well as increased catch rates (CPUE). • Catch levels have remained within an acceptable range, consistent with DPIRD's fisheries management objectives for sustainability and consistent with the principles of ESD. • Disturbances to fisheries are likely to be infrequent and short-term. These are not expected to impact the overall annual catch rates and annual performance of the fisheries to the degree that it prevents the fisheries from achieving (or exceeding) the acceptable annual catch tolerance ranges for the fishery, as defined in the North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017). • If a change in impacts and risks to commercial fishing is confirmed, a practical, evidence-based process for reasonable monetary adjustment will be provided to commercial fishers for loss of catch, displacement, or fishing gear loss or damage in the form of a Fishery Impacts Mitigation Plan.
Tourism and Recreation	N/A	On the basis of the assessment provided above, no impacts are expected from seismic noise emissions during the Sauropod 3D MSS on tourism and recreation activities (including recreational fishing, diving and snorkelling at the Rowley Shoals). No stakeholder objections, claims or concerns were raised regarding recreation and tourism. Therefore, no acceptable level of impact has been defined.	Not applicable – No impacts are expected from seismic noise emissions during the Sauropod 3D MSS on tourism and recreation activities (including recreational fishing, diving and snorkelling at the Rowley Shoals).

Acceptability Statement
As identified in Section 6.2.4, impacts and risks classified as 'Decision Type B' are considered acceptable if the criteria outlined in Table 6-7 are met and it can be demonstrated that the predicted levels of impact and/or residual risk, are at or below pre-defined acceptable level(s) for that impact or risk. The evaluation of potential impacts from noise emissions from the seismic source meets these requirements as outlined above. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.1.9 are considered industry best practice and meet legislative requirements. CGG considers the adopted controls appropriate to manage the impacts of noise disturbance from the seismic source to be of an acceptable level.

7.1.10 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	EPO Measurement Criteria
EPO 1.1	Seismic acquisition is undertaken in a manner that prevents injury or mortality to an individual listed marine fauna species protected under the EPBC Act from underwater noise emissions from the seismic source.	PS 1.1 PS 1.2	No records of an incident (including a breach of Environmental Performance Standards) that could result in suspected injury or mortality of listed marine fauna species under the EPBC Act (required to be reported to NOPSEMA as a reportable incident).

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	EPO Measurement Criteria
EPO 1.2	Seismic acquisition is undertaken in a manner that prevents serious or irreversible damage to a marine fauna or ecological communities not listed as threatened or migratory (not matters of NES) under the EPBC Act.	PS 1.3 PS 1.4 PS 1.5 PS 1.6 PS 1.7 PS 1.8 PS 1.9 PS 1.10	No records of an incident (including a breach of Environmental Performance Standards) that could result in serious or irreversible damage to a marine fauna or ecological communities not listed as threatened or migratory (not matters of NES) under the EPBC Act.
EPO 1.3	Seismic acquisition is undertaken in a manner that does not compromise the objectives of relevant recovery plans or wildlife conservation plans/advice that are in force for a marine fauna species.		No records of an incident (including a breach of Environmental Performance Standards) that could result in compromise of the objectives of relevant recovery plans or wildlife conservation plans/advice from underwater noise emissions from the seismic source.
EPO 1.4	Seismic acquisition is undertaken in a manner that does not compromise the principles, values and objectives of protected areas (AMPs and State Marine Parks) from underwater noise emissions from the seismic source (as defined in relevant in-force management plans).		No records of an incident (including a breach of Environmental Performance Standards) that could result in impacts to the principles, values and objectives of protected areas (AMPs and State Marine Parks) from underwater noise emissions from the seismic source.
EPO 1.5	Seismic acquisition is undertaken in a manner that: • Prevents serious or irreversible impacts to key indicator commercial fish populations, such that sufficient spawning fish biomass and recruitment of the stocks may be maintained, and the stocks continue to be assessed by DPIRD as Sustainable • Does not prevent each of the licenced commercial fisheries that overlap with the survey area and Adjustment Area from a catch that meets (or exceeds) the acceptable annual catch tolerance ranges for the fishery, as defined in the relevant harvest strategy (where catch below these tolerance levels cannot be attributed to other factors, such as changes in annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts). • Commercial fishers do not suffer financial loss due to seismic acquisition substantially impacting catchability of target species.		No records of an incident (including a breach of Environmental Performance Standards) that could result in serious or irreversible impacts to key indicator commercial fish populations, or a reduction in the total annual catch levels of the Pilbara Demersal Scalefish Fisheries below the annual catch tolerance ranges. N.B. CGG will monitor the next annual DPIRD Status of the Fisheries report. If: • The status of any of the indicator demersal scalefish stocks in the Pilbara fisher's management unit is reduced to levels where it is no longer classed as sustainable or DPIRD consider stock levels to be under sufficient pressure to require revised management measures; or • Annual catch levels for the Pilbara Demersal Scalefish Fisheries fall below the annual catch tolerance ranges, Then CGG will review this risk assessment in accordance with the Management of Change process and will engage with DPIRD regarding the potential causes and/or potential changes to survey design/mitigation. If a change in impacts and risks to commercial fishing is confirmed through the assessment of merited objections or claims through the ongoing consultation process, a practical, evidence-based process for reasonable monetary adjustment will be provided to commercial fishers for loss of catch, displacement, or fishing gear loss or damage in the form of a Fishery Impacts Mitigation Plan.

Number	Performance Standards	Measurement Criteria
PS 1.1	Operation of the seismic source within the Operational Area for the Sauropod 3D MSS is compliant with EPBC Act Policy Statement 2.1 Part A Standard Management Measures: • Observation zone: 3+ km horizontal radius from the seismic source • Low power zone: 2 km horizontal radius from the seismic source • Shut-down zone: 500 m horizontal radius from the seismic source • Pre-Start-up Visual Observations (30 minutes) • Start-up Delay Procedures (if sighting) • Soft-start Procedures (30 minutes) • Operational Shut-down and Low-power Procedures • Night-time and Low Visibility Procedures • Seismic survey vessel crew will be briefed in marine fauna observations, distance estimation and procedures • Cetacean sighting and compliance reports to be submitted to DAWE within two months of survey completion.	Records demonstrate compliance with Policy Statement 2.1 Part A Standard Management Measures.
PS 1.2	Operation of the seismic source within the Operational Area for the Sauropod 3D MSS is compliant with EPBC Act Policy Statement 2.1 Part B.1 – Additional Management Measures: Marine Mammal Observers. Two trained and experienced MFOs are aboard the seismic survey vessel. The two MFOs (in addition to briefed crew members) alternate shifts during daylight hours in order to manage fatigue and provide some redundancy in the event one MFO is unavailable. The MFOs have adequate training and will have 12 months experience in Australian waters.	Records demonstrate that two MFOs were aboard the survey vessel for the duration of the survey. MFO sighting records and final report. CVs and training records for the MFOs.

Number	Performance Standards	Measurement Criteria
PS 1.3	Operation of the seismic source within the Operational Area for the Sauropod 3D MSS is compliant with EPBC Act Policy Statement 2.1 Part B.4 - Increased precaution zones and buffer zones. Acoustic modelling confirmed that the received sound exposure level from a single seismic pulse will exceed 160 dB re 1 μPa2.s for 95% of pulses at 1 km range. Therefore, instead of a 1 km low power zone, a larger 2 km low power zone will be implemented.	Records demonstrate a 2 km low power zone has been implemented
PS 1.4	The seismic source is not discharged outside the Operational Area. The seismic source is only discharged outside of the Acquisition Area for the purpose of run-outs, source testing and soft starts.	Records demonstrate that there has been no discharge of the seismic source outside the Operational Area.
PS 1.5	CGG has engaged with proponents identified as having potential concurrent MSS activities prior to commencing the Sauropod 3D MSS and have developed a concurrent operations plan for any concurrent surveys identified within 50 km of the Acquisition Area.	Records demonstrate CGG has re-engaged with identified titleholders prior to commencing the Sauropod 3D MSS, and has developed a concurrent operations plan, if required.
PS 1.6	The source volume used during acquisition of the survey is equal to or less than the source volume used for the acoustic modelling and impact assessment.	Records confirm that a source with a maximum volume of 3,090 in^3 has been used throughout the survey.
PS 1.7	Survey acquisition is timed to avoid the migration periods for Humpback whales (June to October).	Records confirm that the survey has been acquired outside the June to October Humpback whale migration season.
PS 1.8	A shut-down zone of 200 m horizontal radius from the seismic source is implemented for Whale sharks.	MFO sighting records and final report confirm implementation of a 200 m shut-down zone for Whale sharks.
PS 1.9	A shut-down zone of 100 m horizontal radius from the seismic source is implemented for marine turtles.	MFO sighting records and final report confirm implementation of a 100 m shut-down zone for marine turtles.
PS 1.10	Implementation of a management of change process that includes specific triggers to review new evidence in relation to commercial fishing impacts and risks and review of the need to enhance existing controls.	Records of Management of Change process being implemented.

7.2 Cumulative Impacts from Seismic Surveys

7.2.1 Source of Impact / Risk

Cumulative impacts from seismic surveys can potentially occur as a result of:

- Consecutive/successive seismic surveys where the spatial footprint of impacts from previous seismic surveys have occurred over the same area as where impacts from the Sauropod 3D MSS are predicted to occur. Cumulative impacts will only occur where the effects of previous surveys overlap the same area and when recovery of the impacts from these seismic surveys has not occurred prior to the Sauropod 3D MSS commencing; or
- Multiple seismic surveys that occur concurrently in a region (i.e. at the same time). Effects may or may not overlap spatially but may result in an incremental increase in impacts within the range and extent of the same receptors, for example, where different surveys overlap with the distribution of the same population of a marine species or with the same commercial fishery.

Therefore, this section assesses the potential for cumulative impacts associated with Sauropod 3D MSS being undertaken:

- In an area where other seismic surveys have occurred previously
- Concurrently (at the same time) as other marine seismic surveys in the areas.

This section does not assess cumulative impacts from seismic surveys that may occur after the Sauropod 3D MSS. It is not possible to anticipate what surveys will be planned after the Sauropod 3D MSS and it is the responsibility of future seismic survey proponents to assess the potential cumulative impacts in their EPs.

7.2.2 Impact/Risk Evaluation

7.2.2.1 Previous Seismic Surveys

7.2.2.1.1 Cumulative Impacts to Ecological Receptors

Table 7-16 presents a summary of the marine seismic surveys that have been undertaken recently within approximately 150 km of the Sauropod 3D MSS Acquisition Area. The footprint of any significant underwater noise effects resulting from the Sauropod 3D MSS has been assessed as being within approximately 15 km from the seismic source (based on the maximum range to TTS and behavioural effects assessed for any receptor type in Section 7.1), however, a 150 km buffer (ten times this distance) has been selected as a conservative search criterion to understand where previous surveys have occurred close by. The location of previous surveys are shown on Figure 7-10.

In some instances, it has not been possible to confirm the exact dates surveys were acquired or the final areas that were acquired. Therefore, for the purposes of the assessment, it has been conservatively assumed that surveys have gone ahead within the total area and timescale proposed in their respective EPs.

Cumulative impacts from successive surveys over the same areas can occur when the timing between surveys is less than the recovery rate of any potential impacts to receptors. As described in Section 7.1, the duration of recovery following exposure to underwater noise emissions from a seismic survey can be in the order of minutes to hours for some receptors, or weeks to months for other receptors, for example:

- Localised changes in zooplankton abundance are likely to be replenished and indistinguishable from natural levels within hours of a seismic survey vessel passing or, based on the most conservative studies (McCauley *et al.* 2017) and a precautionary approach, within a few days of a seismic survey being completed.
- Sub-lethal effects and chronic lethal effects to some benthic invertebrates may occur for weeks or several months after exposure, although changes in overall benthic community composition and structure are expected to be negligible in the context of natural 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) likely returning to normal within hours or days after exposure.

The last seismic survey to be completed over the same area of seabed as the Sauropod 3D MSS was completed in 2016 (Table 7-16). The adjacent Santos Keraudren Extension 3D MSS was partially completed between 28 May and 31 July 2021 (approximately 6 months prior to the commencement of the proposed Sauropod 3D MSS), as such ecological receptors are expected to have completely recovered from these surveys. 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 Sauropod 3D MSS.

The remaining area of the Keraudren Extension 3D MSS may occur concurrently to the Sauropod 3D MSS, which has been assessed in Section 7.2.2.2.

Table 7-16 – Previous Seismic Surveys Completed Within the 150 km of the Sauropod 3D MSS in the last 5 years

Survey Name	Survey Location	Survey Timing and Duration
Santos Limited, Keraudren Extension 3D MSS	The Keraudren Extension 3D MSS ramp-up zone and full power zone partially overlaps with the western edge of the Sauropod 3D MSS Acquisition Area.	Seismic acquisition is planned to occur between 1 February–31 July in 2020, 2021 and 2022.*
Santos WA Northwest Pty Ltd, Keraudren 3D	Sauropod Acquisition Area is located approximately 40 km from the Keraudren survey area.	Acquired May – July 2019
Searcher Seismic Pty Ltd Bilby 2D Phase 3 Multi-client Marine Seismic Survey	The Sauropod 3D MSS Acquisition Area overlaps with the area acquired by Searcher (i.e. Bilby survey area).	Completed between June – July 2016.
TGS-NOPEC Canning-Northern Carnarvon Multi Client Marine Seismic Survey	Sauropod Acquisition Area overlaps approximately 500 km^2 of the TGS survey area.	Completed between June – September 2016.

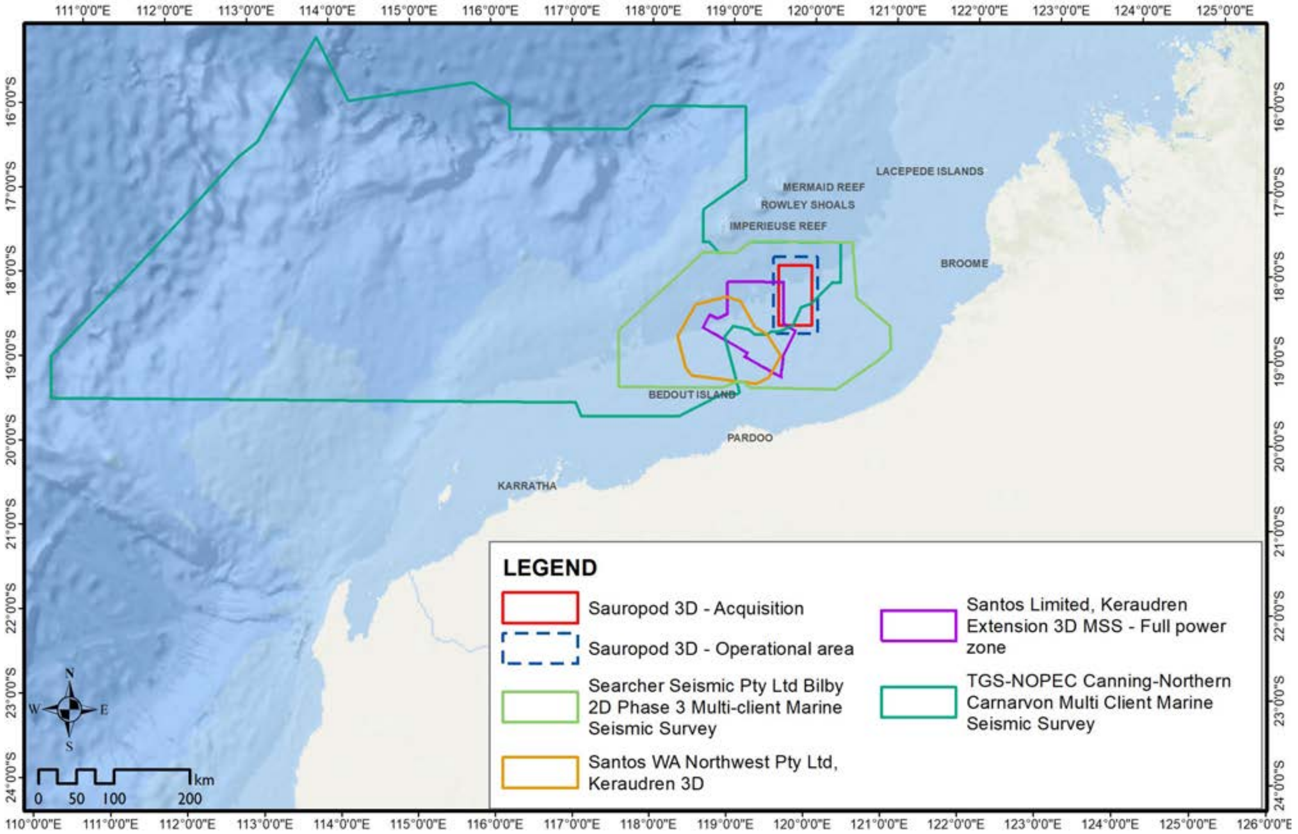


Figure 7-10 - Previous Seismic Surveys Completed Within the 150 km of the Sauropod 3D MSS in the last 5 years

7.2.2.1.2 Cumulative Impacts to Commercial Fisheries and Commercial Fish Stocks

In addition to the assessment of cumulative impacts to ecological receptors, a separate and more detailed assessment has been undertaken of the potential cumulative impacts to commercial fish stocks and commercial fisheries. This assessment addresses concerns from fisheries stakeholders regarding multiple seismic surveys occurring within the fisheries over consecutive years. In this respect, the concerns are not just limited to seismic surveys occurring over the same area of seabed, but the additive effects of different seismic surveys occurring in separate locations within the same fishery or the fish stock distribution. Therefore, to address these concerns, CGG has assessed the potential cumulative impacts to the Pilbara Demersal Scalefish Fisheries using the same fish spawning areas within the Pilbara fisheries management unit that were assessed in Section 7.1.6.6.

To assess the potential cumulative impacts of past surveys to the commercial fisheries historically active within the Operational Area CGG has reviewed both historical seismic surveys and available FishCube data over the period 2015–2020. The assessment focuses on the PFTIMF of the Pilbara Demersal Scalefish Fisheries as this fishery is the most conservative in terms of the potential for marine user interaction and area of overlap with the fishery for the Sauropod 3D MSS. FishCube data for the PFTIMF was available in a 10 nm CAES block resolution. As such, the area of fishing effort and overlap is likely to be overestimated, as fishing is likely limited spatially to discrete locations rather than over the entire area of the 10 nm blocks. The available FishCube data and DPIRD's annual Status of the Fisheries publications indicates between 66% and 78% of the total retained catch in the Pilbara Demersal Scalefish Fisheries retained by the trawl sector in any year. Therefore, the assessment of impacts to the PFTIMF is considered representative of the greatest likely impacts to any of the commercial fisheries historically active within the Operational Area.

Vessel presence per fishing block per month has been used to indicate the level of fishing effort; this was the only complete data set available within the FishCube data, as total fish catch, effort or catch per unit effort was not available (confidential information for fisheries) based on less than three operating vessels being reported in most blocks in the monthly and annual datasets. Hence, fishing vessel presence per month was used as an indicator of the general level of fishing activity in the fishery.

The following limitations and assumptions apply to the assessment, including:

- Survey areas have been calculated based upon the Acquisition Areas as these were the only available areas for all surveys. Operational Areas and ramp-up zones could not be confirmed for most surveys.
- Although the start and end dates of seismic surveys are known, it has not been possible to ascertain the dates when acquisition will have occurred in the parts of the survey areas that overlap the area fished by the PFTIMF. Therefore, it has not been possible to assess temporal overlap.
- It is important to note the overlap of the Acquisition Areas with the fisheries is likely to overestimate the actual area of disturbance to fishers in most cases, as the seismic survey vessel will not be operating across the whole of these areas all of the time. Instead, survey effort will be more focussed on discrete areas at any one time, comprising racetracks in the case of 3D surveys, or individual broadly spaced lines in the case of 2D seismic surveys. For example, the actual areas surveyed during any single day or week during the surveys will be a smaller part of the total survey areas, with survey vessels typically requesting that other vessels keep 3 nm (5.5 km) ahead and either side to avoid the vessel and towed equipment. However, using the larger acquisition areas is useful for making a direct comparison of the areas of overlap and an indication of the potential total area of disturbance during each year.
- 2D surveys are measured in both line kilometres and area (km^2). It is noted that 2D seismic surveys comprise an orthogonal grid of more broadly spaced acquisition lines than 3D seismic surveys, which comprise a "racetrack" of more closely spaced lines. As such, 2D and 3D seismic surveys areas may not be directly comparable in terms of the area occupied by the seismic vessel, where disturbance to fishers may occur, or the duration that survey activities occurred within the fishery. However, given the extent of the 2015 and 2016 2D line plans overlapping and outside of the PFTIMF fished area, it is still possible that a 2D seismic vessel will have been operating within the PFTIMF fished area on most days during each 2D seismic survey.

The spatial areas associated with historic surveys and their overlap with the PFTIMF fished area are shown in Table 7-17.

Based on the assessment, the following conclusions are made regarding impacts to the fisheries from historic seismic surveys:

- The PFTIMF fished area has historically been subject to approximately 25% overlap from 2D and 3D seismic surveys in a single year (maximum occurring in 2015).
- Overall, it is considered that commercial fishers continue to fish in similar areas each year with no obvious variations in fishing vessel distribution attributable to the presence of seismic surveys. However, it is important to acknowledge that more localised and temporary disturbances to fishing activities from seismic survey activities are likely to have occurred during the years shown, (and has been communicated to CGG through consultation with the MMF), but a widespread pattern cannot be identified from the available data for any fishery, which is presented at a coarser spatial and temporal resolution than disturbances may have occurred at. It is also acknowledged that each disturbance to fishers may have resulted in operational inconveniences (e.g. manoeuvring around the seismic vessel) to temporary loss of access to

fishing areas (i.e. displacement). However, the assessment is useful in demonstrating the limited influence of seismic surveys on total overall fishing activity and distribution of fishing effort in any year.

- Since 2014–2015, total fish catch in the PFTIMF has increased each year despite the occurrence of large-scale seismic surveys, attributed to the effective management of the fishery by controlling effort input (DPRID 2020).

The Status Reports Of The Fisheries And Aquatic Resources 2019-20 (DPIRD 2020) also notes that the total annual catch in the Pilbara Demersal Scalefish Fisheries has remained relatively stable, with the PFTIMF averaging ~1,159 tonnes between 2008-15. Again, this has occurred despite seismic surveys being undertaken most years. The Fisheries report further notes that total catch since 2015 has increased despite having the same annual effort allocations, with catches in 2017–2018 and 2018-2019 exceeding the Department's defined acceptable catch range.

Therefore, despite temporary disturbances to fishers from seismic surveys, no long-term impacts on the overall annual performance of the fisheries (in terms of distribution of effort or catch levels) or the sustainability of the fishery is evident from past surveys.

Table 7-17 – Total survey areas completed within the PFTIMF

Year	Total Area Fished (km^2) [1]	Total Fish Caught (tonnes) [2]	Total Surveys Overlapping the Area Fished (km^2)[3]	Total Surveys Overlapping the Area Fished (%) [3]
2015	25,922	1,172	12,956	50
2016	25,922	1,529	6,482	25
2017	30,869	1,795	0	0
2018	30,526	1,975	770	3
2019	31,212	1977	3,502	14
2020	31,555	2142	0	0

1. Total area fished = The total area of all 10 nm CAES blocks with recorded fishing effort per year within PFTIMF.

2. Fishing catch and days effort are derived from FishCube data which is only available up to and including 2020. Total fishing days are not available for some years due to FishCube data confidentiality.

3. Survey areas have been calculated based upon their Acquisition Areas. While the total survey areas will significantly overestimate the area of disturbance to fisheries at any one time (i.e. the areas surveyed during any single day or week during the surveys will be a small part of the total survey areas), it is useful for making a direct comparison of the areas of overlap for each year. Total survey area overlap for multi-year surveys have been included in the first year of survey only.

CGG has also undertaken a spatial-temporal analysis to determine the maximum annual overlap of previous seismic surveys with the spawning areas and periods of the key indicator fish species in the Pilbara Demersal Scalefish Fisheries. 2015 was chosen as the maximum annual case for the analysis, given the greater number and area of 2D and 3D seismic surveys that occurred within the Pilbara Demersal Scalefish Fisheries during this particular year, with 50% overlap of the fished area as compared to a maximum 25% overlap experienced in the following (2016-2021) years (Table 7-17).

As per the analysis undertaken of the spatial-temporal overlap of the Sauropod 3D MSS in Section 7.1.6.6, a number of assumptions have been applied to during the analysis, many of which apply a significant level of conservativism in order to provide a precautionary approach. These are:

- Spatial overlap is based upon the total area of each survey overlapping the spawning areas of the fish stocks. The actual area of disturbance will be significantly smaller and likely to be within hundreds of metres from the seismic source as it moves across the acquisition area. Therefore, the analysis is simply an indication of the total area that may have been ensonified and where potential spawning aggregations may have been exposed to seismic sound. Within any 24-hour period the total area that may have been ensonified would have been tens to hundreds of square kilometres, rather than hundreds to thousands of square kilometres.
- Temporal overlap is based on the total survey durations even though some of these survey periods would have involved seismic acquisition outside of the spawning ranges of the fish species. Therefore, the temporal overlap and resultant spatial-temporal overlap may be over-represented.
- The spatial extent of the spawning areas for each key indicator fish species have been estimated based on each species' depth range and the FRDC (2019) stock assessment data and DPIRD Pilbara fishery management area. It is important to note that 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. As a result, the spatial overlaps accounted for in the analysis are likely to significantly overestimate the percentage of spawning area available to each species. However, the Pilbara fishery management

area is 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 purpose of the analysis is to understand how much of the spawning areas and spawning periods may have been affected by behavioural disturbances in response to seismic sound. It is conservatively assumed that fish spawning in the area and period of exposure will have been compromised. As indicated in Section 7.1.6.3, some studies have observed very limited changes in fish behaviour or behaviours have returned to normal within minutes or an hour of a seismic source passing their location and the 2021 AIMS study observed no impact to fish behaviours as the result of commercial scale seismic surveys (Meekan *et al.* 2021). It is therefore possible that fishes may have continued to spawn regardless or may have moved away from the seismic source and spawned nearby, or spawning may have been delayed but still occurred a short time later once normal behaviours resumed. In either of these cases, the impact on spawning success may be negligible.

The results of the spatial-temporal analysis are presented in Table 7-18. The following observations are made from the 2015 spatial-temporal analysis:

- The maximum spatial-temporal overlap with the spawning area and spawning period of a key indicator demersal fish species in the Pilbara fisheries management area in 2015 was with Goldband snapper (8.73%).
- The maximum spatial-temporal overlap for other key indicator demersal fish species ranged from 1.87% (Bluespotted emperor) to 5.81% (ruby snapper).
- Large areas available for spawning by indicator fish species in the Pilbara were not overlapped by seismic surveys (between approximately 68% and 90%).
- None of the surveys occurred across the full spawning period for any commercially important fish species.

As demonstrated in Section 7.1.6.6, the 1.87% to 8.73% spatial-temporal overlaps are relatively small and is unlikely to have a significant population level affect, considering natural levels of variability in the spawning biomass and recruitment of some of these species have fluctuated by approximately 250% and 350% respectively, as a result of fishing and natural factors.

Even if it is assumed that spawning success was compromised within up to 8.73% of an indicator species spawning area and spawning period, it is of fundamental importance to note that from 2015, the key indicator fish stocks and the Pilbara Demersal Scalefish Fisheries have maintained a classification of 'Sustainable' despite the occurrence of large-scale seismic surveys (DPIRD 2020). The most recent DPIRD Status of the Fisheries report (DPRID 2020) further notes that total annual trawl catches have increased despite having the same annual effort allocations, with catches in 2017–2018 and 2018 -2019 exceeding the Department's defined acceptable catch range. Newman *et al.* (2020) suggest that the increased catch rates indicate that effort reduction measures applied to the fisheries since 2008 have resulted in increased fish abundance and stock rebuilding.

Therefore, despite seismic surveys in 2015 overlapping with relatively large proportions of the spawning areas and periods in the Pilbara management unit and the potential for disturbances to spawning fishes, relatively limited long-term impacts appear to have eventuated to the spawning biomass and recruitment. The stocks in the Pilbara management unit continue to be assessed as 'Sustainable' and cumulative impacts to commercial fisheries and fish stocks from previous seismic surveys are considered to be minor.

Table 7-18 – Cumulative Spatial-Temporal Overlap of 2015 Seismic Surveys with Spawning Areas of Key Indicator Fish Species in the Pilbara

Fish Species	**Depth Range (m)**	**Spawning Area (km^2)***	**Spawning Period**	**Cumulative Spatial Overlap (%)[1]**	**Temporal Overlap (%)[2]**	**Cumulative Spatial-Temporal Overlap (%)[3]**
Red emperor	10–180	99,349	September–June (303 days)	22.91% (0% to 7.63% per survey)	0% to 34.65% per survey	5.40% (0% to 2.64% per survey)
Rankin cod	10–150	92,575	June–December, March (245 days)	23.22% (0% to 7.41% per survey)	0.41% to 17.14% per survey	2.58% (0% to 0.94% per survey)
Goldband snapper	50–200	68,748	October–May (243 days)	32.31% (0% to 11.27% per survey)	0% to 43.21% per survey	8.73% (0% to 4.87% per survey)
Bluespotted emperor	5–110	77,912	July–March (274 days)	17.48% (0% to 5.57% per survey)	0% to 27.37% per survey	1.87% (0% to 0.96% per survey)

Fish Species	Depth Range (m)	Spawning Area (km^2)*	Spawning Period	Cumulative Spatial Overlap (%)[1]	Temporal Overlap (%)[2]	Cumulative Spatial-Temporal Overlap (%)[3]
Giant ruby snapper	150–480	43,566	December–April (151 days)	9.72% (0.06% to 7.63% per survey)	0% to 69.54% per survey	5.81% (0% to 5.47% per survey)

* Spawning areas have been estimated based on each species' depth range and the FRDC (2019) stock assessment data and DPIRD Pilbara fishery management area. It is important to note that genetic connectivity and the biological stocks have been confirmed across significantly larger areas, however, the Pilbara fishery management area is 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.

1. Cumulative spatial overlap is calculated based on the sum of all individual survey areas.
2. The temporal overlap is based on the maximum possible number of days each species may spawn within defined acquisition windows. Temporal overlap is not expressed as a cumulative value because the timing of some surveys partially overlaps with other surveys. Therefore, summing together the temporal overlaps of each survey would not provide an accurate representation of the cumulative temporal overlap.
3. Total cumulative spatial-temporal overlap with each species is calculated based on the spatial overlap × temporal overlap calculated first for each individual survey and then summed together.

2D line kms have been converted to km^2 by applying a 500 m buffer either side of the lines, as representative of the range of "tens to hundreds of metres" where significant behavioural effects to fishes may occur.

7.2.2.2 Concurrent Seismic Surveys

Over the scheduled period of the Sauropod 3D MSS (January to May 2021) other seismic surveys are also proposed in the region. Table 7-19 and Figure 7-11 presents the seismic surveys that:

- May occur within the same EP time frames
- Either have an EP accepted by NOPSEMA or have submitted an EP to NOPSEMA and is currently under assessment.

Table 7-19 - Other Potential Seismic Surveys Occurring in 2022

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
Santos Limited, Keraudren Extension 3D MSS	The full-fold acquisition area is 8,620 km^2.	The Keraudren Extension 3D MSS ramp-up zone and full power zone partially overlaps with the western edge of the Sauropod 3D MSS Acquisition Area. A maximum of 132–162 days of acquisition is proposed.	Seismic acquisition is planned to occur between 1 February–31 July in 2020, 2021 and 2022.*	Accepted and valid to 2022.
INPEX Browse EandP Pty Ltd, 2D Seismic Survey (WA-532-P, WA-533-P, WA-50-L)	The Acquisition Area is 65,138 km^2.	The Sauropod Acquisition Area is located approximately 70 km south-west of the INPEX 2D Acquisition Area.	1 November 2020–31 December 2023. No seismic acquisition between 1 June–31 October 2020 or 2021. A maximum of 210 days of acquisition is proposed.	The EP is accepted and valid to 2023
PGS Australia Pty Ltd, Rollo Multi-client Marine Seismic Survey	The Operational Area is 117,833 km^2. Note – Based on restrictions in the EP, it has been assumed that acquisition is limited to a maximum of 25,000 km^2 per calendar year.	The Sauropod Acquisition Area is located approximately 60 km east of the Rollo-Beagle Operational Area.	The specific commencement dates and durations of individual surveys have not been confirmed.	Accepted and valid to 2023.

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
TGS-NOPEC Geophysical Company Pty Ltd, Capreolus-2 3D Marine Seismic Survey 2020 - 2024	The Acquisition Area is 26,897 km^2. Acquisition is limited to a maximum of 10,000 km^2 per calendar year.	The Sauropod 3D MSS Acquisition Area is located approximately 140 km east of the TGS Acquisition Area.	Oct 2020–Dec 2024. The specific commencement dates and durations of individual surveys have not been confirmed.	Accepted and valid to 2024

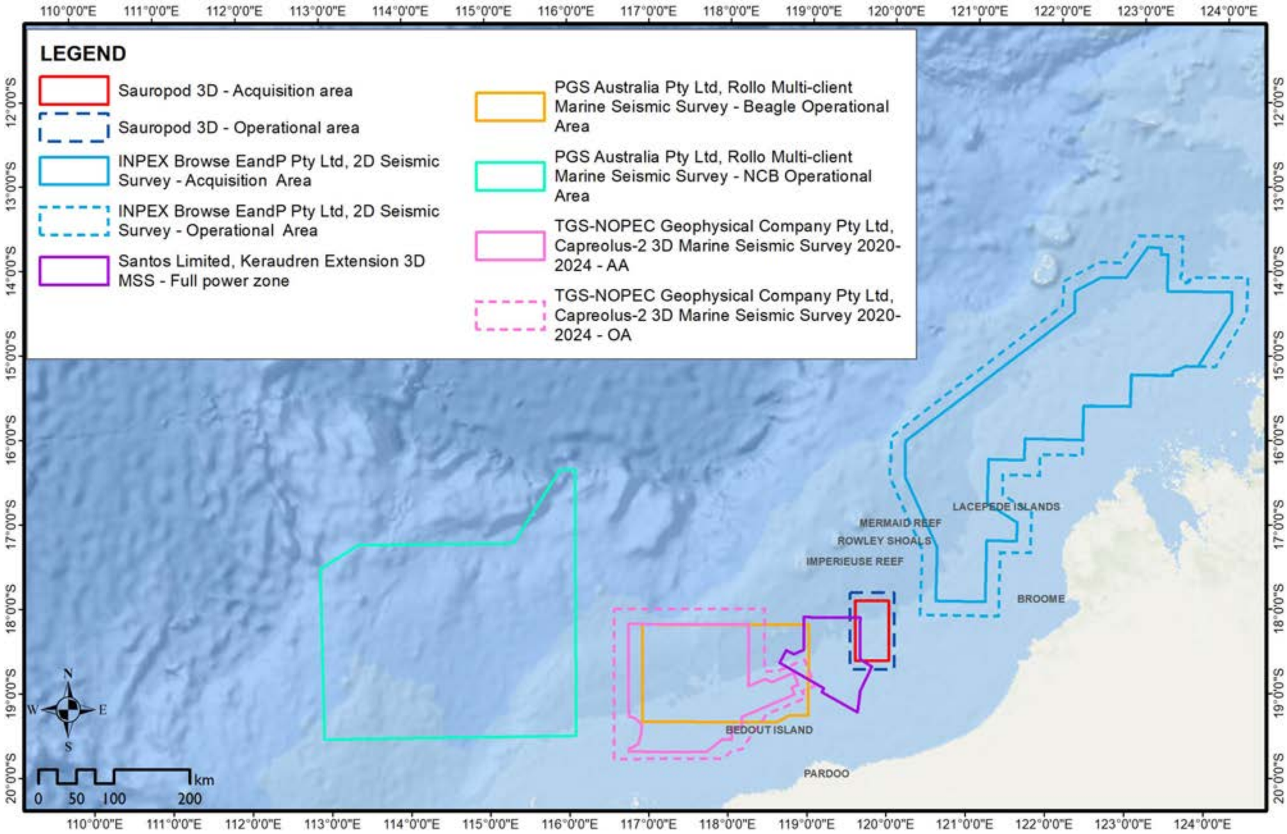


Figure 7-11 - Other potential seismic surveys occurring in 2022 in the vicinity of the Sauropod 3D MSS

It is important to note that, while some of these seismic surveys may go ahead in 2022 and some have the potential to occur at the same time as the Sauropod 3D MSS, for commercial reasons, it is unlikely that all of the proposed seismic surveys will actually proceed in 2022 and it is not credible for all the surveys to occur concurrently or in short succession. It is also unlikely that the entire stated maximum survey areas will be acquired. The large area multi-client surveys in particular are only likely to occur if underwritten by oil and gas operators, and only a proportion of the proposed areas may be acquired. Some of the seismic surveys may not proceed at all.

CGG has undertaken consultation with the relevant titleholders and seismic companies for these seismic surveys, to determine a maximum credible acquisition scenario for 2022. Due to the fluctuating nature of the world market and global uncertainty due to COVID-19, no operators have currently responded to confirm acquisition that will occur in 2022. For the purpose of providing a conservative assessment, CGG therefore has conservatively assumed that the full Santos Keraudren Extension 3D MSS (of 8,620 km^2) will be acquired in 2022 as it cannot be confirmed how much of the survey has already been acquired in 2021. Therefore, the maximum credible scenario for 2022 is based on the following surveys:

- CGG Sauropod 3D MSS
- The entire Santos Keraudren Extension 3D MSS (8,620 km^2), noting that some survey has been completed in smaller phases in 2021.

- An indicative 10,000 km^2 phase of the TGS Capreolus-2 3D MSS that may be completed in 2022. This indicative phase area has been selected as it includes the maximum single-phase area proposed in the EP as well as the Santos 'Archer' survey prospect, which is also noted by Santos in its Keraudren Extension 3D MSS EP (Santos 2020) as having the potential to go ahead. The indicative phase is also selected to maximise the potential spatial overlap with the PFTIMF and spawning areas of key indicator fish species.

It is noted that the PGS Rollo MC MSS covers a similar area to the TGS Capreolus-2 3D MSS and has an accepted EP in place. However, only one of these two multi-client surveys will take place due to underwriting by titleholders. It is important to note that petroleum titleholders will only contract one multi-client geophysical company to collect seismic data over their permit areas. Given limitations imposed in the EP on the maximum spatial overlap with commercial fisheries, the TGS survey phase has been selected as the maximum potential acquisition scenario over this area.

The Santos Keraudren Extension 3D MSS will not take place at the same time as the indicative TGS Capreolus-2 3D MSS phase that includes the Santos 'Archer' survey prospect. Therefore, it is considered credible that the Sauropod 3D MSS could occur concurrently with either the Santos Keraudren Extension 3D MSS or the TGS Capreolus-2 3D MSS, but not at the same time. The two Santos and TGS surveys could occur one after the other in 2022.

CGG considers it highly unlikely that more than three seismic surveys will take place across the Pilbara fisheries in 2022, particularly given the oil and gas and economic situation following the COVID-19 pandemic and oil price, as well as the number of seismic survey vessels that might normally be available in a region.

Note that the following assessment does not assess cumulative impacts from seismic surveys in the region that occur after the Sauropod 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. There are other proposed seismic EPs that may temporally and spatially overlap with the Sauropod EP. If and when those proposed EP are submitted to NOPSEMA CGG will assess the cumulative impact of that survey to the Sauropod survey through either the EP development process or the MoC process as part of the ongoing environmental management of the impacts and risks of the activity (Section 9.2).

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 coordinated. However, in most instances, pulses will be uncoordinated 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 uncoordinated 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).

CGG 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 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 Sauropod 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 case 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 Sauropod 3D MSS (Quijano and McPherson 2020) demonstrates that sound levels will be below 145 dB re 1µPa at 20 km from the source (halfway between two seismic sources at their minimum separation distance). 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 148 dB re 1µPa, which is below the defined behavioural response thresholds for marine fauna (e.g. 160 dB re 1µPa 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.

7.2.2.2.1 Marine Fauna

No significant cumulative impacts to marine fauna are expected, given the minimum separation distance of 40 km between the Sauropod 3D MSS seismic source and other operating seismic sources. Any behavioural avoidance or deviations from course are expected to be small relative to the long distances over which transient marine fauna such as cetaceans, turtles and whale sharks may normally travel.

Short-term behavioural impacts are expected to occur up to approximately 8 km from the operating seismic source for the most sensitive species of cetacean (depending upon location and water depth) and at lesser distances for other marine fauna (see Section 7.1.6.1). As the Sauropod 3D MSS avoids the Humpback whale migration period, avoids most of the Pygmy blue whale migration period (with the exception of some animals that may potentially arrive as early as April), and is located 72 km from the Pygmy blue whale migration BIA, no cumulative impacts from the Sauropod 3D MSS or concurrent surveys are expected to these species. Other species are expected to be transient as no significant habitat areas have been identified in the vicinity of the surveys. Therefore, no significant impacts to cetaceans are expected.

The Sauropod 3D MSS also avoids significant internesting and foraging habitats for marine turtles and so no cumulative impacts to these species are expected to result from the Sauropod 3D MSS and other concurrent surveys. Other transient marine fauna, such as whale sharks, may also experience localised disturbances when passing each of the seismic surveys. However, as the vessels will maintain the minimum separation of 40 km, separate isolated incidents of disturbance are not expected to result in significant impacts.

7.2.2.2.2 Fish and Elasmobranchs

Short-term behavioural impacts in fish are expected to occur at distances of tens or hundreds of metres from the Sauropod 3D MSS acquisition lines, returning to normal within minutes or hours. Potential changes in distribution of fishes are also expected to return to normal within hours or days (see Section 7.1.6.3).

No significant discernible cumulative impacts to fish are expected, given the minimum separation distance of 40 km between the Sauropod 3D MSS seismic source and other operating seismic sources. Individual groups of fishes in each survey area may be subject to occasional disturbances. Therefore, no cumulative overlap of strong behavioural responses is expected. Some mild changes in fish abundance and distribution could occur as a result of exposure from multiple operating seismic surveys, but such changes are expected to return to normal within a few hours or days.

7.2.2.2.3 Fish Spawning

A combined spatial-temporal analysis has been conducted to determine the maximum spatial and temporal overlap of concurrent seismic surveys with the spawning times and ranges of key commercial fish species (refer to Table 7-20). The method and assumptions applied are the same as the analyses in Section 7.1.6.6 and Section 7.2.2.1 above.

The Santos Keraudren Extension 3D MSS and TGS Capreolus-2 3D MSS (indicative phase area) are not expected to be acquired concurrently. If it is assumed that one of these surveys commences in early 2022, by the time one survey is completed, the next survey would not commence until approximately May or June. This marks the end of the spawning periods for all key indicator species (which spawn until March to June). Therefore, given that the spatial-temporal analysis considers the overlap with a single spawning season, the total spatial-temporal overlap in Table 7-20 considers the potential cumulative total of Sauropod and one of the other surveys being acquired, but not both.

While not shown in Table 7-19, it is likely that the actual survey areas acquired will be less than stated as survey areas are optimised following detailed operational planning. It is also possible that both the Santos Keraudren Extension 3D MSS and TGS Capreolus-2 3D MSS (indicative phase area) may significantly over-represent the spatial temporal overlap, as the maximum possible area of acquisition for both of these surveys have been used. The actual surveys may cover significantly smaller areas. For example, to reduce the cumulative effects to commercial fisheries, Santos have committed in their EP to reduce the area of acquisition of the Santos Keraudren Extension 3D MSS by 1,859 km^2 should the Archer prospect (within the TGS Capreolus-2 3D MSS survey phase) be acquired in the same year, and a further 930 km^2 should the Sauropod 3D MSS be acquired in the same year (Santos 2020). Therefore, based on the maximum credible scenario considered by CGG in this assessment, the spatial overlap from the Santos Keraudren Extension 3D MSS would reduce by nearly 2,800 km^2, and the corresponding survey duration would also reduce. While it is not possible to predict what reduction to the spatial temporal overlap this might have (the Santos survey phase area is not yet defined and so the area relative to the various different spawning areas is not known), a reduction of this scale could reduce the overlap of the Santos Keraudren Extension 3D MSS with the spawning areas by as much as half. The TGS Capreolus-2 3D MSS is also likely to be significantly smaller than the full 10,000 km^2 considered in this assessment, should the Santos Archer area (approximately 1,659 km^2; Santos 2020) be the main underwritten area of the survey. It is therefore recognised that the surveys may be acquired in smaller phases, but should this occur, both the area and duration of the surveys (and the spatial-temporal overlap) would reduce proportionately.

Based on the maximum areas and durations of the seismic surveys, the cumulative spatial-temporal overlap for key indicator species ranges from 0.7% (Ruby snapper) to 9.41% (Goldband snapper), depending on exactly which survey areas may be acquired (Table 7-20).

However, as previously discussed in Section 7.1.6.6, the analysis is simply an indication of the total area and duration that may be ensonified and where potential spawning fish behaviours may be influenced over the course of the entire surveys. Therefore, the percent spatial-temporal overlap significantly over-represents the actual spatial footprint of disturbance, noting that not all of the acquisition areas will be ensonified for the full duration of each survey. A more representative, but still conservative scenario may be considered based on a similar scenario as that described in Section 7.1.6.6, which involves a single week of racetrack acquisition in each survey area with a highly conservative 5 km buffer applied to broadly represent where some fishes may have some awareness of sound pressure changes (noting, however, that the demersal species are more likely to experience significant behavioural effects within tens or hundreds of metres from the seismic source, while behavioural effects at distances of kilometres are unlikely). Over the duration of each survey, the seismic vessel and same racetrack area would gradually move across the survey areas; following a few days or 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. Based on this approach, the estimated spatial extent of disturbance and spatial-temporal overlap from each survey would be:

- Sauropod 3D MSS: Approximately 1,450 km^2, resulting in a proportionate spatial-temporal overlap of between approximately 0.12% (ruby snapper) and 0.52% (goldband snapper)
- Santos Keraudren Extension 3D MSS: Approximately 1,932 km^2, resulting in a proportionate spatial-temporal overlap of between approximately 0.23% (ruby snapper) and 1.54% (goldband snapper)
- TGS Capreolus-2 3D MSS: Approximately 5,160 km^2, resulting in a proportionate spatial-temporal overlap of between approximately 1.6% (ruby snapper) and 5% (goldband snapper).

Depending on which combination of the above surveys are acquired during the spawning seasons, the total cumulative spatial-temporal overlap would range from between 0.35% and 1.72% (ruby snapper) to between 2.1% and 5.52% (goldband snapper). While this is still only an indicative scenario, it is more likely to be representative of the potential area of disturbance than considering entire acquisition areas, but still applies a reasonable level of conservatism in the applied disturbance buffer.

It is, therefore, acknowledged that in addition to natural factors and fishing catches, the 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 7.1.6.6).

It is important to note that the Sauropod 3D MSS contributes a relatively small proportion of the overlap with each species, while the larger Santos Keraudren Extension 3D MSS and TGS Capreolus-2 3D MSS (indicative phase area) result in the greatest contribution to the spatial-temporal overlap with the spawning areas and periods. In addition, as indicated by Gaughan *et al.* (2018), catch-per-unit-effort (CPUE) data on the fish stocks indicates that these fish species are least abundant in the Sauropod 3D MSS Acquisition Area and, therefore, the Sauropod 3D MSS has limited potential for disturbance to these species as well as an even more limited contribution to any cumulative effects to the fish stocks (refer to Section 7.1.6.6).

Table 7-20 – Cumulative Spatial-Temporal Overlap with Key Indicator Species Spawning Periods and Ranges

Survey Name	Red Emperor	Rankin Cod	Goldband Snapper	Bluespotted Emperor	Ruby Snapper
Sauropod 3D MSS	0.70%	0.44%	1.26%	0.28%	0.27%
Santos Keraudren Extension 3D MSS	4.20%	3.36%	6.17%	1.70%	0.43%
TGS Capreolus-2 3D MSS (indicative phase area)	4.42%	5.55%	8.15%	3.95%	2.79%
Total Overlap (Sauropod + Keraudren Extension)	4.90%	3.80%	7.43%	1.98%	0.70%
Total Overlap (Sauropod + Capreolus-2)	5.12%	5.99%	9.41%	4.23%	3.07%

* Spawning areas have been estimated based on each species' depth range and the Pilbara fishery management area. It is important to note that genetic connectivity and the biological stocks have been confirmed across significantly larger areas, however, the Pilbara fishery

management area is 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.

Temporal overlap is based on the maximum number of days that the survey may coincide with the days that each species is known to spawn.

Potential cumulative 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 (10%) 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 Pilbara 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. 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.
- 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.

Therefore, the cumulative effects from the credible concurrent survey scenario are not expected to result in a serious or irreversible impact to the recruitment or sustainability of key indicator commercial fish stocks.

7.2.2.2.4 Plankton, Fish Eggs and Larvae

Based on the maximum worst case mortality exposure suggested by McCauley *et al.* (2017) and modelling completed by CSIRO (Richardson *et al.* 2017), impacts to zooplankton are only expected to be significant within a short range (e.g. 15 km) of seismic survey areas. Beyond 22 days of acquisition, Richardson *et al.* (2017) found that no further relative increase in zooplankton mortality occurs, due to recruitment of zooplankton via currents from adjacent areas, and conditions return to normal within a few days of a survey ceasing. At the regional scale, these impacts are not expected to be significant (Richardson *et al.* 2017). Further, natural mortality rates can be as high as ~60%, and not entirely as a result of predation (see Section 7.1.6.5), therefore, limited impacts are expected relative to the natural variation in zooplankton concentrations and mortality rates.

No significant discernible cumulative impacts to marine fauna are expected, given the separation distances between the Sauropod 3D MSS seismic source and other operating seismic sources. Therefore, the cumulative impacts to plankton are expected to be negligible.

7.2.2.2.5 Benthic Invertebrates

The maximum worst case impacts reported for invertebrates include sub-lethal impacts such as statocyst impairment, temporary reduced immune response function, temporary impaired reflexes, and potentially some chronic effects that lead to mortality of a very small number of sessile benthic invertebrates over and above natural mortality rates. For the Sauropod 3D MSS, such impacts are expected to occur at close range to the seismic source (i.e. 260 m) (see Section 7.1.6.4). In the context of natural mortality, recruitment and recovery rates, the impacts to overall benthic communities are expected to be negligible (see Section 7.1.6.4).

There is the potential for cumulative impacts to occur to benthic invertebrate communities in areas where the Keraudren Extension 3D MSS overlaps with the Sauropod 3D MSS. Repeated exposures of some sessile invertebrates, such as bivalves, have been observed to result in additional chronic mortality in the weeks and months following exposure compared with invertebrates exposed to just one pass of a seismic source (i.e. an increase of approximately 2–5%) (Day *et al.* 2016b). However, such effects may still be within the range of naturally occurring mortality rates documented in the wild (Day *et al.* 2017). The repeat exposures will therefore affect only a small proportion of benthic invertebrate organisms, and the continuous natural cycle of death and recruitment of invertebrates from adjacent sediments will occur in parallel over these same timescales. Therefore, the effects of repeat seismic exposure may still not be detectable from natural fluctuations in benthic community structure and full recovery of these communities is expected following completion of the surveys.

7.2.2.2.6 Commercial Fisheries

An analysis has been conducted to determine the area of overlap between the potential seismic surveys in 2022 and commercial fisheries. As per the analysis undertaken in Section 7.2.2.1 above, this assessment has focussed on the spatial overlap of the proposed surveys with the PFTIMF, being representative of the fishery with the greatest catch and effort levels and therefore representative of the greatest potential impacts.

The Santos Keraudren Extension 3D MSS and TGS Capreolus-2 3D MSS (indicative phase area) are not expected to be acquired concurrently. Therefore the maximum spatial overlap that may occur with this fishery at any one time is based on either:

- The Sauropod 3D MSS (4,867 km^2 overlap) combined with the indicative 10,000 km^2 phase of the TGS Capreolus-2 3D MSS (the largest possible area in any given year); or
- The Sauropod 3D MSS (4,867 km^2 overlap) combined with the Santos Keraudren Extension 3D MSS (maximum of 4,134 km^2 overlap).

The percent spatial overlap of these surveys with the PFTIMF is presented in Table 7-21. Depending on the combination and order of surveys that take place, up to approximately 48% of the PFTIMF fished area may be subject to seismic surveys at some point in 2022.

For example, the Sauropod 3D MSS and the Santos Keraudren Extension 3D MSS may occur concurrently, followed by the TGS Capreolus-2 3D MSS; the Sauropod 3D MSS (15.94% overlap) would be completed within 60 days, while the Santos Keraudren Extension 3D MSS (15.95% overlap) may continue for a couple of months longer, before the TGS Capreolus-2 3D MSS indicative phase (21.54% overlap) commences and may continue for much of the remainder of the year. However, Santos have committed in their EP to reduce the area of acquisition of the Santos Keraudren Extension 3D MSS overlapping the PFTIMF by 1,859 km^2 should the Archer prospect (within the TGS Capreolus-2 3D MSS survey phase) be acquired in the same year, and a further 930 km^2 should the Sauropod 3D MSS be acquired in the same year (Santos 2020). Therefore, based on the maximum credible scenario considered by CGG in this assessment, the spatial overlap from the Santos Keraudren Extension 3D MSS would reduce by nearly 2,800 km^2, and the corresponding spatial overlap with the PFTIMF would reduce to 10.76%. The corresponding survey duration would also reduce proportionately. The TGS Capreolus-2 3D MSS may also be significantly smaller than the full 10,000 km^2 considered in this assessment, should the Santos Archer area (approximately 1,659 km^2; Santos 2020) be the main underwritten area of the survey. However, this assessment assumes that the full 10,000 km^2 may be acquired.

Table 7-21 – Spatial Overlap of Potential 2022 Seismic Surveys with the PFTIMF

Survey Name	Pilbara Fish Trawl Interim Managed Fishery
CGG Sauropod 3D MSS	15.94%
Santos Keraudren Extension 3D MSS	15.95% [10.76%]
TGS Capreolus-2 3D MSS (indicative phase)	21.54%
Total Overlap (Sauropod + Keraudren Extension)	31.89%
Total Overlap (Sauropod + Capreolus-2)	37.48%
Maximum Total 2021 Overlap (Sauropod + Keraudren Extension [reduced] + Capreolus-2)	48.24%

FishCube data indicates that alternative and viable fishing grounds may be available outside of the defined survey areas, however, it is acknowledged that multiple surveys in a region may result in disruption to fishing activities in multiple locations and an incremental reduction in access to some fishing grounds. The area of fishing effort that is concentrated in the central part of the PFTIMF, where the surveys are located, is most likely to be affected while the western parts of the PFTIMF, where fishing effort is also heavily concentrated, is not expected to be disrupted.

As previously discussed, accounting for the entire acquisition areas of each survey is a highly conservative approach and simply provides an indication of the total area and duration that may be surveyed in the year and where there is potential for interactions with fishers to occur. This is conservative because the survey vessel will only be operating in part of each survey area at any one time. Therefore, the percent spatial overlap in Table 7-21 significantly over-represents the actual spatial footprint of potential disturbance to commercial fishers. For example, a more representative scenario for understanding the potential area where disruption to fishers may occur would be to consider a single week of seismic acquisition (based on the proposed racetrack formation and a 3 nm [5.5 km] buffer applied around the seismic vessel towed array to represent the avoidance distance typically requested of other vessels). Based on this approach, the estimated spatial extent of disturbance and spatial-temporal overlap from each survey would be:

- Sauropod 3D MSS: Approximately 2,176 km^2, with a spatial overlap with the PFTIMF fished area of approximately 2.5%
- Santos Keraudren Extension 3D MSS: Approximately 2,001 km^2, with a spatial overlap with the PFTIMF fished area of approximately 7.6%
- TGS Capreolus-2 3D MSS: Approximately 5,400 km^2, with a spatial overlap with the PFTIMF fished area of approximately 14.2%.

Based on this more representative scenario, approximately 10-14% of the PFTIMF fished area may be subject to interactions between seismic vessels and fishing vessels during 2022.

It is important to note that the Sauropod 3D MSS is expected to contribute only a very small proportion of the overlap with the PFTIMF fished area. The Operational Area overlaps with 6.97% of the fished area and the representative scenario above indicates that approximately 2.5% may be subject to disruption to fishers at any one time. However, as is evident from the FishCube data analysis in Section 4.4.4 and Figure 4-21, the fishing effort in this area has been limited to less than 50 days effort during the entire five-year (1,826 day) period from 2016 to 2020. CPUE data (Section 7.1.6.6) also indicates that more viable fishing grounds are available and accessible elsewhere. Interactions and the potential for disturbances to commercial fishers in the Sauropod 3D MSS may be infrequent or may not occur at all. Therefore, the potential for impacts to result from the Sauropod 3D MSS is substantially less than could result from the other seismic surveys in the region.

Despite potential interactions with fishers resulting from two concurrent seismic surveys in the PFTIMF (and potentially from a third separate survey within the same fishery at a later time in the year), no long-term impacts on the overall annual performance of the fisheries (in terms of distribution of effort or catch levels) or the sustainability of the fishery are expected, for the following reasons:

- A maximum of 10% to 14% of the PFTIMF fished area may be subject to seismic survey activities, and therefore potential disruption to fishers, at any one time. This is based on the maximum credible survey scenario and so the area may be less. Although some of the areas overlapped by some of the seismic surveys include areas of relatively high fishing effort, there are also other areas of comparable fishing effort (i.e. alternative viable fishing grounds) adjacent to these areas that will remain accessible to fishers.
- The total spatial overlap of 2021 survey acquisition areas with the PFTIMF is approximately 46%, which is broadly comparable to the 50% overlap that occurred in 2015 (acknowledging that one of the surveys that occurred in 2015 was a 2D seismic survey and not directly comparable in terms of vessel occupancy). As described in Section 7.2.2.1, no

long-term impacts on the overall annual performance of the fisheries (in terms of distribution of effort or catch levels) or the sustainability of the fishery was evident from 2015 or other past surveys, total catch remained stable, and the distribution of fishing effort remained broadly the same.

CGG recognises that clear and regular communication with fisheries stakeholders is required in order to provide timely information on the location and timing of different surveys in order to facilitate better planning and resource sharing. CGG will notify stakeholders prior to the commencement of the survey and will provide regular updates to fishery licence holders during survey operations.

7.2.2.2.7 Summary

Based on the assessment presented above and the implementation of the identified controls (Section 7.2.4, the worst-case cumulative impacts that may result from concurrent seismic surveys is assessed as Medium.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability are provided below.

7.2.3 Decision Context

The decision context for underwater sound emissions from the seismic source has been assessed as ‘Type B’ due to stakeholder concerns raised in relation to potential impacts to commercial fisheries, including fish spawning. As described in Section 6.7.1, further analysis is recommended in addition to using the tools for a Decision Type A, including assessing the results of probabilistic analyses such as modelling, quantitative risk assessment and/or cost benefit analysis to support the selection of control measures.

7.2.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
No relevant legislation has been identified.	N/A	N/A	N/A
Good Industry Practice			
Issue of marine navigation warnings and Notice to Mariners of survey presence and towed array	Yes	AHO will be contacted four weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of interactions with other marine users. Good industry practice, environmental benefit outweighs additional cost.	2.1
Pre-survey notification to AMSA JRCC, issue of AUSCOAST warnings	Yes	The AMSA JRCC will be contacted 24-48 hrs before operations commence for issuing of radio-navigation warnings. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of interactions with other marine users. Good industry practice, environmental benefit outweighs additional cost.	2.2
Notification will be provided to fisheries stakeholders, prior to survey commencement and following survey completion.	Yes	Notification will be provided to fisheries stakeholders four weeks prior to commencement of the survey and two weeks following completion of the survey. Implementation of the control will reduce the likelihood of interactions with marine users. Good industry practice, environmental benefit outweighs additional cost.	2.3
CGG will engage with proponents identified as having potential concurrent seismic activities prior to commencing the Sauropod survey and develop a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area.	Yes	Engagement with titleholders for potential concurrent MSS activities prior to acquisition commencing, and development of a concurrent operations plan, which will include the following aspects: • Communications protocols • SIMOPS and work programming • Hazard management • Emergency response. Good industry practice, environmental benefit outweighs additional cost.	1.5
Alternatives/Substitutes Considered			
No practicable alternative or substitutes to the above controls have been identified.	N/A	N/A	N/A
Additional Controls Considered			
A minimum separation distance of 40 km shall be maintained between the Sauropod 3D MSS seismic sources and other operating seismic sources.	Yes	This measure will reduce the risk of cumulative impacts occurring and also preserves seismic data quality.	2.4
Survey acquisition timed to avoid or limit temporal overlap with the spawning periods for key indicator species for commercial fisheries	No	The maximum spatial-temporal overlap of the Sauropod 3D MSS with the spawning areas and periods of commercial fish species is approximately 1.26%. Depending on which combination of seismic surveys are acquired during the spawning seasons, the total cumulative spatial-temporal overlap may range from between 0.35% and 5.52% (based on representative but conservative exposure scenarios). This is likely to be negligible in the context of normal variability in spawning biomass and recruitment. Further limiting the temporal overlap with the spawning periods has been considered. The proposed schedule and temporal window for the Sauropod 3D MSS (January to May) was determined taking into account the: • Timing of key environmental and socio-economic receptors • Hearing ability and sensitivity of those receptors to sound from the seismic survey • Proximity of sensitive habitat areas to seismic survey areas • Species distribution and range • Level of overlap (in space and time) by the survey with important habitats and life stages of sensitive species • Species vulnerability / conservation status • Potential for impacts to species at both an individual level and at a population level The optimum window of opportunity was determined to be from January to May (inclusive). The proposed survey timing was selected primarily to avoid the Humpback whale migration through the region (June to October), as well as reduce exposure to Pygmy blue whales during their migrations to the north of the Operational Area (April – August and October to December). Both of these species are low-frequency cetaceans and sensitive to seismic sound over several kilometres. The defined survey period, therefore, limits the potential for impacts to these protected	N/A

Control Measure	Control Adopted	Justification	Performance Standard Ref.
		species, including preventing injury/hearing impairment (PTS/TTS) or significant behavioural effects during their migrations. It is noted that the Pygmy blue whale migration BIA is located sufficiently far from the Operational Area for impacts to be avoided but the timing had also originally taken into account Pygmy blue whale distribution outside of the main migration BIA. Fish spawning periods were also considered in detail, noting the importance of spawning and recruitment of fish stocks, but also noting fishes' sensitivity to seismic sound is significantly less than that of cetaceans. Significant disturbance to groups of spawning fishes may occur for short periods when the seismic source is passing within hundreds of metres of their location. The spawning periods of the many different key indicator fish species for the commercial fisheries in the region extend throughout the majority of the year but can vary significantly between species. It is noted that most key indicator species spawn between October and March, April or May. In order to avoid or reduce the survey's overlap with this period, the survey window would extend into both the Humpback whale and more of the Pygmy blue whale migration periods. As noted in the above risk assessment, occasional localised disturbances of groups of spawning fishes may occur, but this is not expected to have a significant impact on the stocks, due to their high fecundity, protracted spawning periods, biological connectivity through recruitment from across the region, as well as large natural variability in the spawning biomass and recruitment levels. Avoidance of fish spawning periods would provide limited additional environmental benefit at a disproportionate cost (in terms of potential impacts to more sensitive marine fauna and costs associated with additional measures that would likely be required for whales such as additional shut-downs, adaptive management, etc.). Therefore, this option is not considered practicable. Further constraining the survey window and limiting the overlap of the survey with fish spawning periods may mean that the proposed seismic survey could not be completed, potentially equivalent to a cost in the order of millions of dollars of lost seismic survey effort time and data. Given the predicted risk to fish spawning and fish stocks, the costs are disproportionate to the limited environmental benefit that may be gained.	
Reduce temporal overlap with commercial fishing operations	No	The Sauropod 3D MSS primarily overlaps with the Pilbara Demersal Scalefish Fisheries, specifically the fished areas of the PFTIMF and the PTMF. Other seismic surveys considered in the cumulative impact assessment also overlap with the Pilbara Demersal Scalefish Fisheries. The Sauropod 3D MSS does not overlap with the fished area of the PLF or the Mackerel Managed Fishery. Overlap between the Sauropod 3D MSS Operational Area and the NDSMF is negligible (as explained in the above risk assessment). The PFTIMF, PTMF and NDSMF operate throughout the year. Analysis of FishCube data for the fisheries monthly catch and effort does not provide sufficient information to indicate any clear seasonal trends. Therefore, it is not practicable to alter the timing of the survey in a way that would reduce the temporal overlap with these fisheries.	N/A
Reduce survey area to decrease cumulative area of overlap with commercial fisheries	No	Not justified. The Sauropod 3D MSS has minimal spatial overlap with any commercial fishing activities. The greatest overlap is with the PFTIMF, where there is approximately 4% spatial overlap. In addition, the level of fishing effort reported in this area is low (less than 50 days over a five-year period) and historical CPUE data also indicates low fish abundance in the Operational Area. Reducing the size of the Acquisition Area would mean that CGG would not be able to obtain data for all hydrocarbon prospects being targeted. Recognising the need to minimise disturbance to fisheries as much as practicable, CGG has considered whether it might be feasible to reduce the Acquisition Area by approximately half (the minimum acquisition area that may be considered, if the alternative meant the survey could not be approved and the inability to meet work commitments under the permit). However, the primary target that would still be surveyed is in the western half of the Acquisition Area. This includes the south-west corner of the Acquisition Area where PFTIMF fishing effort has mainly been recorded in past years. The area of the PFTIMF that would be avoided has recorded less than 25 days of fishing activity or has been trawled by less than 3 vessels during the entire five-year (1,826 day) period from 2014 to 2018 (refer to Section 4.4.4.1 and Figure 4.20). Therefore, reducing overlap with this small, infrequently fished area would provide limited benefit to fisheries but would result in millions of dollars of lost work programme to CGG. The south-west corner itself also experiences low levels of fishing effort (less than 50 days fishing effort during the entire five-year (1,826 day) period from 2014 to 2018 and interactions with trawl vessels in this area are already expected to be infrequent if they occur at all. The costs of this option are grossly disproportionate to the limited benefit gained. Therefore, while acknowledging the importance of managing cumulative impacts to commercial fisheries, CGG cannot practicably do anything further to manage the risk posed with other titleholders' surveys.	N/A
Implementation of a management of change process that includes a specific trigger to review new evidence in relation to impacts and risks to commercial fishing from the survey, and the review of the need to enhance existing controls	Yes	CGG is cognisant of the concerns raised by commercial MMF fishers over the potential impacts of noise emissions from the survey on mackerel catches. These concerns are based on declines in catches during the past few years. However it is not reasonable to assume that this data reflects a future impact from the proposed seismic survey; firstly because there is no overlap of MMF historical fishing effort within the Acquisition Area and the ensonified area (as supported by acoustic modelling described in Section 7.1 of the EP), and also because the survey period (January to May) avoids the majority of the peak mackerel fishing season in the Pilbara (May-August). In addition, it is noted that recent declines in mackerel catches and catch rates in the Kimberley and Pilbara fishery management areas, as reported by DPIRD (2020), may 'indicate a decline in the spawning stock [of mackerel] after the influence of the 2016 northern heat pulse [marine heatwave] during the spawning period'. Nevertheless, whilst the above evidence supports the assessment that potential impacts from the seismic survey on mackerel fishers will be Negligible, it is appreciated that MMF fishers have ongoing concerns over impacts due to the survey. As such CGG will implement an environmental management process for the activity (Section 9.1) that includes a specific trigger to review new evidence in relation to impacts and risks to commercial fishing from the survey. If a change in impacts and risks to commercial fishing is confirmed a practical, evidence-based process for reasonable monetary adjustment will be provided to commercial fishers for loss of catch, displacement, or fishing gear loss or damage in the form of a Fishery Impacts Mitigation Plan. Good practice principles that will be incorporated into the Fishery Impacts Mitigation Plan include: • Mitigation will be made available during the acquisition phase of the seismic survey and up to two months after the conclusion of the acquisition of the seismic survey. • Mitigation will be available to a commercial fisher who fishes as a normal part of their commercial fishing activity within the Adjustment Area (an area extending 10 km around the perimeter of the acquired survey area [where guns are fired at full power for the purpose of data acquisition], noting this may be smaller than the defined Acquisition Area of the survey as defined in the EP). A commercial fisher must be able to demonstrate that they would have received the revenue from the landed catch that is the subject of a claim and adjustment is dependent on a	1.10

Control Measure	Control Adopted	Justification	Performance Standard Ref.
		commercial fisher continuing to carry out their fishing activities to the best of their ability and to mitigate and limit financial loss despite the occurrence of a seismic survey, i.e. adjustment would not be available where a fisher chooses to move away from a survey and makes no attempt to fish within the survey Adjustment Area. • The mitigation process will apply to historical fishing activity over established fishing grounds, and not to speculative fishing activity • Mitigation claims may be lodged up to 4 months after the conclusion of the acquisition of the seismic survey If a commercial fisher is unable to fish in their historical fishing area within the Adjustment Area during the seismic survey and incurs costs over and above the normal running costs for a fishing trip while relocating to another historical fishing area, then costs associated with increased distance/transit time, fuel and crewing will be considered for monetary adjustment.	
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable improvements have been identified.	N/A	N/A	N/A
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the risk of cumulative impacts. As the risk has been classified as Low and no reasonable additional or alternative controls were identified that would further reduce the risk, without jeopardising the objectives of the survey, the risk is considered to be ALARP.			

Receptor	Risk Ranking	Consequence	Likelihood	Risk Ranking
Marine Fauna	Residual Risk	Moderate (2)	Unlikely (B)	Medium
Fishes and elasmobranchs	Residual Risk	Minor (1)	Possible (C)	Medium
Benthic invertebrates	Residual Risk	Minor (1)	Unlikely (B)	Low
Zooplankton	Residual Risk	Minor (1)	Possible (C)	Medium
Fish spawning	Residual Risk	Moderate (2)	Unlikely (B)	Medium
Commercial fisheries	Residual Risk	Moderate (2)	Unlikely (B)	Medium

7.2.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing cumulative impacts is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.7) • Notification and Reporting (Section 9.12).
External	Values and Sensitivities of the Natural Environment	EPBC Policy Statement 1.1. – Significant guidelines The residual risk to cetaceans has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. Conservation Advice, Recovery Plans, and Other Guidelines N/A: No advice or guidelines have been identified that specifically address cumulative impacts from multiple seismic surveys. Conservation values and objectives of the North-west Marine Parks Management Plan No impacts are predicted to occur to the natural, cultural and socio-economic values of the Argo-Rowley Terrace Marine Park and Mermaid Marine Park.
	Relevant Persons Expectations	During stakeholder consultation for the Sauropod 3D MSS, WAFIC specifically expressed an interest in the cumulative impacts of multiple seismic surveys and requested that cumulative impact assessment is addressed in the EP. The above assessment has considered the cumulative impacts.
Legislation and Other	Legal Requirements	The controls adopted comply with the *Navigation Act 2012* and *Offshore Petroleum Greenhouse Gas Storage Act 2006*.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practice is demonstrated by the commitment to maintain a 40 km separation distance from other operating seismic sources.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with cumulative impacts from the Sauropod 3D MSS and other concurrent seismic surveys.

7.2.5.1 Defined acceptable levels of impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
Marine Fauna or Ecological Communities Listed as Threatened or Migratory under the EPBC Act (Matters of NES)	EPBC Act Part 3 (18A and 20A); EPBC Act Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013).	Seismic survey activities are undertaken in alignment with: • the EPBC Act Part 3 (18A and 20A) and Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013), whereby activities do not have a significant impact on a listed threatened or migratory species population or a listed threatened ecological community • do not result in the mortality or physical injury of an individual of an EPBC listed (marine fauna) species.	The predicted level of impact from underwater noise emissions from the seismic source, as assessed above, does not exceed the defined acceptable level of impact to marine fauna given the controls adopted will: • Prevent mortality or physical injury to EPBC listed marine fauna species • Prevent a significant impact on a listed threatened or migratory species population or a listed threatened ecological community. Other potential concurrent surveys in the region also propose similar management measures and propose measures to limit or avoid impacts with sensitive areas. The potential for disturbances from two seismic surveys and their separate sound fields are acknowledged, however, no significant impacts, mortality or injury are expected.
	Conservation Management Plan for the Blue Whale	Seismic survey activities are undertaken in a manner consistent with the requirements of the Conservation Management Plan for the Blue Whale, specifically: • 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.	No injury/hearing impairment (PTS/TTS) or significant behavioural impacts are expected to occur to Pygmy blue whales within the migration BIA, which is located 72 km to the north of the Operational Area. The proposed timing of the Sauropod 3D MSS (between January and April) has also been selected to limit overlap with the Pygmy blue whale migration periods (April to August and October to December) and therefore reduce the risk of impacts to migrating Pygmy blue whales outside of the migration BIA. Therefore, no significant cumulative impacts from concurrent survey activities are expected.
	Conservation Advice for *Megaptera novaeangliae* (Humpback whale).	Seismic survey activities are undertaken in a manner consistent with the requirements of Conservation Advice for *Megaptera novaeangliae* (Humpback whale), specifically: • 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 consistently with 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.	Consistent with the Conservation advice for Humpback whales, acoustic modelling has been undertaken to assess the potential single pulse and cumulative sound exposure impacts on Humpback whales. The seismic survey will also be undertaken consistent with Part A of EPBC Act Policy Statement 2.1, although the survey will not take place near a calving, resting or foraging area. The proposed timing of the Sauropod 3D MSS (between January and April) has been selected to avoid the Humpback whale migration through the region, therefore, no impacts to Humpback whales are expected. Therefore, no significant cumulative impacts from concurrent survey activities are expected.
	Recovery Plan for Marine Turtles in Australia 2017-2027.	Seismic survey activities are undertaken in a manner consistent with the requirements of the Recovery Plan for Marine Turtles in Australia 2017-2027, specifically: • Seismic surveys should not occur inside important internesting habitat during the nesting season. • Consistent 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	The Sauropod 3D MSS seismic source will not be operated within any important internesting habitats. The Operational Area is located at least 15 km from the closest BIA or 'Habitat Critical' for marine turtles and no significant impacts to marine turtle populations are expected. Soft-starts (as well as shut-down procedures for turtles, which exceed this requirement) will be implemented during the seismic survey. Other potential concurrent surveys in the region also propose similar management measures and propose measures to limit or avoid impacts with sensitive areas. The potential for disturbances from two seismic surveys and their separate sound fields are acknowledged, however, no significant impacts, mortality or injury are expected.
Marine Fauna or Ecological Communities not listed as threatened or migratory (not matters of NES) under the EPBC Act	Principles of ESD, specifically no serious or irreversible damage.	No serious* or irreversible damage to a population of any marine fauna species or ecological community not listed as threatened or migratory (matters of NES) under the EPBC Act, including: • Marine fauna species not listed under the EPBC Act as threatened or migratory • Benthic invertebrate communities, including those associated with KEFs • Fish communities, including those associated with KEFs • Planktonic communities. * In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, CGG considers	The predicted level of impact from underwater noise emissions from the seismic source, as assessed above, does not exceed the defined acceptable level of impact to non-listed marine fauna given that: <u>Non-listed marine fauna</u> – The controls adopted to reduce risks to marine fauna such as cetaceans and turtles, apply to all species in these groups irrespective of their status under the EPBC Act. No injury or mortality to such marine fauna is expected to occur given the controls proposed consistent with EPBC Policy Statement 2.1 (e.g. marine fauna observers, precaution zones, soft-starts, shut-down procedures). No species is expected to be displaced from an area of significant habitat; no significant areas for non-listed species are identified in the Operational Area and no serious (i.e. population level) or irreversible impacts are predicted to occur. The structure and ecological function of the ancient coastline at 125 m depth contour KEF will not be impacted. <u>Benthic communities</u> – Impacts to benthic communities are expected to be recoverable. While some benthic invertebrate organisms may experience sub-lethal or effects or chronic mortality, benthic communities are expected to recover in the weeks or months following exposure and changes in community structure and composition are not expected to be detectable from natural variability. No serious (i.e. community

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
		a serious impact to be impacts with the potential to result in a threat to population or community viability, consistent with a consequence ranking of 'Significant' or greater.	level) or irreversible impacts are predicted to occur. The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered Fish communities – Consistent with fisheries management principles, key indicator species have been considered as representative of the full suite of fishes that occur in the Operational Area. The effects of the seismic survey on the spawning biomass of the various stocks are expected to comprise occasional localised behavioural disturbances to spawning groups of fish, but the level of impact to the populations (spawning biomass and recruitment) is predicted to negligible, particularly in the context of normal variability in the fish biomass and recruitment levels (250–350%). Injury or mortality to the types of fish found in the Operational Area is highly unlikely. No serious (i.e. population level) or irreversible impacts are predicted to occur. The physical structure, ecosystem functioning and integrity of the ancient coastline at 125 m depth contour KEF are not predicted to be altered. Planktonic communities – Zooplankton may be injured or killed in close proximity to the seismic source, however, 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. No serious (i.e. community level) or irreversible impacts are predicted to occur. The potential for disturbances from two seismic surveys and their separate sound fields are acknowledged, however, no serious or irreversible impacts are expected.
Marine Protected Areas	Conservation objectives and zone rules/requirements of the North-west Marine Parks Management Plan and other marine protected area management plans	Seismic activities are undertaken in a manner consistent with a management plan that is in force for AMPs or State Marine Parks in the region (i.e. Eighty Mile Beach AMP, Argo-Rowley Terrace AMP, Rowley Shoals Marine Park and Mermaid Reef Marine Park).	The predicted level of impact from underwater noise emissions from the seismic source, as assessed above, does not exceed the defined acceptable level of impact to marine protected areas given the activity will be managed in a manner that is consistent with management objectives for relevant AMPs and State Marine Parks.

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
Commercial Fisheries and Commercial Fish Stocks	Commercial fisheries stakeholder objections, claims and concerns regarding: • effects of seismic sound on key indicator commercially targeted finfish and invertebrate stocks, and • effects of seismic sound on fish behaviour and commercial catch levels.	Commercial fish stocks: Seismic activities are undertaken in a manner that does not result in serious* or irreversible impacts to key indicator commercial fish populations, such that sufficient spawning fish biomass and recruitment of the stocks may be maintained, and the stocks continue to be assessed by DPIRD as Sustainable. * In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, CGG considers a serious impact to be impacts with the potential to result in a threat to population or community viability, consistent with a consequence ranking of 'Significant' or greater. Commercial fisheries: Seismic activities are undertaken in a manner that: • Does not interfere with commercial fishing to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities. • Does not prevent each of the licenced commercial fisheries that overlap with the survey area from a catch that meets (or exceeds) the acceptable annual catch tolerance ranges for the fishery, as defined in the relevant harvest strategy (where catch below these tolerance levels cannot be attributed to other factors, such as changes in annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts). Note - It is a legislated function of DPIRD to annually report the status of the fisheries and fish stocks to WA Parliament and so the status and trends can be considered over time.	CGG considers the level of cumulative impact to commercial fisheries and fish stocks to be of an acceptable level. CGG acknowledges that localised and temporary disturbances to fishing activities from seismic survey activities may occur. However, the level of impact from seismic surveys is considered to be acceptable due to the following reasons: • Based on DPIRD FishCube data and CPUE data (Gaughan *et al.* 2018), the Sauropod 3D MSS Acquisition Area only overlaps with areas fished by the PFTIMF and the PTMF, however, fishing catch and effort as well as the CPUE (indicative of fish abundance) are low. • The level of interference CGG may have on commercial fisheries is no greater than is necessary to exercise of right conferred by the titles granted to carry out exploration activities. • A maximum of 10% to 14% of the PFTIMF fished area may be subject to seismic survey activities at one time in 2021, based on the maximum credible survey scenario. Areas of comparable fishing effort (i.e. alternative viable fishing grounds) adjacent to these areas will remain accessible to fishers. • The total spatial overlap of 2021 survey acquisition areas with the PFTIMF is broadly comparable to the overlap that occurred in 2015. No long-term impacts on the overall annual performance of the fisheries or the sustainability of the fishery was evident from 2015 or other past years, total catch remained stable, and the distribution of fishing effort remained broadly the same. • Despite ongoing fishing and seismic surveys across the fisheries in previous years, the demersal scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017–2018 exceeding the Department's defined acceptable catch range, indicating an increased level of fish abundance, as well as increased catch rates (CPUE). • Disturbances to fisheries are likely to be infrequent and short-term. These are not expected to impact the overall annual catch rates and annual performance of the fisheries to the degree that it prevents the fisheries from achieving (or exceeding) the acceptable annual catch tolerance ranges for the fishery, as defined in the North Coast Demersal Scalefish Resource Harvest Strategy 2017–2021 (DPIRD 2017). The cumulative effects of seismic surveys are also not expected to result in any direct reduction in the spawning biomass through fish mortalities, and the potential spatial-temporal overlap of the survey with spawning fish stocks will be minor (10% worst case), which will not be significant in the context of natural variability in spawning biomass and recruitment. Therefore, seismic surveys are not expected to result in a serious or irreversible impact to the sustainability of key indicator commercial fish stocks. This is confirmed in the stock assessment and fishery status reports referenced in the above risk assessment, which indicate that fishing effort and annual catch levels have remained stable or increased despite a history of ongoing commercial fishing and seismic surveys across the fisheries. Catch levels and the spawning biomass of key indicator species have remained within an acceptable range, consistent with fisheries management objectives for sustainability and consistent with the principles of ESD. If a change in impacts and risks to commercial fishing is confirmed, a practical, evidence-based process for reasonable monetary adjustment will be provided to commercial fishers for loss of catch, displacement, or fishing gear loss or damage in the form of a Fishery Impacts Mitigation Plan.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type B' are considered acceptable if the criteria outlined in Table 6-7 are met and it can be demonstrated that the predicted levels of impact and/or residual risk, are at or below pre-defined acceptable level(s) for that impact or risk. The evaluation of potential cumulative impacts meets these requirements as outlined above. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.2.4 are considered industry best practice and meet legislative requirements. CGG considers the adopted controls appropriate to manage the cumulative impacts of noise disturbance from the seismic source to be of an acceptable level.

7.2.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	
EPO 2	Multiple seismic surveys do not occur concurrently in the same location, with a minimum separation distance of 40 km maintained between the Sauropod 3D MSS seismic sources and other operating seismic sources.	PS 1.5	PS 2.3
		PS 2.1	PS 2.4
		PS 2.2	PS 1.10

Number	Performance Standards	Measurement Criteria
PS 2.1	The AHO is advised four weeks prior to survey commencement to allow for the issue of a Notice to Mariners.	Records verify that Notice to Mariners issued by AHO prior to survey commencement.
PS 2.2	AMSA RCC are notified of survey activities 24-48 hours before operations commence, to allow for issue of AUSCOAST warnings, at survey commencement and at completion.	Available records verify AMSA JRCC notifications have been made, and that AUSCOAST warnings have been issued.
PS 2.3	Notification is provided to fisheries stakeholders, four weeks prior to commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within two weeks of completion of the survey.	Consultation and notification records verify stakeholders have been informed of survey activities throughout the survey period.
PS (refer to PS 1.5)	CGG have engaged with proponents identified as having potential concurrent seismic activities prior to commencing the Sauropod survey and have developed a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area.	Records verify that CGG has engaged with proponents prior to acquisition commencement (if relevant), and a concurrent operations plan has been developed.
PS 2.4	A minimum separation distance of 40 km is maintained between the Sauropod 3D MSS seismic sources and other operating seismic sources.	Records verify that a minimum separation distance of 40 km has been maintained between the Sauropod 3D MSS seismic sources and other operating seismic sources.
PS (refer PS 1.10)	Implementation of a management of change process that includes specific triggers to review new evidence in relation to commercial fishing impacts and risks and review of the need to enhance existing controls.	Records of Management of Change process being implemented.

7.3 Noise Emissions: Vessel, Helicopter and Mechanical Equipment

7.3.1 Details of Impacts and Risks

7.3.1.1 Source of Impact/Risk

Generation of noise emissions from vessels, helicopters and mechanical equipment during routine operations has the potential to cause behavioural disturbance to marine fauna.

A purpose-built seismic vessel and two support vessels (one supply and one chase) will be employed for the Sauropod 3D MSS. 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 2009; Jensen *et al.* 2009; Wales and Heitmeyer, 2002; Hildebrand, 2009). Vessel noise emissions vary 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).

A helicopter may be employed for the Sauropod 3D MSS for the purpose of crew changes. Crew changes are expected to occur every 4–6 weeks. 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.

Potential impacts associated with underwater sound emission from the seismic source is addressed in Section 7.1.

7.3.1.2 Receptors

- Cetaceans.
- Marine turtles
- Whale sharks
- Seabirds.

7.3.2 Impact/Risk Evaluation

Elevated underwater noise can affect marine fauna, including cetaceans, in three main ways (Richardson *et al.* 1995; Simmonds *et al.* 2004):

- By causing direct physical effects on hearing or other organs (injury)
- By masking or interfering with other biologically important sounds (including vocal communication, echolocation, signals and sounds produced by predators or prey)
- Through disturbance leading to behavioural changes or displacement from important areas.

The Operational Area is located in water depths ranging from approximately 95 m to 172 m. The fauna associated with these areas will be predominantly pelagic species of fish with the potential for the transient presence of other megafauna species encounters such as turtles, whale sharks and large whales passing through the areas (Section 4.3). The Operational Area overlaps with the Pygmy blue whale distribution BIA and whale shark foraging BIA. However, it is expected low numbers of marine fauna will be present in the Operational Area (refer to Section 4.3).

Given there are no high energy impulsive sound sources associated with the routine operation of vessels, there may be some localised behavioural disturbance of marine fauna in the immediate vicinity of vessels during operations, but physiological effects on fauna are not anticipated. Gradual exposure to continuous noise, such as noise produced by an approaching vessel, is generally regarded as being unlikely to startle or stress marine fauna (Southall *et al.* 2007). Permanent injury would be expected to occur at 230 dB re 1 µPa (peak) (Southall *et al.* 2007) for cetaceans. Noise generated by vessels is unlikely to exceed that level so permanent or temporary injury to protected migratory whale species is not anticipated.

Some transient marine fauna individuals may choose to avoid the immediate proximity of the vessel, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations. Hence, any avoidance or attraction behaviours displayed are expected to be localised and temporary, based on the limited duration of the survey (approximately

60 days). Predicted noise levels are not considered to be ecologically significant at a population level and the potential impacts are considered to be localised with no lasting effect.

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 landing helicopters. 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. Seabirds are expected to avoid the immediate vicinity of a helicopter, but again no long-term impacts are anticipated.

Based on the assessment presented above and the implementation of the identified controls (Section 7.3.4), the consequence of occasional short term and localised disturbance to marine fauna is Negligible (0). The likelihood of this consequence occurring is Rare (A) and the risk is considered to be Low.

Further information about the selected control measure, the ALARP evaluation, and the demonstration of Acceptability are provided below.

7.3.3 Decision Context

The decision context for noise from seismic vessel, support vessels and mechanical equipment has been assessed as ‘Type A’, given the impacts/risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

7.3.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Vessels will comply, when safe to do so, with the relevant requirements of EPBC Regulations 2000 - Part 8 Division 8.1, including: • Taking action to avoid approaching or drifting closer than 50 m to a dolphin or 100 m to a whale • Not exceeding a speed of six knots within the caution zone of a cetacean (300 m).	Yes	The requirements of the EPBC regulations set out clear measures to reduce speed and avoid approaching cetaceans, which also reduce the risk of engine noise in close proximity to cetaceans. It is a legislative requirement for vessels to comply with the EPBC Act.	3.1
Helicopter movements will be undertaken in accordance with EPBC Regulations 2000 – Part 8 Division 8.1, including: • Helicopters not to operate at a height lower than 1650 feet within a horizontal radius of 500 metres of a cetacean • Helicopters not to approach a cetacean from head on.	Yes	The requirements of the EPBC regulations set out clear measures on altitudes above cetaceans and on approaching cetaceans, which reduce the risk of noise in close proximity to cetaceans. It is a legislative requirement for helicopters to comply with the EPBC Act.	3.2
Good Industry Practice			
No good industry practice measures have been identified	N/A	N/A	N/A
Alternatives/Substitutes Considered			
No helicopter transfers	No	The alternative option of eliminating helicopter transfers was considered but not selected. Helicopter transfers are necessary from time to time to make crew transfers. The alternative would require the vessel to return to port to change crew or the use of an additional transfer vessel which would be costly, time consuming and would increase vessel movements and potential interactions with receptors. Given the already low risk of potential short term, localised behavioural responses from up to a few individuals, the control is disproportionate to the level of risk and is not expected to provide any benefit.	N/A
Additional Controls Considered			
Vessel engines maintained according to manufacturer's specification. Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)	Yes	This will ensure reliability of equipment to reduce noise impacts. Good industry practice, environmental benefit outweighs additional cost.	3.3
In addition to the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for cetaceans, vessels, when safe to do so, will also: • Take action to avoid approaching or drifting closer than 50 m to a turtle • Not exceeding a speed of six knots within 300 m of a turtle.	Yes	In addition to implementing avoidance measures for cetaceans, CGG has considered extending the prescribed avoidance measures to turtles. Good industry practice, environmental benefit outweighs additional cost.	3.4
Vessels, when safe to do so, will also adopt measures consistent with the DPaW Whale Shark Management Programme (2013), including: • Taking action to avoid approaching or drifting closer than 30 m of a whale shark • Not exceeding eight knots within 250 m of a whale shark.	Yes	In addition to implementing the EPBC Regulations 2000 avoidance measures for cetaceans, CGG has extended avoidance measures to whale sharks. Good industry practice, environmental benefit outweighs additional cost.	3.5
Extend the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for helicopters to turtles and whale sharks.	No	Helicopter transfers will be infrequent. Extending the legislative requirements of the regulations for cetaceans to other fauna could prevent the helicopter from landing, should fauna be observed. When making a descent towards the helideck of the vessel, the pilot's attention is on landing the helicopter and the relative position of the craft with the vessel. For safety and practicality reasons, the helicopter needs to land safely and the pilot or others on-board should not need to observe for additional fauna. The potential impacts and risks associated with occasional helicopter landings are low given the short-term and localised behavioural response that may occur to individual or small numbers of animals. No significant impacts are expected, and the risk is deemed acceptable. Therefore, applying measures to other fauna is impractical, unnecessary and disproportionate to the limited additional benefit it may provide to reducing the already low level of risk.	N/A
ALARP Statement			
The residual risk associated with the generation of noise from seismic vessel, support vessels and mechanical equipment has been determined to be Low. CGG considers the adopted control measures appropriate to manage the impacts and risks of noise from seismic vessel, support vessels and mechanical equipment. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Negligible (0)	Rare (A)	Low

7.3.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing noise emissions from seismic vessel, support vessels and mechanical equipment operation, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: Contractor and Supplier Management (Section 9.6); Notification and Reporting (Section 9.12).
External	Values and Sensitivities of the Natural Environment	EPBC Policy Statement 1.1. – Significant guidelines The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. Conservation Advice, Recovery Plans, and Other Guidelines: Proposed control measures and the low residual risk of vessel and mechanical equipment noise are consistent with the various Conservation Advice, Conservation Management Plans and Recovery Plans for whales, whale sharks and turtles. Conservation values and objectives of the North-west Marine Parks Management Plan: No impacts are expected to the natural or cultural heritage values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs.
	Relevant Persons Expectations	No feedback relating specifically to vessel noise has been received during stakeholder consultation. This issue is considered to be addressed and will be managed to acceptable levels.
Legislation and Other	Legal Requirements	The impact/risk will comply with EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans').
Industry Standards	Industry Standards and Best Practices	Compliance with best practice guidance is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with the generation of noise emissions from seismic vessel, support vessels and mechanical equipment operation during the Sauropod 3D MSS.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential impacts from noise emissions from vessels, helicopters and mechanical equipment meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, noise disturbance from the seismic vessel, support vessels and mechanical equipment operation are unlikely to result in potential impact greater than localised and temporary disruption to a small proportion of the population. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.3.4 are considered industry best practice and meet legislative requirements. CGG considers the adopted controls appropriate to manage the impacts of noise disturbance from the seismic vessel, support vessels and mechanical equipment operation to be of an acceptable level.

7.3.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	
EPO 3	Vessel and helicopter activities are undertaken in accordance with Part 8 of the EPBC Regulations 2000.	PS 3.1 PS 3.2 PS 3.3	PS 3.4 PS 3.5

Number	Performance Standards	Measurement Criteria
PS 3.1	Marine navigation warnings and Notice to Mariners of survey presence and towed array are issued. Survey is compliant with EPBC Regulations 2000 – Part 8 Division 8.1, including: • Taking action to avoid approaching or drifting closer than 50 m to a dolphin or 100 m to a whale • Not exceeding a speed of six knots within the caution zone of a cetacean (300 m).	MFO records verify interaction between the seismic vessel and marine mammals comply with these requirements where safe to do so. Support vessel observation sheets verify interactions between the vessel and marine mammals comply with these requirements.
PS 3.2	Helicopter movements are undertaken in accordance with EPBC Regulations 2000 – Part 8 Division 8.1, including: • Helicopters not to operate at a height lower than 1650 feet within a horizontal radius of 500 metres of a cetacean. • Helicopters not to approach a cetacean from head on.	MFO records verify that helicopter movements comply with these requirements.
PS 3.3	Vessel engines maintained according to manufacturer's specification.	Records verify that engines and propulsion system maintenance meet this standard.
PS 3.4	In addition to the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for cetaceans, vessels also, where safe to do so: • Take action to avoid approaching or drifting closer than 50 m to a turtle • Not exceeding a speed of six knots within 300 m of a turtle.	MFO records verify interaction between the seismic vessel and marine turtles comply with these requirements where safe to do so. Support vessel observation sheets verify interactions between the vessel and marine turtles comply with these requirements where safe to do so.
PS 3.5	Vessels, when safe to do so, will also adopt measures consistent with the DPaW Whale Shark Management Programme (2013), including: • Taking action to avoid approaching or drifting closer than 30 m of a whale shark • Not exceeding eight knots within 250 m of a whale shark.	MFO records verify interaction between the seismic vessel and whale sharks comply with these requirements where safe to do so. Support vessel observation sheets verify interactions between the vessel and whale sharks comply with these requirements where safe to do so.

7.4 Physical Presence: Disruption/Interference with Other Marine Users

7.4.1 Details of Impacts and Risks

7.4.1.1 Source of Impact/Risk

Potential disruption/interference with other marine users associated with the physical presence of the seismic vessel, in-water equipment and support vessels in the Operational Area.

The seismic vessel will typically move along pre-determined seismic lines at a constant speed of approximately 4.5 knots and will proactively and collaboratively manage operational information between the seismic vessel and other marine users in the Operational Area. The seismic vessel and towed array will be comprised of the airgun array and streamer array, which includes header buoys, starboard and port spreaders or vanes, streamers and tail buoys.

This section deals with disruption/interference with other marine users. Risk associated with vessel collision/diesel spill is addressed in Section 8.2 and potential underwater sound impacts on commercial fishing is addressed in Section 7.1 and 7.2.

7.4.1.2 Receptors

- Commercial fishing
- Commercial shipping
- Tourism/recreational activities
- Petroleum exploration and production operations.

7.4.2 Impact/Risk Evaluation

A range of activities associated with other marine users may occur within or near to the Operational Area, including:

- Commercial fishing – WA State commercial fishing licence holders may be encountered during the Sauropod 3D MSS (Section 4.4.4)
- Tourism and recreational operations – Tourism and recreational activities take place to the north of the Operational Area at Rowley Shoals. No activities are known to take place in the Operational Area; however, vessels may traverse the area in low numbers (Section 4.4.5)
- Petroleum exploration and production operations, including associated vessel activities (Section 4.4.6)
- Commercial shipping - Trading vessels may pass through on occasion; however, a relatively low density of shipping is expected in the Operational Area (Section 4.4.10).

The limited manoeuvrability of the seismic vessel means that vessels associated with shipping, commercial fisheries, tourism operations and existing oil and gas operations may be asked to take measures to avoid the immediate vicinity of the seismic vessel and associated equipment. Skippers of commercial fishing vessels may be asked to remove fishing gear such as traps and lines to avoid interaction with the seismic vessel and in-water equipment. A chase vessel will be employed for the survey to ensure that third party vessels are informed and aware of the seismic activities.

7.4.2.1 Commercial Fishing

As described in Section 4.4.4, there are four WA State managed fisheries that have historically (in the past five years) had catch effort within the Operational or Acquisition Areas (MMF, PTMF, PFTIMF and NDSMF; Section 4.4.4).

The physical presence of the seismic vessel, in-water equipment and the support vessels have the potential to interfere with the movements and operations of fishing vessels. There is a possibility that commercial fishing vessels will be displaced from the area whilst the seismic vessel is conducting seismic acquisition.

An analysis has been conducted to determine the area of overlap of historic fishing activity (effort) and the Operational Area (refer to Table 7-22).

Table 7-22 – Spatial Overlap with Fishing Effort for Relevant Commercial Fisheries

Relevant Commercial Fisheries	Average actively fished area (2016-2020) (km^2)*	Maximum Potential Spatial Overlap	
		Overlap (km^2)	%
Pilbara Fish Trawl (Interim) Managed Fishery	30,526.15	4,867.36	15.94
Mackerel Managed Fishery	61,258.09	29.61	0.05
Pilbara Trap Managed Fishery	175,336.69	4,867.36	2.78
Northern Demersal Scalefish Managed Fishery	80,945.73	351.96	0.43

As shown in Table 7-22, the spatial overlap between the Operational or Acquisition Area and historic fishing effort in the WA commercial fisheries ranges from 2.78% (Pilbara Trap Managed Fishery) to 15.94% (Pilbara Fish Trawl Interim Managed Fishery). Fishing effort occurs relatively consistently across the entire year with no identified peak periods. The Sauropod 3D MSS is expected to take 60 days to acquire, therefore the temporal overlap is approximately 16%.

In addition, as noted in Section 4.4.4, fishing effort is highest in eastern areas of the fisheries compared to the western areas of the fisheries (where the Sauropod 3D MSS is located). Reported fishing effort within the Operational Area is relatively low (56 days effort during the entire five-year period from 2016 to 2020 for the PFTIMF). Therefore, interactions and disturbances to commercial fishing vessels in the Operational Area may be infrequent or may not occur at all. The distribution of fishing effort as well as CPUE (Section 4.4.4) indicates that more viable fishing grounds are available and accessible elsewhere.

Although there is a very small overlap between the Operational Area and the NDSMF (0.43%), the Acquisition Area does not overlap with this fishery. Given that the Sauropod 3D MSS is expected to be acquired along lines in a north–south orientation and less than three NDSMF vessels have been reported to fish in the blocks overlapped by the Operational Area during the five-year period 2016-2020 (refer to Section 4.4.4), it is unlikely that disturbances to fishers in the NDSMF will occur.

There is also a small overlap between the Operational Area and the Mackerel Managed Fishery (0.05%). Given that less than three vessels have been reported in the entire 29.61 km^2 of historical fishing effort that occurs within the Sauropod Operational Area, it is unlikely that disturbances to fishers in the MMF will occur.

In addition to the limited overlap between the Operational Area and commercial fishing effort, it is important to note that the spatial overlaps in Table 7-13 are conservative as this assumes that disturbance / reduced access to fishing grounds occurs across the entire CAES reporting block (up to 12,348 km^2). In reality, the area where the seismic vessel and towed streamers will be operating at any one time during the survey will be significantly less. For example, the area where disruption to fishers may occur during an entire week of seismic acquisition (based on the proposed racetrack formation and a 3 nm [5.5 km] buffer applied around the seismic vessel towed array to represent the avoidance distance typically requested of other vessels) would be equivalent to 2,176 km^2, or approximately one third of the total Operational Area.

It is also important to note that, despite ongoing fishing and seismic surveys across the fisheries in previous years, the demersal scalefish catch in the Pilbara remained stable between 2012 and 2017, with the PFTIMF averaging approximately 1,200 tonnes per year during this period (DPIRD 2017). Subsequently, the most recent DPIRD Status of the Fisheries report (Newman *et al.* 2019) notes that total annual trawl catches have since increased despite having the same annual effort allocations, with catches in 2017–2018 exceeding the Department's defined acceptable catch range. Given that the effort allocations are the same, Newman *et al.* (2019) suggest that the increased catch rates indicate that fishing effort reductions since 2008 have been effective and have resulted in increased fish abundance.

Reduced catches have been observed in the mackerel fishery across recent years. Short-term movement by mobile pelagic species away from a survey area is not unexpected and is discussed in Section 7.1 and 7.2. However, the behaviour and distribution of mackerel is also affected by various factors such as water temperature (Mackie *et al.* 2003) and it is understood that there has been a moderate depletion of the stock because of a decline in catch rates in recent years (FRDC 2021). There was a decline in effort and catch rates in the MMF over the 2011/12 year, which may have been due to the 2011 marine heatwave causing changes in biomass and availability of mackerel (DOF 2012). Declining catches were seen again following the 2016 marine heatwave (which occurred over the spawning period) in all three areas of the MMF (DPIRD 2020). DPIRD has considered this an 'acceptable moderate depletion of stock' (FRDC 2021). The low catches in Western Australia are attributed to 'widespread environmental changes' and the status report notes that other Australian states have also recorded declining catches (DPIRD 2020). Whilst considered three distinct stocks, declines in CPUE have been observed across the Queensland and Torres Strait fisheries in recent years (ABARES 2020, DAF 2021). The stock for the

Gulf of Carpentaria fishery is currently considered a depleting stock (FRDC 2021), which is in part attributed to "extreme climatic conditions observed in 2015-2016 (that) may have exacerbated declines in biomass post 2017 once fish spawned in those years became vulnerable to fishing".

It is acknowledged that localised and temporary disturbances to fishing activities from seismic survey activities can occur, but overall annual catch rates and fishery performance do not appear to be impacted, despite seismic surveys occurring previously in the region (refer to Section 7.2 for further evaluation of the effects of past seismic surveys on the commercial fisheries).

Disruptions to fishing operations are anticipated to be temporary and not significant for the following reasons:

- The fisheries cover wide spatial areas with only a small portion of the fished areas overlapping with the Operational or Acquisition Areas (refer Section 4.4.4), with significantly smaller areas being affected by seismic survey activities and temporarily unavailable to fishing operations at any one time.
- Accounting for the 60-day duration of the survey, the total spatial-temporal overlap with the Pilbara demersal scalefish fisheries would be ≤1.1%.
- Fishing catch and effort within the Sauropod 3D MSS Acquisition Area is relatively low (refer to Section 4.4.4). Historic catch effort indicates effort is more focussed in other areas than it is in the Sauropod 3D MSS Operational Area. Therefore, disturbance to actual fishing activities is likely to be even less than what is indicated by the spatial-temporal overlap.
- Reported fishing effort within the Operational Area is relatively low (56 days effort during the entire five-year period from 2016 to 2020 for the PFTIMF). Therefore, interactions and disturbances to commercial fishing vessels in the Operational Area may be infrequent or may not occur at all.
- The distribution of fishing effort as well as CPUE (Section 4.4.4) indicates that more viable fishing grounds are available and accessible elsewhere.
- Early notifications to fisheries licence holders, Notice to Mariners and Auscoast warnings, will enable pre-planning of fishing activities to avoid disruption.
- Radar detection systems, survey support vessels and ongoing radio communications with licence holders will provide advanced and timely notice to fishers during operations.

7.4.2.2 Commercial Shipping

Some commercial shipping may also need to deviate from intended routes to avoid the seismic vessel, in-water equipment and the support vessels. Consultation with AMSA confirms that only light traffic occurs within the Operational Area. The closest shipping fairway is located to the north-western corner of the Operational Area (Section 4.4.10). The use of the fairways is strongly recommended by AMSA but is not mandatory and shipping vessels still have to adhere to the International Regulations for Preventing Collisions at Sea 1972 (COLREGS). Based on this and the inherent controls identified above, no significant navigational implications or changes in shipping traffic patterns are expected.

7.4.2.3 Tourism/Recreational Activities

Tourism/recreational activities are known to take place approximately 62 km north of the Operational Area at Imperieuse and Clerke reefs in the Rowley Shoals Marine Park (state waters), however no tourism/recreational activities have been identified to take place within the Operational Area. In the event that tourism/recreational activities are present within the Operational Area, displacement would be minimal given the transient nature of the seismic activities. Therefore, no significant implications are expected.

7.4.2.4 Petroleum Exploration and Production Operations

Apart from WA-527-P, the Operational Area overlaps three other exploration permits (WA-487-P, WA-436-P and WA-438-P) that are operated by Pathfinder Energy Pty Ltd and Santos WA Northwest Pty Ltd. The potential for concurrent seismic activities has been identified in Section 4.4.6. There are four accepted EPs covering seismic surveys that could be undertaken within the same timeframe as the Sauropod 3D MSS, and potentially occur within 150 km of the Operational Area. Prior to commencement of the Sauropod 3D MSS, CGG will consult with the titleholders/proponents of these EPs to establish whether there is any likelihood of concurrent operations. Concurrent seismic surveys within close proximity to each other (i.e. within tens of kilometres) are routinely managed via CONOPS (concurrent operations plans) and time-sharing arrangements. The potential impact is considered to be slight and short-term.

Cumulative impacts from concurrent seismic surveys are described in Section 7.2.

7.4.2.5 Summary

Based on the assessment presented above and the implementation of the identified controls (Section 7.4.4), it is expected that localised and temporary disruptions to other users and activities will be Minor (1), with fishing vessels and other users able to return to a particular area once the seismic vessel has passed. The likelihood of interaction is considered to be Unlikely (B), resulting in a Low residual risk to other users in the Operational Area.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability are provided below.

7.4.3 Decision Context

The decision context for disruption/interference with other marine users, has been assessed as ‘Type A’ for most receptors, given the impacts/risks are well understood and uncertainty is minimal, with little or no stakeholder interest. However, given the level of interest and nature of issues raised by fisheries stakeholders during consultation, the decision context is ‘Type B’ for commercial fisheries.

7.4.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Adherence with requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea (SOLAS) as implemented in Commonwealth Waters through the *Navigation Act 2012* and associated Marine Orders 21, 30, 58 – safety and emergency arrangements, prevention of collisions, safe management of vessels, including: • Appropriate lighting, navigation and communication to inform other users • Use of radar and 24/7 watch.	Yes	Legislative requirement for vessels operating in Commonwealth waters. All vessels associated with the Sauropod 3D MSS are required to comply with the *Navigation Act 2012*.	4.1
Good Industry Practice			
Issue of marine navigation warnings and Notice to Mariners of survey presence and towed array	Yes	AHO will be contacted 4 weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of interactions with other marine users. Good industry practice, environmental benefit outweighs additional cost.	2.1
Pre-survey notification to AMSA JRCC, issue of AUSCOAST warnings	Yes	The AMSA JRCC will be contacted 24-48 hrs before operations commence for issuing of radio-navigation warnings. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of interactions with other marine users. Good industry practice, environmental benefit outweighs additional cost.	2.2
Streamers marked with tail buoys.	Yes	Tail buoys will be used to mark ends of the streamers so that they can be detected by other vessels. Good industry practice, environmental benefit outweighs additional cost.	4.2
Notification will be provided to fisheries stakeholders, prior to commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders upon completion of the survey.	Yes	Notification will be provided to fisheries stakeholders 4 weeks prior to commencement of the survey and 2 weeks following completion of the survey. Implementation of the control will reduce the likelihood of interactions with marine users. Good industry practice, environmental benefit outweighs additional cost.	2.3
A communications protocol will be in place between the survey and support vessels and other users (e.g. known commercial fishing vessels within the Operational Area), to actively manage concurrent activities.	Yes	The survey vessel operator will provide effective 'look-aheads' to commercial fisheries fleet managers and vessel skippers to inform them of the current positions of the survey and support vessels, and of proposed operations for the next 48-72-hour period. Implementation will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	4.3
At least one additional vessel (support or chase vessel) will accompany the survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods).	Yes	The chase vessel will conduct advanced scouting when safe to do so (e.g. outside of inclement weather periods) to ensure that other marine users in the area are provided with advance notice of seismic activities. The chase vessel will provide effective communications with other activities and users. Good industry practice, socio-economic benefit outweighs the additional cost.	4.4
CGG will engage with proponents identified as having potential concurrent seismic activities prior to commencing the Sauropod survey and develop a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area.	Yes	Engagement with titleholders for potential concurrent MSS activities prior to acquisition commencing, and development of a concurrent operations plan, which will include the following aspects: • Communications protocols • SIMOPS and work programming • Hazard management • Emergency response. Good industry practice, environmental benefit outweighs additional cost.	1.5
Alternatives/Substitutes Considered			
No practicable alternative or substitutes to the acquisition or the good practice controls have been identified	N/A	N/A	N/A
Additional Controls Considered			
No additional controls have been identified	N/A	N/A	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable improvements have been identified	N/A	N/A	N/A
ALARP Statement			

Control Measure	Control Adopted	Justification	Performance Standard Ref.
The residual risk associated with the disruption/interference with marine users has been determined to be Low. CGG considers the adopted control measures appropriate to manage the risks of disruption/interference with other marine users. As the risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the risk, without jeopardising the objectives of the survey, the risk is considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Minor (1)	Unlikely (B)	Low

7.4.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing interactions between the seismic vessel, survey equipment, support vessels and other vessels/activities, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible, managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6); • Notification and Reporting (Section 9.12).
External	Values and Sensitivities of the Natural Environment	EPBC Policy Statement 1.1. – Significant guidelines The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. Conservation Advice, Recovery Plans, and Other Guidelines N/A: No advice or guidelines have been identified that are relevant to the disruption/interference with other marine users Conservation values and objectives of the North-west Marine Parks Management Plan No impacts are predicted to occur to the cultural and socio-economic values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs as a result of disruption/interference with other marine users.
	Socio-economic Environment – Commercial Fisheries	The assessment of impacts to commercial fisheries has been undertaken based on relevant external context, including the following data and publications: • North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017), which describes the stock assessment and management approach (consistent with the principles of ESD), including annual fishing effort allocations and catch tolerance levels; • Spatial and temporal patterns in fisheries catch and effort distribution (based on DPIRD 2016-2020 FishCube data);
	Relevant Persons Expectations	Stakeholder concerns have been assessed, responded to and controls adopted for objections and claims which hold merit. The proposed control measures have been developed based on the advice of AMSA and AHO.
Legislation and Other	Legal Requirements	All requirements under the *Navigation Act 2012* and associated Marine Orders for navigation, collision, and support vessels are identified as control measures.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practice is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with disruption/interference with other users during the Sauropod 3D MSS.

7.4.5.1 Defined acceptable levels of impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact
Commercial Fisheries	Commercial fisheries stakeholder objections, claims and concerns regarding the effects of seismic surveys on commercial catch levels and displacement from fishing grounds. Commercial fisheries data and publications: • North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017), which describes the stock assessment and management approach (consistent with the principles of ESD), including annual fishing effort allocations and catch tolerance levels	Seismic activities are undertaken in a manner that: • Does not interfere with fishing to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities. • Does not prevent the total annual catch of each of the Pilbara Demersal Scalefish Fisheries from achieving (or exceeding) the acceptable annual catch tolerance ranges for the fishery, as defined in the North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017) (where catch below these tolerance levels cannot be adequately explained by other factors, such as changes in	CGG considers the level of impact to commercial fisheries to be of an acceptable level. CGG recognises that clear and regular communication with fisheries stakeholders is required in order to facilitate better planning and resource sharing. CGG acknowledges that localised and temporary disturbances to fishing activities from seismic survey activities may occur. However, the level of impact from the Sauropod 3D MSS is considered to be acceptable due to the following reasons: • Based on DPIRD FishCube data and CPUE data (Gaughan *et al.* 2018), the Sauropod 3D MSS Acquisition Area only overlaps with areas fished by the PFTIMF and the PTMF, and fishing effort is low. • The level of interference CGG may have on commercial fisheries is no greater than is necessary to exercise of right conferred by the titles granted to carry out exploration activities. • Despite ongoing fishing and seismic surveys across the fisheries in previous years, the demersal scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017–2018 exceeding the Department's defined acceptable catch range, indicating an increased level of fish abundance, as well as increased catch rates (CPUE).

• Spatial and temporal patterns in fisheries catch and effort distribution (based on DPIRD 2016-2020 FishCube data).	annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts).	• Disturbances to fisheries are likely to be infrequent and short-term. These are not expected to impact the overall annual catch rates and annual performance of the fisheries to the degree that it prevents the fisheries from achieving (or exceeding) the acceptable annual catch tolerance ranges for the fishery, as defined in the North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017). • CGG has based its risk assessments on information and advice provided or published by DPIRD and the FRDC.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type B' are considered acceptable if the criteria outlined in Table 6-7 are met and it can be demonstrated that the predicted levels of impact and/or residual risk, are at or below pre-defined acceptable level(s) for that impact or risk. The evaluation of potential impacts from the physical presence meets these requirements as outlined above. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.4.4 are considered industry best practice and meet legislative requirements. CGG considers the adopted controls appropriate to manage the impacts of the physical presence of the vessel and subsequent disruption or interference with other marine users to be of an acceptable level.

7.4.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID		
EPO 4	Marine users are aware of the survey location, timing and safety navigation zone	PS 4.1	PS 4.2	PS 4.4
		PS 2.1	PS 2.3	PS 1.5
		PS 2.2	PS 4.3	

Number	Performance Standards	Measurement Criteria
PS 4.1	Adherence with requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea (SOLAS) as implemented in Commonwealth Waters through the *Navigation Act 2012* and associated Marine Orders 21, 30, 58 – safety and emergency arrangements, prevention of collisions, safe management of vessels, including: Appropriate lighting, navigation and communication to inform other users. Use of radar and 24/7 watch.	No records of survey or support vessels failing to comply with appropriate navigation, lighting and communication requirements under the *Navigation Act 2012* or its associated Marine Orders.
PS (refer to PS 2.1)	The AHO is advised 4 weeks prior to survey commencement to allow for the issue of a Notice to Mariners.	Records verify that Notice to Mariners issued by AHO prior to survey commencement.
PS (refer to PS 2.2)	AMSA JRCC is notified of survey activities 24-48 hours before operations commence, to allow for issue of AUSCOAST warning, at survey commencement and at completion.	Records verify AMSA JRCC notifications have been made.
PS 4.2	Streamers are marked with tail buoys.	Records confirm tail buoys are fitted to each streamer.
PS (refer to PS 2.3)	Notification has been provided to fisheries stakeholders four weeks prior to commencement of the survey, indicating location and expected timing. Notification has also been provided to fisheries stakeholders within two weeks of cessation of the survey.	Consultation records confirm that fisheries stakeholders were notified four weeks prior to survey commencement and within two weeks of cessation of activities.
PS 4.3	A communications protocol is in place between the survey and support vessels and other users (e.g. known commercial fishing vessels within the Operational Area), to actively manage concurrent activities.	Records demonstrate that 48-72-hour 'look-aheads' have been provided to stakeholders that have requested to receive them.
PS 4.4	At least one chase vessel is employed to assist the seismic vessel to mitigate interference associated with third party vessel operations.	Records demonstrate that a dedicated chase vessel is employed for the survey
PS 1.5	CGG have engaged with proponents identified as having potential concurrent seismic activities prior to commencing the Sauropod survey and develop a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area.	Records verify that CGG has engaged with proponents prior to acquisition commencement (if relevant), and a concurrent operations plan has been developed.

7.5 Discharge: Treated Sewage, Grey Water and Putrescible Waste

7.5.1 Details of Impacts and Risks

7.5.1.1 Source of Impact/Risk

Discharge of treated sewage, grey water and putrescible wastes to the marine environment from the seismic and support vessels has the potential to cause temporary/localised reduction in water quality, and minor/temporary toxicity on marine biota.

The seismic and support vessels employed for the Sauropod 3D MSS will generate liquid wastes (i.e. treated sewage, grey water and putrescible food waste). These vessels will routinely generate/discharge small volumes (up to 15 m^3 per vessel per day) of domestic waste to the marine environment. Routine discharges generated from the survey have the potential to cause temporary and localised reduction in water quality.

Potential impacts associated with the discharge of deck and bilge water from vessels is addressed in Section 7.6.

7.5.1.2 Receptors

- Water quality
- Marine biota.

7.5.2 Impact/Risk Evaluation

Routine discharges of domestic wastes have the potential outcome of temporary and localised increased nutrient levels resulting in localised, minor and temporary ecological impacts (e.g. changes in certain nutrients and/or dissolved oxygen).

Impacts resulting from the discharge of domestic liquid wastes are expected to be negligible, as treated discharges would rapidly disperse in close proximity to the release location given surface currents and the assimilative capacity of the open ocean environment. The resulting change in water quality in the water column will be highly localised and short term, with nutrient concentrations returning to background levels shortly after discharge. Thus, significant impacts to marine biota are not expected.

Considering the required controls, the consequence of occasional short term and localised disturbance to water quality and marine biota is Minor (1). The likelihood of this consequence occurring is Rare (A) and the risk is considered to be Low.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability are provided below.

7.5.3 Decision Context

The decision context for discharge of sewage, grey water and putrescible wastes from the seismic vessel and support vessels to the marine environment has been assessed as ‘Type A’, given the impacts/risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

7.5.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Seismic vessel and support vessels will be compliant with Marine Order 96 - pollution prevention – sewage (as appropriate to vessel class): • A valid International Sewage Pollution Prevention (ISPP) Certificate, as required by vessel class • Sewage will only be discharged via an IMO-approved sewage treatment plant; or • Comminuted/disinfected sewage via an IMO-approved system will only be discharged when 3 nm from land and when the vessel is moving at four knots: or • Sewage that has not been comminuted/disinfected via an IMO-approved system will only be discharged when 12 nm from land and when the vessel is moving at 4 knots.	Yes	Sewage discharges to the marine environment during the survey will be undertaken in accordance with the requirements of MARPOL Annex IV and AMSA Marine Order 96, including via approved systems and the required discharge rates to ensure adequate dispersion of discharges to reduce the potential for impacts. It is a legislative requirement for vessels to comply with AMSA Marine Orders.	5.1
Seismic vessel and support vessels will be compliant with Marine Orders 95 – pollution prevention – Garbage (as appropriate to vessel class), specifically: • Putrescible waste and food scraps are passed through a macerator so that it is capable of passing through a screen with no opening wider than 25 mm, prior to discharge while the vessel is moving and 3 nm from land.	Yes	Discharges of putrescible waste (e.g. food waste) will be undertaken in accordance with the requirements of MARPOL Annex V and AMSA Marine Order 95 to ensure adequate dispersion of discharges to reduce the potential for impacts. It is a legislative requirement for vessels to comply with AMSA Marine Orders.	5.2
Good Industry Practice			
No additional good industry practice measures have been identified	N/A	N/A	N/A
Alternatives/Substitutes Considered			
Alternative to the discharge of domestic waste to the marine environment is the retention of all liquid wastes on-board and transfer to a licensed onshore disposal site.	No	The alternative was discounted as being impractical for the following reasons: • Environmental risks associated with offshore discharge are low given the use of IMO-standard sewage systems and macerator, and the commitment to discharge offshore in accordance with MARPOL and associated Marine Orders. • Retaining wastes on-board for transfer to shore would require additional supply vessel journeys to be made during the survey, resulting in additional vessel movements and associated increased risks of physical presence, noise, atmospheric emissions etc. • Transfer and disposal of liquid wastes to shore would have significant additional cost and time implications. Given the already low environmental risk associated with proposed discharges, the planning, time and cost implications are grossly disproportionate to the negligible reduction in risk that would be achieved and the already low level of risk.	N/A
Additional Controls Considered			
In addition to vessels complying with the requirement to be fitted with an IMO-approved sewage treatment plant or sewage holding tank (where applicable), vessels may be required to have an IMO-approved sewage treatment plant regardless of vessel size and people capacity.	No	This additional control would add to the overall cost of the survey, impacting on the commerciality. Given the already low environmental risk associated with proposed discharges, the planning, time and cost implications are grossly disproportionate to the negligible reduction in risk that would be achieved and the already low level of risk.	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No further practicable improvements to the above controls have been identified.	N/A	N/A	N/A
ALARP Statement			
The residual risk associated with the discharge of treated sewage, grey water and putrescible wastes has been determined to be Low. CGG considers the adopted control measures appropriate to manage the impacts and risks of discharge of sewage, grey water and putrescible wastes. As the impact has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts, without jeopardising the objectives of the survey, the impacts are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Residual Risk Ranking
Residual Risk	Minor (1)	Rare (A)	Low

7.5.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing discharge of domestic liquid wastes is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6);

Context	Factor	Demonstration
		• Environmental Performance Monitoring and Reporting (Section 9.3).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines:** No species Recovery Plans or Conservation Advice set requirements relating to the management of liquid waste discharges. **Conservation values and objectives of the North-west Marine Parks Management Plan** Although the Operational Area is not located within any AMPs, management of discharges in accordance with the requirements of MARPOL meets the management prescriptions for MUZ in the North-west Marine Parks Network Management Plans. Vessel discharges will also not occur in AMP Sanctuary Zones.
	Relevant Persons Expectations	No feedback relating specifically to liquid waste has been received during stakeholder consultation.
Legislation and Other	Legal Requirements	The impact/risk mitigation will comply with International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and associated AMSA Marine Orders made under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* for the management of discharges at sea.
Industry Standards	Industry Standards and Best Practices	Compliance with best practice is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with discharge of treated sewage, grey water and putrescible wastes from the seismic vessel and support vessels.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential impacts from the discharge of sewage, grey water and putrescible wastes meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, discharge of sewage, grey water and putrescible wastes are unlikely to result in potential impact greater than localised and short-term local concern to water quality and marine biota. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.5.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.

7.5.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID
EPO 5	No impact to water quality greater than Minor (1) from discharge of sewage, grey water and putrescible waste to the marine environment during the survey.	PS 5.1 PS 5.2

Number	Performance Standards	Measurement Criteria
PS 5.1	Seismic vessel and support vessels are compliant with Marine Order 96 - pollution prevention – sewage (as appropriate to vessel class): • A valid International Sewage Pollution Prevention (ISPP) Certificate, as required by vessel class • Sewage will only be discharged via an IMO-approved sewage treatment plant; or • Comminuted/disinfected sewage via an IMO-approved system will only be discharged when 3 nm from land and when the vessel is moving at four knots: or • Sewage that has not been comminuted/ disinfected via an IMO-approved system will only be discharged when 12 nm from land and when the vessel is moving at four knots.	Records demonstrate seismic vessel and support vessels are compliant with Marine Orders 96 - pollution prevention – sewage (as appropriate to vessel class).
PS 5.2	Seismic vessel and support vessels are compliant with Marine Orders 95 – pollution prevention – Garbage (as appropriate to vessel class), specifically: • Putrescible waste and food scraps are passed through a macerator so that it is capable of passing through a screen with no opening wider than 25 mm.	Records demonstrate Survey and support vessels are compliant with Marine Orders 95 – pollution prevention (as appropriate to vessel class).

7.6 Discharge: Drains, Deck and Bilge Water

7.6.1 Details of Impacts and Risks

7.6.1.1 Source of Impact/Risk

Discharge of deck drainage and oily water to the marine environment from the seismic and support vessels has the potential to cause temporary/localised reduction in water quality, and minor/temporary toxicity on marine biota.

The seismic and support vessels routinely generate/discharge:

- Relatively small volumes of bilge water. Bilge tanks receive fluids from many parts of the vessel. Bilge water can contain water, oil, detergents, solvents, chemicals, particles and other liquids, solids or chemicals. The amount of bilge wastes accumulated on-board is dependent on vessel characteristics, such as size, engine room design, and preventative maintenance schedule.
- Variable volumes of wastewater from decks directly overboard or via deck drainage systems. Water sources could include rainfall events and/or from deck activities such as cleaning/wash-down of equipment/decks. The volume of drain discharge during the survey is dependent on the amount of rainfall received and the frequency of the deck washing activities. Discharge from open drain areas will be conducted directly overboard.

The discharge of deck drainage and bilge from the seismic and support vessels has the potential to result in a reduction in water quality (through an increase in nutrient levels or contaminants such as hydrocarbons), which has the potential to affect marine biota.

Potential impacts associated with the accidental discharge of solid wastes is addressed in Section 8.7.

7.6.1.2 Receptors

- Water quality.
- Marine biota.

7.6.2 Impact/Risk Evaluation

Routine discharge of deck drainage and bilge water, if not managed or treated, has the potential to temporarily reduce water quality resulting in localised toxicity impacts on marine biota through an increase in nutrient levels or contaminants such as hydrocarbons.

Areas of potential contamination on vessels such as machinery and bulk liquid storage areas are contained or bunded to capture any spilled chemicals or oil residues. Drainage from these areas will be directed to holding tanks for either treatment through an oil-in-water separator prior to discharge or disposed of onshore. All vessels ≥400 gross tonnes will hold a current International Oil Pollution Prevention (IOPP) Certificate demonstrating that vessels are fitted with an oil discharge monitoring and control system and oil filtering equipment, which will be maintained and operated to 15 ppm standard. The bilge stream is treated to reduce hydrocarbon concentrations below 15 ppm prior to discharge overboard. Discharges would rapidly disperse in close proximity to the release location, given the surface currents and the assimilative capacity of the open ocean environment. Given the minor quantities of contaminants expected from the open drains, the expected rapid dispersal of both open drain and treated bilge discharges, and the management measures to be implemented for the bilge waste stream, toxicity impacts to marine biota are not expected.

Considering the required controls, the consequence of occasional short term and localised disturbance to water quality and marine biota is Negligible (0). The likelihood of this consequence occurring is Rare (A) and the risk is considered to be Low.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability are provided below.

7.6.3 Decision Context

The decision context for the discharge of deck drainage and bilge water has been assessed as 'Type A', given the impacts/risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

7.6.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
In accordance with MARPOL Annex 1 and Marine Order 91 (Under agreement 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972), vessels ≥400 gross tonnes will have an oil discharge monitoring and control system and oil filtering equipment on-board, hold a current IOPP Certificate and maintain an oil usage management logbook. Treated bilge water will be discharged only when the vessel is moving, and the oil discharge monitoring and control system and oil filtering equipment is operating. If oil discharge monitoring and control system and oil filtering equipment is unavailable, bilge water mixtures will be retained on-board for on shore disposal.	Yes	Vessels employed for the Sauropod 3D MSS ≥400 gross tonnes will hold a current IOPP certificate and have an oil discharge monitoring and control system in accordance with the requirements of MARPOL Annex I and AMSA Marine Order 91. Bilge water discharges will be undertaken in accordance with the requirements of MARPOL Annex I and AMSA Marine Order 91. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.	6.1
Good Industry Practice			
No additional good industry practice measures have been identified.	N/A	N/A	N/A
Alternatives/Substitutes Considered			
Seismic and support vessels discharge treated bilge or all contaminated bilge to onshore facilities for treatment and disposal.	No	For the seismic vessel there is substantial additional cost due to onshore treatment and disposal, acquisition downtime, increase in survey duration, increased fuel consumption given the additional transits required by support vessel. Risk of spills and leaks during transfer operations and additional safety risks to personnel during vessel transfer activities. No net benefit observed if treated bilge can be discharged in accordance with MARPOL requirements.	N/A
Additional Controls Considered			
Oil discharge monitoring and control systems on-board the survey vessels will be maintained and calibrated to ensure monitoring readings are accurate.	Yes	Records of equipment calibration can be retained and checked to confirm that equipment is operating to the standard it should be to meet the requirements of MARPOL and associated Marine Orders. The environmental benefit outweighs the additional cost.	6.2
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No further practicable improvements to the above controls have been identified.	N/A	N/A	N/A
ALARP Statement			
The residual risk associated with the discharge of deck drainage and bilge water has been determined to be Low. CGG considers the adopted control measures appropriate to manage the impacts and risks of discharge of deck drainage and bilge water. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Negligible (0)	Rare (A)	Low

7.6.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing discharge of deck drainage and bilge water, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible, managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Environmental Performance Monitoring and Reporting (Section 9.3).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines:** No species Recovery Plans or Conservation Advice set requirements relating to the management of deck drainage and bilge water discharges. **Conservation values and objectives of the North-west Marine Parks Management Plan** The Operational Area is not located within any AMPs. All vessel discharges will comply with the management prescriptions for AMPs. Vessel discharges will also not occur in AMP Sanctuary Zones.
	Relevant Persons Expectations	No feedback relating specifically to deck drainage and bilge water discharges has been received during stakeholder consultation. This issue is considered to be addressed and will be managed to acceptable levels.

Context	Factor	Demonstration
Legislation and Other	Legal Requirements	The proposed controls meet or exceed the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and associated AMSA Marine Orders made under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* for the management of discharges at sea.
Industry Standards	Industry Standards and Best Practices	Compliance with best practice guidance is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with discharge of discharge of deck drainage and bilge water from the seismic vessel and support vessels.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential impacts from the discharge of deck drainage and bilge water meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, discharge of deck drainage and bilge water are unlikely to result in potential impact greater than localised and short-term local concern to water quality and marine biota. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.6.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.

7.6.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID
EPO 6	No impact to water quality greater than Negligible (0) from discharge of bilge and deck drainage to the marine environment during the survey.	PS 6.1 PS 6.2

Number	Performance Standards	Measurement Criteria
PS 6.1	Seismic and support vessels are compliant with MARPOL Annex I and AMSA Marine Order 91: • A valid IOPP Certificate, as required by vessel class • Mandatory measures for the processing of oily water prior to discharge • Machinery space bilge/oily water has International Maritime Organisation (IMO) approved oil filtering equipment (oil/water separator) with an on-line monitoring device to measure Oil in Water (OIW) content to be less than 15 ppm prior to discharge • IMO approved oil filtering equipment also has an alarm and an automatic stopping device or be capably of recirculating in the event that OIW concentration exceeds 15 ppm • In the event that machinery space bilge and deck drainage discharges cannot meet the oil content standard of 15 ppm without dilution or be treated by an IMO approved oil/water separator, they are contained on-board and disposed of onshore • Treated bilge water is discharged only when the vessel is moving, and the oil discharge monitoring and control system and oil filtering equipment is operating to specification.	Records demonstrate compliance with the requirements of MARPOL Annex I and AMSA Marine Order 91.
PS 6.2	Oil discharge monitoring and control systems on-board the survey vessels are maintained and calibrated to ensure monitoring readings are accurate.	Records demonstrate oil discharge monitoring and control systems have been maintained.

7.7 Artificial Light Emissions: Vessels

7.7.1 Details of Impacts and Risks

7.7.1.1 Source of Impact/Risk

Navigational and safety lighting on the seismic and support vessels emit light, which may disrupt marine fauna normal behaviours.

The seismic and support vessels present in the Operational Area will display artificial lighting to meet navigational and safety requirements under the Prevention of Collision Convention (Marine Order 30). Essential lighting from work related areas and navigational beacons, mainly during night-time operations, has the potential to result in the disruption of marine fauna behaviours.

7.7.1.2 Receptors

Marine fauna sensitive to artificial lighting (i.e. turtles, fishes and seabirds).

7.7.2 Impact/Risk Evaluation

Essential lighting from work related areas and navigational beacons, mainly during night-time operations, has the potential to result in the disruption of marine fauna behaviours. The extent of impacts to marine fauna from artificial light emissions is dependent on the:

- Density and wavelength of the light source
- Extent to which the light spills into areas that are significant for breeding and foraging
- Timing of the light spill relative to breeding and foraging activity
- Ability of the fauna populations to return to their original state following the activity.

Due to the size of the seismic vessel and the height above sea level where lights will be positioned, it is expected that light emissions, particularly the area that is directly lit by lights on the vessel, will be localised and limited to the immediate vicinity of the vessel.

7.7.2.1 Turtles

Artificial light has the potential to disrupt critical behaviours in turtles, particularly in relation to nesting at the shoreline. Light has been shown to affect how turtles choose nesting sites, how they return to the sea after nesting and how hatchlings find the sea following emergence from nests (Witherington and Martin 2003). Artificial lighting may affect the location that turtles emerge to the beach, the success of nest construction, whether nesting is abandoned, and even the seaward return of adults (Salmon *et al.* 1995). However, the Operational Area is approximately 120 km away from the closest known turtle nesting beach (Eighty Mile Beach) and impacts to turtle hatchlings and nesting turtles are therefore not anticipated (Section 4.3.8.1).

Adult turtles that may be present within the Operational Area may be attracted to the survey 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 (moving at 4.5 knots)
- Limited distance of visible light from the seismic vessel
- Operational Area being located outside of any turtle internesting or foraging BIAs.

In addition, during acquisition, sound emissions from the survey and support vessels, and from the seismic source, are expected to act as a localised and temporary deterrent to approaching adult turtles (refer to Section 7.1).

7.7.2.2 Fishes

Light emissions from the vessels in the Operational Area may result in localised aggregation of fishes in the immediate vicinity of the vessels at night. This may result in an increase in predation on prey species aggregating in the area, or exclusion of nocturnal foragers/predators (Marchesan *et al.* 2006). These aggregations of fishes are considered localised and temporary and any long-term changes to fish species composition or abundance is considered highly unlikely.

Light emission impact to fishes within the Operational Area would be highly localised and short-term due to the transient nature of the survey, the limited distance of visible light from the survey and support vessels and light use being limited to night-time operations. Sound emissions from the survey and support vessels, and from the seismic source, are also expected to act as a localised and temporary deterrent to fishes (refer to Section 7.1).

7.7.2.3 Seabirds

Studies conducted in the North Sea indicate that migratory birds may be attracted to offshore lights when travelling within a radius of 3 to 5 km from the light source. Outside this area, their migratory paths are likely to be unaffected (Marquenie *et al.* 2008). Light emission effects to birds within the Operational Area (including those migrating through and those foraging within the Lesser frigatebird foraging BIA and the White-tailed tropicbird breeding/foraging BIAs) are expected to be localised and temporary based on the transient nature of the survey and limited distance of visible light from the survey and support vessels. Any behavioural effects to migratory and foraging birds while in transit to/from these locations, such as attraction to the light source are expected to be highly localised and short-term and therefore are not expected to have any discernible impacts on migration or behavioural patterns.

7.7.2.4 Summary

Given the transient nature of the survey, the limited number of vessels operating in the Operational Area, together with the short duration of the survey (60 days) and the predominantly open oceanic and offshore location of the Operational Area, the potential impacts are expected to be localised with no lasting effect, with light spill limited to the immediate vicinity of vessels. The consequence of occasional short-term and localised disturbance to marine fauna sensitive to artificial lighting is Negligible (0). The likelihood of this consequence occurring is Rare (A) and the risk is considered to be Low.

Further information about the selected control measure, the ALARP evaluation, and the evaluation of Acceptability are provided below.

7.7.3 Decision Context

The decision context for artificial light emissions has been assessed as ‘Type A’, given the impacts/risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

7.7.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Adherence with requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea (SOLAS) as implemented in Commonwealth Waters through the *Navigation Act 2012* and associated Marine Orders 21, 30, 58 – safety and emergency arrangements, prevention of collisions, safe management of vessels, including: • Appropriate lighting, navigation and communication to inform other users. • Use of radar and 24/7 watch.	Yes	Legislative requirement for vessels operating in Commonwealth waters. All vessels associated with the Sauropod 3D MSS are required to comply with the *Navigation Act 2012*	4.1
Good Industry Practice			
No additional good industry practice measures have been identified.	N/A	N/A	N/A
Alternatives/Substitutes Considered			
No practicable alternative or substitutes to the above controls have been identified	N/A	N/A	N/A
Additional Controls Considered			
Restriction on night-time activities or activities in low light conditions.	No	Significant light impacts to birds and turtles are not expected due to the transient nature of the survey and support vessels and the offshore location of the survey. Given the resulting increase in survey time and cost, this option was considered impractical and disproportionate to the limited benefit that would be gained.	N/A
Survey crews shall be instructed to minimise unnecessary external lighting where practicable during the activity.	Yes	Survey crews will be instructed to minimise unnecessary external lighting where practicable during the activity. Lighting for the purpose of safety or navigation purposes is necessary. The environmental benefit outweighs the additional cost.	7.1
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No further practicable improvements to the above controls have been identified.	N/A	N/A	N/A
ALARP Statement			
The residual risk associated with the artificial light emissions has been determined to be Low. CGG considers the adopted control measures appropriate to manage the impacts and risks of artificial light emissions. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Negligible (0)	Rare (A)	Low

7.7.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing artificial light emissions, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6); • Environmental Performance Monitoring and Reporting (Section 9.3).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines:** CGG has reduced any adverse impacts of artificial lighting from the activities on Australian turtle species noting the linkages with the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017). **Conservation values and objectives of the North-west Marine Parks Management Plan** The Operational Area is not located within any AMPs. The management prescriptions for AMPs do not include information on artificial light emissions from commercial vessels.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to artificial light emissions.
Legislation and Other	Legal Requirements	Artificial lighting will be managed in accordance with the requirements of the International Regulations for Preventing Collisions at Sea, 1972 (COLREGS) and associated AMSA Marine Orders under the *Protection of Sea (Prevention of Collisions) Act 1983*.

Context	Factor	Demonstration
Industry Standards	Industry Standards and Best Practices	No industry standards and best practice have been identified that relate to artificial light emissions.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with artificial light emissions during the Sauropod 3D MSS.
Acceptability Statement		
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential impacts from artificial light emissions meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, artificial light emissions are unlikely to result in potential impact greater than localised and short-term local concern to marine fauna. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.7.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.		

7.7.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID
EPO 7	Lighting reduced to levels required for navigational and safety purposes, so as to not disrupt behaviour patterns of marine fauna.	PS 4.1 PS 7.1

Number	Performance Standards	Measurement Criteria
PS (refer to PS 4.1)	Vessels will comply with *Navigation Act 2012* and associated Marine Orders 21, 30, 58 - safety and emergency arrangements, prevention of collisions, safe management of vessels, including: • Appropriate lighting, navigation and communication to inform other users • Use of radar and 24/7 watch.	No records of survey or support vessels failing to comply with appropriate navigation, lighting and communication requirements under the *Navigation Act 2012* or its associated Marine Orders.
PS 7.1	Survey crews are instructed to minimise unnecessary external lighting where practicable during the activity (note that lighting for the purpose of safety or navigation purposes is necessary).	Survey crew induction materials include a summary of the requirements to minimise artificial lighting. Survey induction attended by all crew as demonstrated by induction records.

7.8 Atmospheric Emissions: Vessels and Mechanical Equipment

7.8.1 Details of Impacts and Risks

7.8.1.1 Source of Impact/Risk

Atmospheric emissions from the seismic and support vessels during the survey may result in a temporary and localised reduction in air quality.

The seismic survey vessel and support vessels present in the Operational Area will generate atmospheric emissions from power generation equipment, engine exhaust and waste incinerators. Atmospheric emissions generated from internal combustion engines of seismic vessel and support vessels and machinery used during the survey will include SO2, NOX, ozone depleting substances, CO2, particulates and volatile organic compounds (VOCs).

7.8.1.2 Receptors

- Air quality in the immediate vicinity of the vessel exhaust.
- Contribution of greenhouse gases (GHG) and pollutants to the atmosphere.

7.8.2 Impact/Risk Evaluation

The seismic survey vessel and support vessels present in the Operational Area will generate atmospheric emissions from power generation and waste incineration. Atmospheric emissions have the potential to result in a localised reduction in air quality in the immediate vicinity of the vessel exhaust and to contribute to Australian and global levels of GHG in the atmosphere.

Overall emissions from the seismic vessel are expected to be low given the class of vessels to be used and the duration of the survey (60 days). Given the location of the Operational Area offshore is approximately 120 km from the mainland coastline, any emissions are expected to disperse rapidly in the open oceanic conditions and background levels of atmospheric pollutants are expected to be low. Due to the low emissions levels and very low background levels of pollutants, it is anticipated that emissions resulting from the survey will only result in a short term and localised reduction in air quality, with emissions quickly dispersing and decreasing to within background levels. No lasting effect on sensitive receptors is likely. 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.

The consequence of occasional short term and localised disturbance to air quality is Negligible (0). The likelihood of this consequence occurring is Rare (A) and the risk is considered to be Low.

Further information about the selected control measure, the ALARP evaluation, and the demonstration of Acceptability are provided below.

7.8.3 Decision Context

The decision context for atmospheric emissions has been assessed as ‘Type A’, given the impacts/risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

7.8.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
In accordance with MARPOL 73/78 Annex VI (Prevention of Air Pollution) and Marine Order 97, vessels to have a valid IAPP Certificate (International air pollution prevention certificate) confirming: • Incinerators are certified to meet prescribed emissions standards • Diesel engines 130 kW are certified to meet prescribed emission standards	Yes	MARPOL is a legislative requirement for vessels operating in Australian Commonwealth waters and will be implemented by all vessels. Implementation of the regulations will reduce the atmospheric emissions released into the environment. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.	8.1
Vessels will use MGO or MDO grade fuel during the survey, which will have low sulphur content.	Yes	Vessels will use low sulphur Marine Gas Oil (MGO) or Marine Diesel Oil (MDO) during the survey. The current requirement of MARPOL Annex VI is that sulphur content of fuel oil is to not exceed 3.5% by mass (m/m). From 1 January 2020, the new limit for sulphur in fuel oil used on-board vessels will be 0.50% m/m. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.	8.2
Good Industry Practice			
Vessel engines maintained according to manufacturer's specification.	Yes	Vessel engines will be maintained to manufacturer's specification and in accordance with MARPOL 73/78 Annex VI to reduce the atmospheric emissions released into the environment. Good industry practice, environmental benefit outweighs additional cost.	3.3
Vessel incinerators maintained according to manufacturer's specification.	Yes	Vessel incinerators will be maintained to manufacturer's specification and in accordance with MARPOL 73/78 Annex VI to reduce the atmospheric emissions released into the environment. Good industry practice, environmental benefit outweighs additional cost.	8.3
Alternatives/Substitutes Considered			
No practical alternative or substitute to the above controls have been identified.	N/A	N/A	N/A
Additional Controls Considered			
Use of renewable fuels to provide vessel power and no incineration of waste offshore.	No	Adopting renewable energy sources would incur considerable cost associated with vessel modifications. Given the low-level of risk identified, this option is not considered commercially viable. Non-fuel powered engines are not considered technically efficient to execute.	N/A
Transferring non-hazardous combustible waste to shore for disposal.	No	If waste were not incinerated offshore, additional cost, safety and environmental implications would be incurred associated with transferring non-hazardous combustible waste to shore for disposal. This would also be unlikely to reduce overall emissions as additional supply vessel visit would be required to collect and transfer the waste to shore, where it would then need to be dealt with.	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No further practicable improvements to the above controls have been identified.	N/A	N/A	N/A
ALARP Statement			
The residual risk associated with atmospheric emissions has been determined to be Low. CGG considers the adopted control measures appropriate to manage the impacts and risks of atmospheric emissions. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Negligible (0)	Rare (A)	Low

7.8.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for atmospheric emissions, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Environmental Performance Monitoring and Reporting (Section 9.3).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.

Context	Factor	Demonstration
		Conservation Advice, Recovery Plans, and Other Guidelines:
		No species Recovery Plans or Conservation Advice set requirements relating to the management of atmospheric emissions.
		Conservation values and objectives of the North-west Marine Parks Management Plan
		The Operational Area is not located within any AMPs. The management prescriptions for AMPs does not include information on atmospheric emissions from commercial vessels/operations.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to atmospheric emissions.
Legislation and Other	Legal Requirements	The proposed controls meet or exceed the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and associated AMSA Marine Orders under the *Protection of the Sea (Prevention of Air Pollution) Act 1983* for the management of emissions at sea.
Industry Standards	Industry Standards and Best Practices	No industry standards and best practice have been identified that relate to atmospheric emissions.
Ecological Sustainability Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with atmospheric emissions during the Sauropod 3D MSS.
Acceptability Statement		
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential impacts from atmospheric emissions meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, atmospheric emissions are unlikely to result in potential impact greater than localised and short-term local concern to air quality. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 7.8.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.		

7.8.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID
EPO 8	Atmospheric emissions to meet or exceed the requirements of MARPOL Annex VI and AMSA Marine Order 97	PS 8.1 PS 8.2 PS 8.3

Number	Performance Standards	Measurement Criteria
PS 8.1	In accordance with MARPOL 73/78 Annex VI (Prevention of Air Pollution) and Marine Order 97, vessels have a valid IAPP Certificate confirming: • Incinerators certified to meet prescribed emissions standards • Diesel engines 130 kW certified to meet prescribed emission standards.	Records of the pre-survey environmental checklist confirm that a current IAPP certificate is sighted on-board vessels.
PS 8.2	Vessels use MGO or MDO with a low sulphur content of ≤3.5% by mass (m/m). If the survey is completed after 1 January 2020 sulphur content is not to exceed 0.50% m/m.	Records / oil logbook confirm MGO or MDO grade fuel is used, and fuel data sheet confirms sulphur content.
PS (refer to PS 3.3)	Vessel engines are maintained according to manufacturer's specifications.	Records verify that engines and propulsion system maintenance meet this standard.
PS 8.3	Incinerators are certified and maintained according to manufacturer's specifications.	Records confirm that the incinerator's MARPOL 73/78 certification is current and sighted, and maintained as per maintenance records.

8 Environmental Risk Assessment – Unplanned Events

This section presents the evaluation of environmental impacts and risks completed for unplanned events associated with the Sauropod 3D MSS using the methodology described in Section 6, as required by OPGGS (E) Regulations 13(5) and 13(6).

A summary of the residual rankings for all impacts and risks identified and assessed in this section are summarised in Table 8-1.

Table 8-1 – Environmental Impact and Risk Ranking Summary

Impact/Risk	**EP Section No.**	**Residual Risk**		
		Consequence	**Likelihood**	**Risk Ranking**
Hydrocarbon Spill – Vessel Collision	8.2	Moderate (2)	Rare (A)	Low
Hydrocarbon Spill – Bunkering	8.3	Negligible (0)	Rare (A)	Low
Chemical Spill – Single Point Failure	8.4	Negligible (0)	Rare (A)	Low
Physical Presence: Entanglement / Collision with Marine Fauna	8.5	Major (4)	Rare (A)	Medium
Physical Presence: Loss of Equipment	8.6	Minor (1)	Rare (A)	Low
Discharge: Loss of Hazardous or Non-Hazardous Solid Waste	8.7	Minor (1)	Rare (A)	Low
Introduction of Invasive Marine Species: Ballast Water and Biofouling	8.8	Moderate (2)	Rare (A)	Low

8.1 Hydrocarbon and Chemical Spills

8.1.1 Hydrocarbon and Chemical Properties

The following types of hydrocarbons and chemicals are likely to be present on the seismic vessel and support vessels in varying quantities during the survey:

- Marine diesel (Marine Gas Oil [MGO] or Marine Diesel Oil [MDO]) used to fuel the vessels
- Hydraulic fluids such as engine and synthetic oils required for equipment and engine use
- Chemicals for cleaning and maintenance purposes.

8.1.2 Credible Spill Scenarios

Credible hydrocarbon and chemical spill scenarios were identified during the environmental risk assessment undertaken for this EP, taking into account:

- Survey activities
- Known volumes of hydrocarbons and chemicals stored on the vessels, as well as material transfer rates and reaction times for spill detection and mitigation
- Design features inherent to the vessel and storage areas (e.g. bunds)
- Proximity to sensitive receptors and features of conservation significance.

The resulting credible spill scenarios selected for assessment are summarised in Table 8-2.

Table 8-2 – Credible Hydrocarbon and Chemical Spill Scenarios

Scenario	Spilt material and volume	Description
Vessel fuel tank rupture	257 m^3 of marine diesel	A collision between the survey vessel, support vessel or a third-party vessel has the potential to result in the breach of the hull and subsequent rupture of a fuel tank. A major spill to sea as a result of vessel collision/grounding is only likely to occur under exceptional circumstances where these conditions resulted in significant damage to one or more of the fuel tanks in the hull of the vessel. These may include: • Navigational error • Vessel loss of power • Floundering due to weather. If a collision/grounding involving the seismic vessel occurred, the worst-case credible scenario would be the loss of the largest single fuel tank volume (consistent with AMSA (2013) guidelines), which is 257 m^3 of marine diesel. 3D Oil conducted hydrocarbon spill modelling for the largest fuel tank size in their planned vessel type (of 280 m^3). This scenario (results in Appendix F:) is used for the basis of this risk assessment as it is larger than that of the proposed vessel (of 257 m^3) and therefore is considered to be a conservative assessment.
Vessel refuelling failure	1.2 m^3 to 25 m^3 of marine diesel	Vessel refuelling failure may result in the release of marine diesel to the marine environment. Through the use of dry-break couplings (which provide an automatic mechanism to seal off both the hose and the fixed pipe end when the hose is disconnected), the maximum credible spill volume from a refuelling failure is considered to be the maximum typical volume of a transfer hose (1.2 m^3). In the event dry break couplings fail, guidelines indicate the maximum credible spill volume from a refuelling incident with continuous supervision is equivalent to the volume of marine diesel transferred within a 15-minute period (AMSA 2013a), which represent the estimated time required to shut down refuelling operations following discovery of a spill. Based on a transfer volume of 100 m^3/hr, this may result in a spill volume of 25 m^3.
Single point failure (overboard)	1 m^3 of hydraulic fluids or chemicals	A single point failure may occur as a result of mechanical/ structural failure, human error or poor housekeeping. Should a spill occur on deck, controls such as equipment bunds, scupper plugs and on-board clean up should prevent the spilt material reaching the marine environment. However, in the event these controls fail, or are not implemented, spill volumes released to the environment are likely to be less than 1 m^3 based on the inventory typically used on deck.

The identified credible spill scenarios shown in Table 8-2 provide a representative range of spill sizes and locations. Other scenarios were either deemed non-credible, or else the risk of environmental impacts associated with spill scenarios involving fewer sensitive locations, shorter durations or smaller spill volumes was already captured through the assessment of the selected scenarios for consideration in this EP.

To understand the fate and trajectory of a potential spill, hydrocarbon spill modelling was undertaken on the identified worst-case credible scenario (Appendix F:). Given the volumes involved, impacts and risks associated with a single point failure or a vessel refuelling spill would be expected to be considerably less than those described for a vessel collision scenario.

8.1.3 Spill Modelling Methodology

3D Oil commissioned RPS to undertake quantitative hydrocarbon spill modelling for the Sauropod 3D MSS, using a three-dimensional hydrocarbon spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program) (RPS 2019, Appendix F:). SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding *et al.* 1994; French *et al.* 1999; French-McCay 2003; French-McCay 2004; French-McCay *et al.* 2004; Spaulding *et al.* 2015).

The SIMAP model calculates two components: (i) the transport, spreading, entrainment, evaporation and decay of surface oil slicks and, (ii) the entrained and dissolved hydrocarbons released from the slicks into the water column. Input specifications for oil types include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

The SIMAP trajectory model separately calculates the movement of the material that: (i) is on the water surface (as surface slicks), (ii) in the water column (as either entrained whole oil droplets or dissolved hydrocarbons), (iii) has stranded on shorelines, or (iv) that has precipitated out of the water column onto the seabed. The model calculates the transport of surface slicks from the combined forces exerted by surface currents and wind acting on the oil. Transport of entrained oil (oil that is below the water surface) is calculated using the currents only.

SIMAP's stochastic model was used to quantify the probability of exposure to the sea surface and in-water and probability of shoreline contact from the hypothetical spill scenario.

Each simulation was configured with the same spill information (i.e. spill volume, duration and oil type) except for the start time and date. This approach ensures that the predicted transport and weathering of an oil slick is subject to a wide range of possible current and wind conditions.

During each spill trajectory, the model records the grid cells exposed to hydrocarbons, as well as the time elapsed. Once all the spill trajectories have been run, the model then combines the results from the individual simulations to determine the following:

- Maximum exposure (or load) observed on the sea surface
- Probability of contact to any shorelines
- Probability of contact to individual sections of shorelines
- Maximum volume of oil that may contact shorelines from a single simulation
- Maximum load that an individual shoreline may experience
- Maximum exposure from entrained hydrocarbons observed in the water column
- Maximum exposure from dissolved aromatic hydrocarbons observed in the water column.

The stochastic model output does not represent the extent of any one spill trajectory (which would be significantly smaller) but rather provides a summary of all trajectories run for the scenario.

Inputs for the modelling are summarised in Table 8-3.

Table 8-3 – Spill Modelling Inputs

Parameters	Modelling Inputs
Spill release locations	One – northern boundary of Operational Area
Spill volume	280 m^3
Hydrocarbon type	MDO
Release type	Surface
Spill duration	Six hours
Simulation duration	30 days
No. of simulations	One hundred randomly selected trajectories modelled per season (three) using a range of wind and current conditions. Three hundred simulations in total
Modelled seasons	Summer (December to February) Transitional (March, October and November) Winter (April to September)

8.1.3.1 Release Location Selection

The release location selected for the spill modelling is the closest point on the northern boundary of the Operational Area to the Argo-Rowley Terrace Marine Park, the Rowley Shoals Marine Park (State waters) and the Mermaid Reef Marine Park, which represent the nearest sensitive environmental receptors. The specific location is detailed in Table 8-4.

Table 8-4 – Location of the Spill Release Site

Latitude	Longitude	Water Depth (m)
-17°56"17.0'	119°30"14.8'	160

8.1.3.2 Seasonality

To ensure that modelling results are representative of the range of metocean conditions experienced during the survey period, random conditions were selected to represent different wind and current conditions. A total of 100 spill trajectories per season were modelled, resulting in a total of possible 300 spill trajectories.

8.1.3.3 Hydrocarbon Exposure Thresholds

Based on the modelling outcomes, nearby sensitive locations may be contacted by hydrocarbons either at the surface or in the water column. In order to determine the ecological effects of a spill, different thresholds were considered for the risk assessment as follows:

- Surface hydrocarbon thresholds, to assess physical effects on sensitive receptors offshore
- Shoreline accumulation thresholds, to assess physical effects on sensitive receptors onshore
- Water column exposure thresholds, to assess toxicity effects to sensitive receptors offshore from entrained and dissolved aromatic hydrocarbons.

The hydrocarbon exposure thresholds are summarised in Table 8-5, with further detail provided below. These thresholds are consistent with, and in some cases more conservative than, the exposure thresholds for floating, shoreline, dissolved and entrained hydrocarbons recommended by NOPSEMA in the Bulletin #1 "Oil spill modelling" April 2019.

Table 8-5 – Hydrocarbon Exposure Thresholds

Exposure Type	Hydrocarbon Concentration	Potential Level of Exposure
Surface Exposure (g/m^2)	1	Low
	10	Moderate
	25	High
Shoreline Contact (g/m^2)	10	Low
	100	Moderate
	1,000	High
Dissolved Hydrocarbon Concentration (ppb)#	6	Low
	50	Moderate
	400	High
Entrained Concentration (ppb)#	10	Low
	100	Moderate
	1,000	High

#These threshold values refer to a) instantaneous concentrations (i.e. exposure over a one-hour period) and b) time-averaged exposure over a 48-hour window. Both exposure durations are considered in the presentation of results below.

8.1.3.4 Hydrocarbon Characteristics

MDO is a light-persistent fuel oil used in the maritime industry. It has a density of 829.1 kg/m^3 (API of 37.6) and a low pour point (-14 °C). The low viscosity (4 cP) indicates that this oil will spread quickly when released and will form a thin to low thickness film on the sea surface, increasing the rate of evaporation. Approximately, 5% (by mass) of the oil is categorised as a group II oil (light-persistent) based on categorisation and classification derived from AMSA (2015) guidelines. The classification is based on the specific gravity of hydrocarbons in combination with relevant boiling point ranges.

Table 8-6 details the physical properties of MDO, while Table 8-7 presents the boiling point ranges of the MDO used in the modelling study.

Table 8-6 – Physical Properties of MDO

Characteristic	Value
Density (kg/m^3)	829.1
API	37.6
Dynamic viscosity (cP)	4
Pour point (°C)	-14
Wax content (%)	1
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light - Persistent

Table 8-7 – Boiling Point Ranges of MDO

Characteristic	Not Persistent			Persistent
	Volatile	Semi-volatile	Low volatility	Residual
Boiling point (°C)	180	180-265	265-380	380
Percent	6.0	34.6	54.4	5.0

Figure 8-1 shows weathering graphs for a 280 m^3 release of MDO over six hours (tracked for 30 days) during three static wind conditions. The prevailing weather conditions will influence the weathering and fate of the MDO. Under lower wind-speeds (five knots), the MDO will remain on the surface longer, spread quicker, and in turn increase the evaporative process. Conversely, sustained stronger winds (15 knots) will generate breaking waves at the surface, causing a higher amount of MDO to be entrained into the water column and reducing the amount available to evaporate.

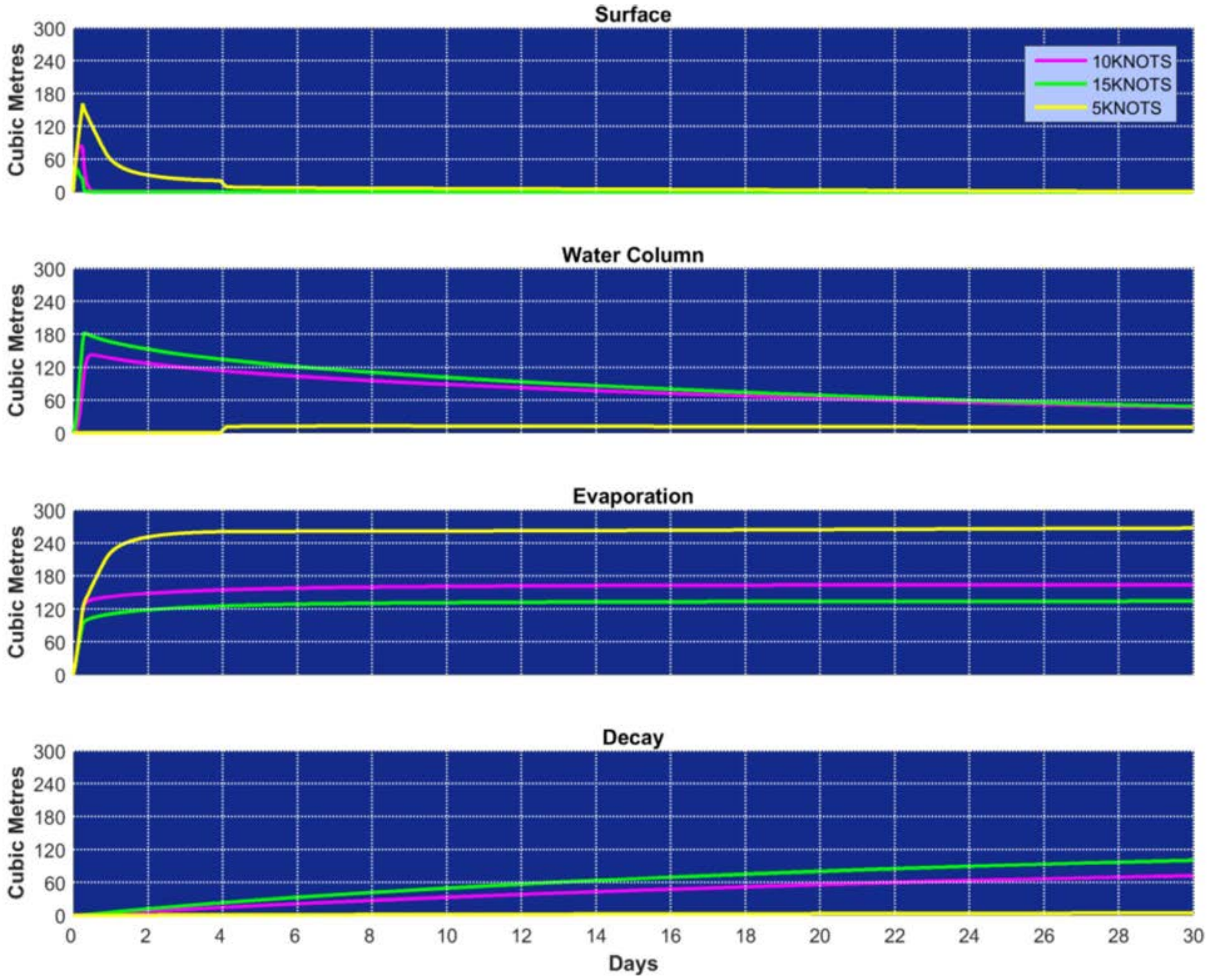


Figure 8-1 – Weathering of MDO under Three Static Wind Conditions (5, 10 and 15 Knots). The Results are Based on a 280 m^3 Surface Release of MDO Over Six Hours, Tracked for 30 Days

8.2 Hydrocarbon Spill – Vessel Collision

8.2.1 Details of Impacts and Risks

8.2.1.1 Source of Impact/Risk

Accidental hydrocarbon release to the marine environment due to a vessel collision, with the potential hazards of temporary and localised reduction in water quality and temporary toxicity effects to marine biota.

A seismic survey vessel can have a fuel capacity in excess of 1,000 m^3 that is distributed through multiple isolated tanks typically located mid-ship, and typically ranging in capacity from 22–280 m^3. There will be two support vessels utilised throughout the Sauropod 3D MSS. The marine diesel storage capacity of a support vessel can also be in the order of 1,000 m^3 in total, which is distributed through multiple isolated tanks typically located mid-ship and ranging in capacity from 22–105 m^3.

If a vessel collision occurred, the worst-case credible scenario would be the loss of the largest single fuel tank volume (consistent with AMSA (2013) guidelines), which is 257 m^3 of marine diesel. This is less than the modelled scenario of 280 in^3 therefore this scenario is considered to be conservative.

8.2.1.2 Receptors

- Marine fauna
  - Cetaceans, marine reptiles, seabirds, fishes/elasmobranchs, planktonic communities.

- Water quality.
- Marine protected areas.
- Commercial fisheries.

8.2.2 Impact/Risk Evaluation

8.2.2.1 Spill Modelling Results

8.2.2.1.1 Surface Hydrocarbons

Modelling indicated that, in the event of a 280 m^3 spill of MDO, sea surface hydrocarbons at low (1 g/m^2), moderate (10 g/m^2) and high (25 g/m^2) exposure levels may occur up to a maximum of approximately 66 km, 14 km and 7 km from the spill release locations, respectively (Table 8-8 and Figure 8-2). This result does not indicate a continuous slick, but that patches of the surface slick may exceed thresholds out to these distances from the spill release location. The evaporative nature of MDO and environmental conditions in the area result in short-lived surface hydrocarbon exposures, with surface exposures reduced to less than 10 g/m^2 after approximately 24–48 hours (RPS 2019). Generally, sea surface hydrocarbon volumes were negligible after approximately 10-15 days and did not persist beyond 17 days.

The area of potential instantaneous exposure to surface hydrocarbons for the low, moderate and high thresholds during the transitional season is presented in Figure 8-2. It is important to note that the area presented is based on 100 hypothetical spill trajectories and does not represent the predicted outcome of a single spill event. This area falls within the predicted annualised EMBA for entrained hydrocarbons, and hence no separate EMBA for surface hydrocarbons has been defined.

No sensitive receptors were predicted to be exposed to surface oil at the moderate and high thresholds. The Argo-Rowley Terrace Marine Park is the only sensitive receptor showing potential exposure to surface oil at the low threshold, with a low likelihood of 1–2% (during the summer and winter seasons only) (Table 8-8).

Table 8-8 – Summary of Spill Modelling Results for Surface Hydrocarbons, Including Sensitive Receptors with Predicted Exposure Above Threshold Concentrations

Season	Distance and direction	Areas of potential sea surface exposure		
		1 g/m^2	**10 g/m^2**	**25 g/m^2**
Summer	Maximum distance from release site (km)	31	11	4
	Direction	N	SSE	NW
	Probability of oil exposure to Argo-Rowley Terrace Marine Park (%)	2	-	-
	Minimum time before oil exposure to Argo-Rowley Terrace AMP (hrs)	1	-	-
Transitional	Maximum distance from release site (km)	66	14	7
	Direction	WSW	SSE	SE
	Probability of oil exposure to Argo-Rowley Terrace AMP (%)	-	-	-
	Minimum time before oil exposure to Argo-Rowley Terrace AMP (hrs)	-	-	-
Winter	Maximum distance from release site (km)	31	12	6
	Direction	NNE	WNW	NW
	Probability of oil exposure to Argo-Rowley Terrace AMP (%)	1	-	-
	Minimum time before oil exposure to Argo-Rowley Terrace AMP (hrs)	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.

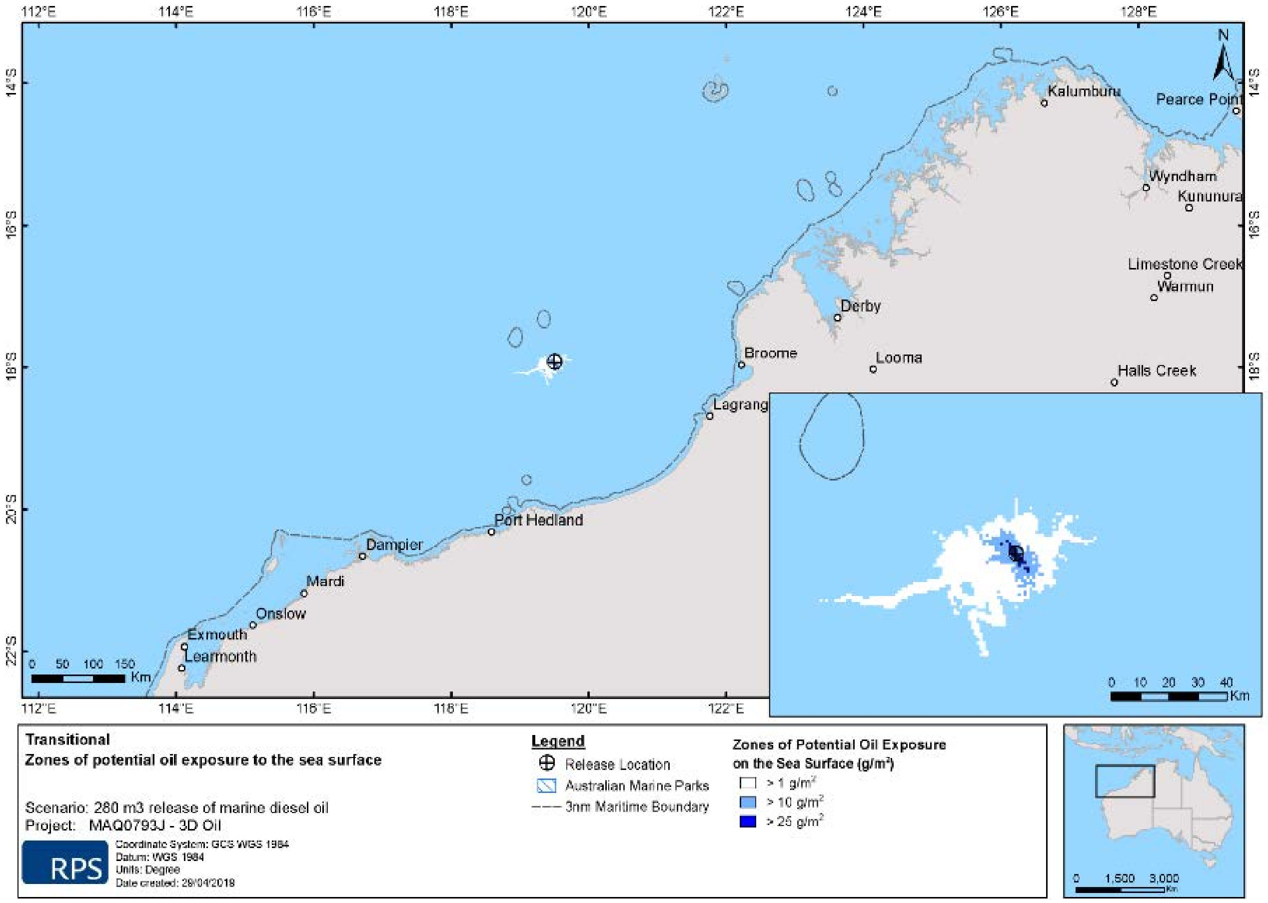


Figure 8-2 – Zones of Potential Oil Exposure on the Sea Surface, In the Event of a 280 m³ MDO Spill Within the Operational Area During the Transitional Season

8.2.2.1.2 Shoreline Accumulation

No shoreline contact above the exposure thresholds was predicted by the modelling at any location. It is acknowledged that modelling was only conducted at a single location along the northern boundary of the Operational Area. Given the extent of the predicted EMBA (refer Figure 4-1) no shoreline contact at any mainland location is predicted to occur for a 280 m³ marine diesel spill anywhere within the Operational Area, including at the southeast corner, which is closest to the coast.

8.2.2.1.3 Entrained Hydrocarbons

Modelling of entrained hydrocarbons considered exposure to receptors at 0–10 m water depth at or above the exposure thresholds discussed in Section 8.1.3.3. The maximum entrained hydrocarbon exposure was considered against the thresholds for both instantaneous exposure concentrations and time-averaged exposure concentrations over a 48-hour period.

The maximum time-averaged exposure to entrained hydrocarbons over 48 hours ranged from 402 ppb to 499 ppb for the transitional and summer seasons respectively. The maximum instantaneous exposure to entrained hydrocarbons ranged from 3,251 ppb to 6,287 ppb for the winter and summer seasons respectively (Table 8-9).

The zone of potential instantaneous entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m³ of surface release of MDO is presented in Figure 8.3 for the summer season. The predicted annualised (i.e. all seasons) EMBA for entrained hydrocarbons above the moderate threshold (100 ppb), based on instantaneous exposures, is presented in Figure 8-4. It is important to note that the area presented is based on 300 hypothetical spill trajectories (100 per season) and does not represent the predicted outcome of a single spill event. The EMBA for the north-west corner of the Operational Area was also extrapolated to the three other corners to encompass all environmental values and sensitivities that could potentially be affected in the event of a spill (Figure 8-4).

No sensitive receptors were predicted to be impacted by entrained hydrocarbons above the high threshold (1,000 ppb). Sensitive receptors potentially impacted above the low and moderate thresholds (10 ppb and 100 ppb respectively) are summarised in Table 8-9.

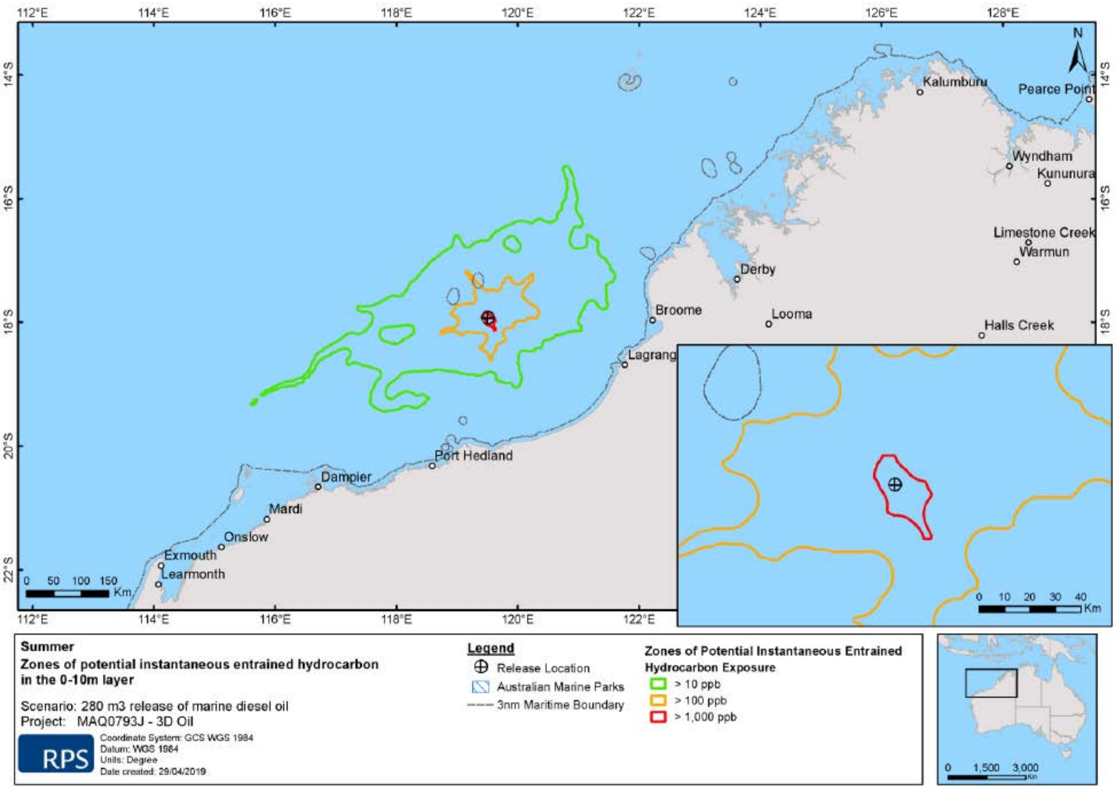


Figure 8-3 – Zones of Potential Instantaneous Entrained Oil Exposure at 1-10 m Below the Sea Surface, in the Event of a 280 m³ MDO Spill Within the Operational Area During the Summer Season

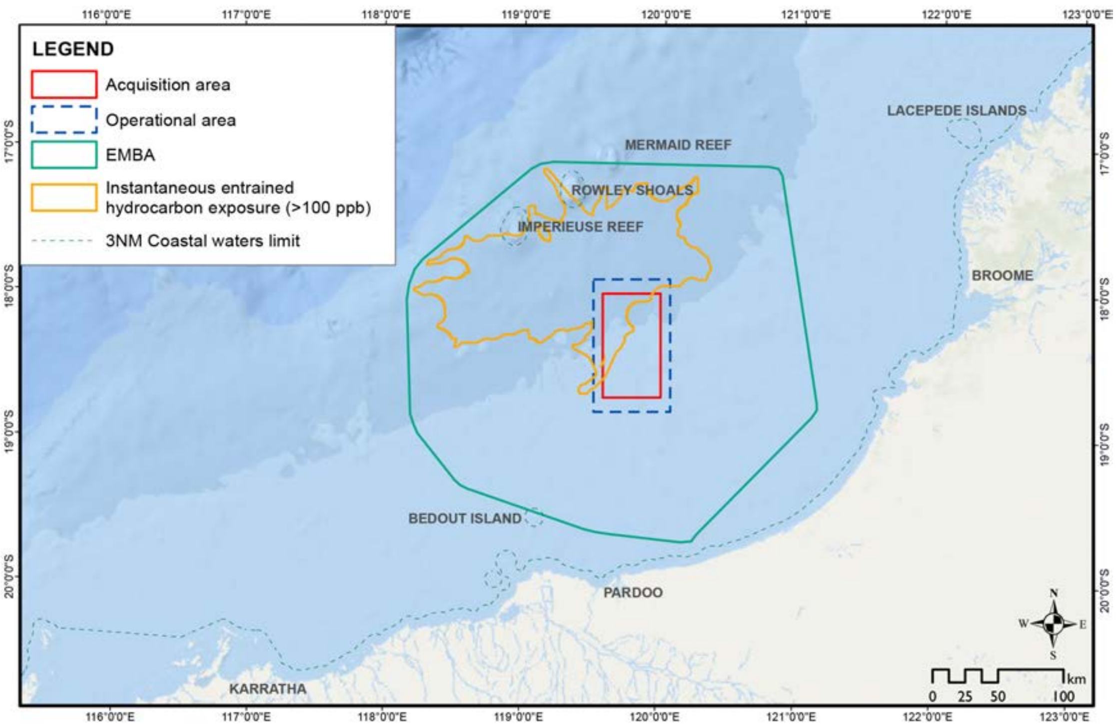


Figure 8-4 – Predicted Annualised EMBA for Entrained Hydrocarbons Above 100 ppb Resulting from a 280 m³ MDO Spill Within the Operational Area

Table 8-9 – Summary of Spill Modelling Results for Entrained Hydrocarbons, Including Sensitive Receptors with Predicted Exposure Above Threshold Concentrations

Seas	Receptor	Time-averaged (48-hr) entrained hydrocarbon exposure			Instantaneous entrained hydrocarbon exposure		
		Maximum concentration (ppb)	Probability of exposure (%) at 10 ppb	Probability of exposure (%) at 100 ppb	Maximum concentration (ppb)	Probability of exposure (%) at 10 ppb	Probability of exposure (%) at 100 ppb
Summer	Argo-Rowley Terrace AMP	114	11	2	607	23	8
	Mermaid Reef AMP	21	2	-	66	3	-
	Rowley Shoals MP	49	5	-	185	8	2
	Imperieuse Reef	33	4	-	59	7	-
	Clerke Reef	40	2	-	158	7	1
	Mermaid Reef	20	1	-	55	2	-
	Mermaid Reef KEF	49	5	-	213	12	2
	North West Shelf IMCRA	402	66	14	6,287	89	74
Transitional	Argo-Rowley Terrace AMP	89	14	-	401	21	6
	Mermaid Reef AMP	26	5	-	76	10	-
	Rowley Shoals MP	30	7	-	94	14	-
	Imperieuse Reef	26	3	-	89	8	-
	Clerke Reef	26	6	-	84	14	-
	Mermaid Reef	8	-	-	28	3	-
	Mermaid Reef KEF	73	9	-	177	16	2
	North West Shelf IMCRA	499	49	16	3,251	79	54
Winter	Argo-Rowley Terrace AMP	95	13	-	338	17	6
	Mermaid Reef AMP	18	1	-	100	6	1
	Rowley Shoals MP	57	8	-	207	17	2
	Imperieuse Reef	42	4	-	105	11	1
	Clerke Reef	7	-	-	27	2	-
	Mermaid Reef	8	-	-	57	3	-
	Mermaid Reef KEF	57	13	-	261	18	6
	North West Shelf IMCRA	398	64	21	4,355	84	70

A dash indicates that the threshold was not reached. The results were calculated from 300 spill trajectories and do not represent a single spill event.

8.2.2.1.4 Dissolved Hydrocarbons

Modelling of dissolved hydrocarbons considered exposure to receptors at 0–10 m water depth at or above the exposure thresholds discussed in Section 8.1.3.3. The maximum dissolved hydrocarbon exposure was considered against the thresholds for both instantaneous exposure concentrations and time-averaged exposure concentrations over a 48-hour period.

The maximum time-averaged exposure to dissolved hydrocarbons over 48 hours remained below the low threshold value of 6 ppb for all modelled seasons. The maximum instantaneous exposure to dissolved hydrocarbons ranged from 6 ppb to 73 ppb for the transitional and summer seasons respectively (Table 8-10).

The area of potential instantaneous exposure to dissolved hydrocarbons for the low and moderate thresholds during the winter season is presented in Figure 8.5 (the high threshold was not exceeded). It is important to note that the area presented is based on 100 hypothetical spill trajectories and does not represent the predicted outcome of a single spill event. This area falls within the predicted annualised EMBA for entrained hydrocarbons (Figure 8-4), and hence no separate EMBA for dissolved hydrocarbons has been defined.

No sensitive receptors were predicted to be exposed above the low threshold of 6 ppb to dissolved hydrocarbons over a time-averaged period of 48 hours (Table 8-10).

No sensitive receptors were predicted to be exposed instantaneously to dissolved hydrocarbons at the moderate threshold (50 ppb). The Argo-Rowley Terrace Marine Park, Rowley Shoals Marine Park, Mermaid Reef Marine Park and Commonwealth waters KEF showed potential instantaneous exposure to dissolved hydrocarbons at or above the low threshold (6 ppb), with a low likelihood of 1–2% (during the summer and winter seasons only, refer to Table 8-10).

Table 8-10 – Summary of Spill Modelling Results for Dissolved Hydrocarbons, Including Sensitive Receptors with Predicted Exposure Above Threshold Concentrations

Season	Receptor	Time-averaged (48-hr) dissolved hydrocarbon exposure		Instantaneous dissolved hydrocarbon exposure	
		Maximum concentration (ppb)	Probability of exposure (%) at 6 ppb	Maximum concentration (ppb)	Probability of exposure (%) at 6 ppb
Summer	Argo-Rowley Terrace AMP	1	-	8	1
	North West Shelf	4	-	73	21
Transitional	Argo-Rowley Terrace AMP	<1			-
	North West Shelf	3	-	37	16
Winter	Argo-Rowley Terrace AMP	1	-	19	2
	Rowley Shoals	<1	-	13	1
	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF	<1	-	14	1
	North West Shelf IMCRA	4	-	48	36

The results were calculated from 300 spill trajectories and do not represent a single spill event.

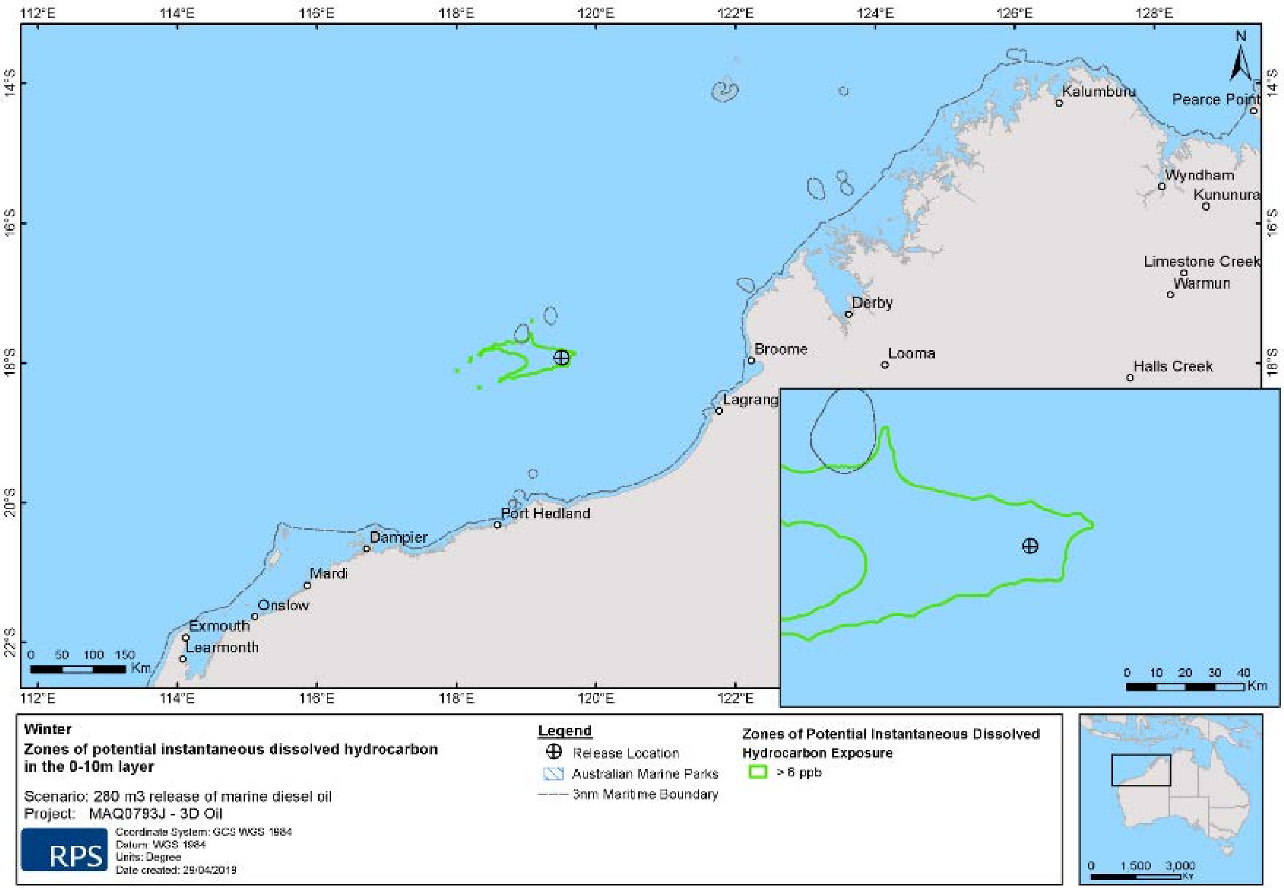


Figure 8-5 – Zones of Potential Instantaneous Dissolved Hydrocarbon Exposure at 0– 10 M Below the Sea Surface in the Event of a 280 m^3 Within the Operational Area During Winter

8.2.2.1.5 Summary of Modelling Results

- No shoreline contact above the low (1 g/m^2) surface oil threshold was predicted for the modelled scenario, for any season.
- Modelling results demonstrated that surface oil at low (1 g/m^2), moderate (10 g/m^2) and high (25 g/m^2) exposure levels could potentially travel greater distances during the transitional period, compared to the summer and winter periods. The maximum distance travelled by surface oil during the transitional season for the low, moderate and high threshold was 66 km, 14 km and 7 km, respectively.
- The modelling results demonstrated a low probability (1–2%) of surface oil exposure at the low threshold to the Argo-Rowley Terrace Marine Park and zero probability of surface oil exposure (at any threshold) to the Rowley Shoal Marine Park and the Mermaid Reef Marine Park.
- The maximum time-averaged exposure to entrained hydrocarbons ranged from 4 ppb to 499 ppb for the transitional and winter seasons respectively. The maximum instantaneous exposure to entrained hydrocarbons ranged from 3,251 ppb to 6,287 ppb for the transitional and summer seasons respectively.
- The maximum time-averaged exposure to dissolved hydrocarbon at the depths of 0-10 m remained less than 1 ppb for the winter and transitional seasons while reaching 4 ppb for the summer and winter seasons for various receptors. The maximum instantaneous exposure to dissolved hydrocarbons ranged from 6 ppb to 73 ppb for the transitional and summer seasons, respectively.
- There were no zones of potential time-averaged exposure to dissolved hydrocarbons above the low exposure threshold (6 ppb).

8.2.2.2 Potential Impacts to Environmental Values

8.2.2.2.1 Planktonic Communities

Planktonic communities within the entrained hydrocarbons EMBA for a 280 m^3 marine diesel spill within the Operational Area will include zooplankton, fish eggs and larvae, and potentially coral spawn and larvae. Spatially, the EMBA has the potential to overlap with spawning aggregations of some fishes. Given the year-round spawning of some species, the Sauropod 3D MSS has the potential to overlap spawning periods for some fish species.

The entrained hydrocarbons EMBA for all seasons partially overlaps Imperieuse and Clerke reefs, and the proposed acquisition period for the survey (January to May) means that the activity could potentially overlap the main spawning episode for corals in the region (March–April). The reproductive cycles of the broadcast spawning species at the Rowley Shoals have been described, with mass spawning occurring biannually in spring (October) and autumn (March) (Gilmour *et al.* 2016). The entrained hydrocarbons EMBA for the transitional period (which includes March) does not overlap either Imperieuse or Clerke reefs.

There is potential for 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, fish and coral eggs and larvae may be impacted by hydrocarbons entrained in the water column. However, following release, the marine diesel 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 fish spawning aggregating near the surface, combined with the quick evaporation and dispersion of marine diesel, impacts to fish eggs and larvae are not expected to be significant.

Any planktonic communities 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 relatively small EMBA and the fast population turnover of open water planktonic populations, it is considered that any potential impacts will be low and temporary.

8.2.2.2.2 Water Quality

It is likely water quality will be reduced within a localised area around the marine diesel spill, with contamination levels above background levels and/or national/international water quality standards. However, such impacts to water quality would be temporary and highly localised spatially due to the relatively small EMBA and the rapid dispersion of marine diesel. The potential impact is therefore considered low.

8.2.2.2.3 Protected Species

As identified in Section 4.3.5, a range of protected species may be encountered within and adjacent to the Operational Area and therefore could be impacted by a marine diesel spill.

8.2.2.2.4 Cetaceans

No critical habitats or aggregation areas (feeding, breeding, resting) for cetaceans have been identified within the EMBA for a 280 m^3 diesel spill within the Operational Area and it is therefore considered that any cetacean species that are present will be in low numbers and transient, as they traverse the area. The Humpback whale migration BIA is located approximately 15 km south of the Operational Area. The breeding, nursing and calving BIA for Humpback whales along the Kimberley coastline is located 255 km east of the Operational Area.

The entrained hydrocarbons EMBA partially overlaps the Humpback whale migration BIA (refer Figure 4.10). However, the proposed timing for acquisition of the Sauropod 3D MSS (January to May) means that there will be no overlap with either the northbound or southbound migration of Humpback whales through the region (June to October). The Pygmy blue whale migration and distribution BIAs pass along the shelf edge at depths between 500 m and 1,000 m. The Operational Area overlaps with the distribution BIA, and the migration BIA is located approximately 72 km from the Operational Area. The entrained hydrocarbons EMBA partially overlaps the Pygmy whale migration BIA (refer Figure 4.10). Hence, there is a low probability of isolated individuals transiting through the entrained hydrocarbons EMBA during the beginning of their northbound migration (April to July). The proposed acquisition period avoids the southbound migration of Pygmy blue whales in the region (September to November).

As summarised in Table 4-6, there is the possibility that a number of other cetacean species may be present in the Operational Area and surrounding waters during acquisition of the survey (e.g. Bryde's, Fin, Sei, Killer and Sperm whales, Spotted bottlenose dolphin). 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.

Marine mammals are highly mobile, and a number of field and experimental observations indicate whales and dolphins may be able to detect and avoid surface slicks. However, instances have been observed where animals have swum directly into oiled areas without seeming to detect the slicks or because the slicks could not be avoided. Cetaceans may exhibit avoidance behaviour and move away from the spill-affected area.

Marine mammals that have direct physical contact with surface slicks and entrained hydrocarbons may suffer surface fouling or ingestion of hydrocarbons and inhalation of toxic vapours. This may result in the irritation of sensitive membranes such as the eyes, mouth, digestive and respiratory tracts and organs, impairment of the immune system or neurological damage (Etkins 1997; IPIECA 1995). For example, fouling of baleen whales (e.g. Humpback and Pygmy blue whales) may disrupt feeding by decreasing the ability to intake prey. If prey (fish and plankton) is also contaminated, this can result in the absorption of toxic components of the hydrocarbons (polycyclic aromatic hydrocarbons - PAHs). Toothed whales (including dolphins) are ‘gulp-feeders’ targeting specific prey at depth in the water column away from any potential surface slick and are likely to be less susceptible to the ingestion of hydrocarbons. Furthermore, given cetaceans are smooth skinned and hydrocarbons would not tend to adhere to body surfaces, the likely biological consequences of physical contact with surface hydrocarbons are likely to be in the form of irritation and sub-lethal stress.

In the unlikely event of a hydrocarbon release, it is considered that contact will be low and temporary in nature due to the relatively small EMBA, the rapid dispersion of marine diesel, and the fact that only isolated individuals transiting the area could come into contact with surface slicks.

8.2.2.2.5 Fishes, Sharks and Rays

Hydrocarbon droplets can physically affect fishes and elasmobranchs (sharks and rays) exposed for an extended duration (weeks to months). Smothering through coating of gills can lead to the lethal and sub-lethal effects of reduced oxygen exchange, and coating of body surfaces may lead to increased incidence of irritation and infection. Fish may also ingest hydrocarbon droplets or contaminated food leading to reduced growth.

Near the sea surface, fishes 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 potentially at risk of exposure to the more toxic aromatic components of marine diesel. 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 of time. 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.

Whale sharks located in open offshore waters are most likely transiting the region. The Operational Area overlaps the whale shark foraging BIA that extends north from North West Cape across the North West Shelf (Figure 4-12); however the survey does not overlap with the foraging season which occurs from August - November for the region (see Table 4-7 for details on seasonality). If individuals are present in the Operational Area, their abundance is not expected to be high. The zone of surface hydrocarbons (all thresholds) and the entrained hydrocarbon EMBA overlap the whale shark foraging BIA (Figure 4-12).

Hydrocarbon contact may affect whale sharks through direct physical coating (surface slicks) and ingestion (surface slicks and entrained/dissolved hydrocarbons), particularly if feeding. Whale sharks are vulnerable to surface, entrained and dissolved aromatic hydrocarbon spill impacts, as they filter large amounts of water over their gills, catching planktonic and nektonic organisms (Jarman and Wilson 2004). Whale sharks at Ningaloo Reef have been observed using two different feeding strategies, including passive subsurface ram-feeding and active surface feeding (Taylor 2007). Passive feeding consists of swimming slowly at the surface with the mouth wide open. During active feeding sharks swim high in the water with the upper part of the body above the surface with the mouth partially open (Taylor 2007). These feeding methods would result in the potential for individuals that are present in worse affected spill areas to ingest potentially toxic amounts of surface, entrained or dissolved aromatic hydrocarbons. Large amounts of ingested hydrocarbons may affect their endocrine and immune system in the longer term. The presence of hydrocarbons may cause displacement of whale sharks from the area where they normally feed and rest, and potentially disrupt migration and aggregations to these areas in subsequent seasons. Whale sharks may also be affected indirectly by surface, entrained or dissolved aromatic hydrocarbons through the contamination of their prey. The contamination of their food supply and the subsequent ingestion of prey by whale sharks may also result in long-term impacts as a result of bioaccumulation.

The offshore waters of the Operational Area are unlikely to represent important or significant foraging habitat for whale sharks, and it is most likely that their presence will be limited to isolated individuals transiting the Operational Area and surrounding waters. Individuals that have direct contact with hydrocarbons within the spill affected area may be impacted, but the consequences to migratory whale shark populations will be minor.

Fish populations in the open water, offshore environment of the Operational Area 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 demersal 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 relatively small EMBA and the rapid dispersion of marine diesel, it is considered that any potential impacts will be negligible.

8.2.2.2.6 Marine Reptiles

At the closest point, the Operational Area is located at least 95 km from the nearest nesting BIA for turtles (flatback turtle nesting BIA adjacent to Eighty Mile Beach), and at least 105 km from the foraging BIA for green, flatback and loggerhead turtles adjacent to the Dampier Peninsula. At the closest point, the Operational Area is located at approximately 60 km from the 'Habitat Critical' for flatback turtles adjacent to Eighty Mile Beach. To the north of the Operational Area, there are no BIAs or 'Habitat Critical' for turtles surrounding the Rowley Shoals.

There is partial overlap between the entrained hydrocarbons EMBA and the flatback turtle 'Habitat Critical' adjacent to Eighty Mile Beach (Figure 4-14). The entrained hydrocarbon EMBA also partially overlaps the flatback turtle internesting buffer BIA adjacent to Eighty Mile Beach (Figure 4-13).

Adult sea turtles exhibit no avoidance behaviour when they encounter hydrocarbon slicks (Odell and MacMurray 1986). Contact with surface slicks, or entrained hydrocarbons, can therefore result in hydrocarbon adherence to body surfaces (Gagnon and Rawson 2010) causing irritation of mucous membranes in the nose, throat and eyes leading to inflammation and infection (NOAA 2010). Oiling can also irritate and injure skin, which is most evident on pliable areas such as the neck and flippers (Lutcavage *et al.* 1995). A stress response associated with this exposure pathway includes an increase in the production of white blood cells, and even a short exposure to hydrocarbons, such as crude oil, may affect the functioning of their salt gland (Lutcavage *et al.* 1995).

Hydrocarbons in surface waters may also impact turtles when they surface to breathe and inhale toxic vapours. Their breathing pattern, involving large 'tidal' volumes and rapid inhalation before diving, results in direct exposure to petroleum vapours which are the most toxic component of the hydrocarbon spill (Milton and Lutz 2002). This can lead to lung damage and congestion, interstitial emphysema, inhalant pneumonia and neurological impairment (Etkins 1997; IPIECA 1995).

Due to the absence of potential nesting habitat (i.e. no emergent islands) and the water depths (95–172 m), the Operational Area is highly unlikely to represent important habitat for marine turtles. The 280 m^3 diesel release scenario indicates a relatively small EMBA and a rapid dispersion and evaporation of marine diesel that will be confined to offshore waters, with no contact between surface, dissolved or entrained hydrocarbons and any turtle nesting beaches in the region.

Impacts to sea snakes from direct contact with surface hydrocarbons are likely to result in similar physical effects to those recorded for marine turtles and may include potential damage to the dermis and irritation to mucous membranes of the eyes, nose and throat (ITOPF 2011). They may also be impacted when they return to the surface to breathe and inhale the toxic vapours associated with the hydrocarbons, resulting in damage to their respiratory system.

In general, sea snakes frequent the waters of the continental shelf area, around offshore islands and potentially submerged shoals (water depths 100 m) and while individuals may be present in the Operational Area, their abundance is not expected to be high, given the deep water and offshore location of the activity. Therefore, a hydrocarbon spill may have a minor disruption to a portion of the population however there is no threat to overall population viability.

8.2.2.2.7 Seabirds

There is overlap between the zone of surface hydrocarbons at low, moderate and high exposure thresholds and the breeding and foraging BIA for the White-tailed tropicbird around the Rowley Shoals. There is no overlap between the zone of surface hydrocarbons (at any threshold) and the breeding BIA for the Lesser frigatebird around Bedout Island.

In the unlikely event of a large diesel spill, there is the potential for seabirds to be exposed to surface, entrained and dissolved hydrocarbons. This could result in lethal or sub-lethal effects. 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. Surface entrained or dissolved hydrocarbons are unlikely to impact nesting or egg-laying individuals in colonies, however, it is possible that breeding individuals could come into contact with surface or entrained hydrocarbons while foraging (dive and skim feeding).

Seabirds are vulnerable to contacting surface slicks during feeding or resting on the sea surface, particularly as they do not generally exhibit avoidance behaviour to floating hydrocarbons. Physical contact of seabirds with surface slicks is by several exposure pathways, primarily, immersion, ingestion and inhalation. Such contact with hydrocarbons may result in plumage fouling and hypothermia (loss of thermoregulation), decreased buoyancy and potential to drown, inability to fly or feed, anaemia, pneumonia and irritation of eyes, skin, nasal cavities and mouths (AMSA 2012; IPIECA 2004) and result in mortality due to oiling of feathers or the ingestion of hydrocarbons. Longer term exposure effects that may potentially impact seabird populations include a loss of reproductive success (loss of breeding adults) and malformation of eggs or chicks (AMSA 2012).

Therefore, a diesel spill may result in impacts on individuals within the White-tailed tropicbird breeding/foraging BIA and potentially disruption to a significant portion of the habitat, however this is not expected to result in a threat to the overall population viability of seabirds, due to the relatively small EMBA and the rapid dispersion of marine diesel.

8.2.2.2.8 Marine Protected Areas

Argo-Rowley Terrace Marine Park

There is a small overlap between the zone of surface hydrocarbons at the low exposure threshold (1 g/m^2) and the Multiple Use Zone (MUZ) of the Argo-Rowley Terrace Marine Park. Additionally, the entrained hydrocarbons EMBA overlaps the MUZ and the Special Purpose Zone (Trawl) of this AMP (Figure 4.15).

The designated natural values of this AMP include a range of species (including species listed as threatened, migratory, marine or cetacean under the EPBC Act), foraging and breeding BIAs for seabirds and a migratory BIA for the Pygmy blue whale. Potential impacts to these values from a 280 m^3 marine diesel spill within the Operational Area are assessed in the subsections above.

Potential impacts to commercial fisheries occurring within the MUZ of this AMP are assessed below.

Mermaid Reef Marine Park

There is no overlap between the zone of surface hydrocarbons at the low exposure threshold (1 g/m^2) and the Mermaid Reef Marine Park. There is a very small overlap between the entrained hydrocarbons EMBA and this AMP (winter season only). Maximum instantaneous entrained hydrocarbon concentrations within the Mermaid Reef Marine Park are predicted to range from 30 ppb (summer) to 100 ppb (winter). The area within the marine park predicted to be exposed to entrained hydrocarbons in the 0–10 m upper layer of the water column is restricted to a small patch approximately 2.5 km east of the reef edge. Hence, no seabed habitats or communities of the submerged reef itself are likely to be exposed to entrained hydrocarbons resulting from a marine diesel release within the Operational Area.

Rowley Shoals Marine Park

There is no overlap between the zone of surface hydrocarbons at the low exposure threshold (1 g/m^2) and the waters or islands within the Rowley Shoals Marine Park (State waters). Hence, there will be no shoreline contact or hydrocarbon accumulation within the marine park. As no surface sheens or slicks are likely to occur within the waters of the Rowley Shoals Marine Park, it is highly unlikely that there will be any impacts to socio-economic values of the marine park (i.e. tourism and recreation activities, including fishing and diving/snorkelling charters).

There is overlap between the entrained hydrocarbons EMBA and the Rowley Shoals Marine Park, including exposure to small areas of both Imperieuse and Clerke reefs. Maximum instantaneous entrained hydrocarbon concentrations at Imperieuse and Clerke reefs are predicted to range from 18 ppb (winter) to 158 ppb (summer). Thus, some benthic habitats and communities in the upper layer of the water column (0–10 m) could be exposed to instantaneous concentrations of entrained hydrocarbons 100 ppb, which could result in some sub-lethal effects (e.g. bioaccumulation of hydrocarbons).

8.2.2.2.9 Commercial Fisheries

A 280 m^3 marine diesel spill in the Operational Area is considered unlikely to cause significant direct impacts on the target species fished by the North West Slope Trawl Fishery (NWSTF), the Pilbara Trawl and Trap fisheries (PTMF, PFTIMF), and the Northern Demersal Scalefish Managed Fishery (NDSMF). The target species for these fisheries (demersal finfish and crustaceans) inhabit water depths in the range of 60–200 m and any in-water hydrocarbons are likely to be confined to the upper layers of the water column (0–10 m).

The Mackerel Managed Fishery (MMF) targets pelagic fish species. As described above, adult pelagic fish species are highly mobile and have the ability to move away from the spill affected area or avoid surface waters. The relatively small spill affected area and temporary nature of the predicted marine diesel spill would infer that it is unlikely the hydrocarbon concentrations in the upper layers of the water column would lead to potential exposure of a significant population of pelagic fish to contamination. Given these pelagic species are distributed over a wide geographical area, the impacts at the population or species level are considered very minor in the unlikely event of a marine diesel spill.

However, there is potential that a fishing exclusion zone would be applied in the area of the spill, which would put a temporary ban on fishing activities and therefore potentially lead to subsequent economic impacts on commercial fishing operators if they were planning on undertaking fishing within the area of the spill.

8.2.2.3 Summary

Based on the assessment presented above and the implementation of the identified controls (Section 8.2.4), it is expected that the consequence associated with an accidental hydrocarbon release to the marine environment due to a vessel collision will be Moderate (2). The likelihood of impacts occurring is considered to be Rare (A), resulting in a Low risk to sensitive receptors within and adjacent to the Operational Area.

8.2.3 Decision Context

The decision context for accidental hydrocarbon release to the marine environment due to a vessel collision has been assessed as ‘Type A’, given the impacts/risks are well understood, uncertainty is minimal and little or no stakeholder interest.

8.2.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Adherence with requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea (SOLAS) as implemented in Commonwealth Waters through the *Navigation Act 2012* and associated Marine Orders 21, 30, 58 – safety and emergency arrangements, prevention of collisions, safe management of vessels, including: • Appropriate lighting, navigation and communication to inform other users. • Use of radar and 24/7 watch.	Yes	These are a legislative requirement for vessels operating in Commonwealth waters and will be implemented by all vessels. Adherence to these requirements will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	4.1
Issue of marine navigation warnings and Notice to Mariners of survey presence and towed array	Yes	The Australian Hydrographic Office (AHO) will be contacted four weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	2.1
Pre-survey notification to AMSA JRCC, issue of AUSCOAST warnings	Yes	The AMSA JRCC will be contacted 24–48 hrs before operations commence for issuing of AUSCOAST warnings. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	2.2
Good Industry Practice			
Notification will be provided to fisheries stakeholders, prior to commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders upon completion of the survey.	Yes	Notification will be provided to fisheries stakeholders, four weeks prior to commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within two weeks of completion of the survey. This will ensure other users that may potentially be present in the Operational Area are aware of the survey. Implementation will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	2.3
A communications protocol will be in place between the survey and support vessels and other users (e.g. known commercial fishing vessels within the Operational Area), to actively manage concurrent activities.	Yes	The survey vessel operator will provide effective 'look-aheads' to commercial fisheries fleet managers and vessel skippers to inform them of the current positions of the survey and support vessels, and of proposed operations for the next 48–72-hour period. Implementation will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	4.3
At least one additional vessel (support or chase vessel) will accompany the survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods).	Yes	The support and/or chase vessel will conduct advanced scouting to ensure that other activities in the area are provided with advance notice to move away from the path of the survey vessel. Use of two vessels will mean that one vessel can remain with the survey vessel at all times, allowing the other vessel to return to port when necessary. Implementation will reduce the likelihood of vessel collision between the survey and/or support vessels and third-party vessels.	4.4
Alternatives/Substitutes Considered			
No practicable alternative or substitutes to the acquisition or the inherent controls have been identified.	N/A	N/A	N/A
Additional Controls Considered			
No additional controls have been identified.	N/A	N/A	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable improvements have been identified	N/A	N/A	N/A
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the impacts and risks of accidental hydrocarbon release to the marine environment due to a vessel collision. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Moderate (2)	Rare (A)	Low

8.2.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing the impacts and risks of accidental hydrocarbon release to the marine environment due to a vessel collision, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Notification and Reporting (Section 9.12).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** No advice or guidelines have been identified that specifically address potential impacts to protected species resulting from accidental hydrocarbon release. **Conservation values and objectives of the North-west Marine Parks Management Plan** No significant impacts are predicted to occur to the natural, cultural and socio-economic values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to the impacts and risks of accidental hydrocarbon release to the marine environment due to a vessel collision.
Legislation and Other	Legislation and Conventions	All requirements under the Navigation Act and associated Marine Orders for navigation, collision, and support vessels are identified as control measures.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practice is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from an accidental hydrocarbon release to the marine environment due to a vessel collision meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, accidental hydrocarbon release to the marine environment due to a vessel collision is unlikely to result in potential impact greater than localised and short-term effects to marine fauna, water quality, marine protected areas and commercial fisheries. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 8.2.4 are considered industry best practice and meet requirements of the Australian Marine Orders, and expectations of AMSA and the AHO. The potential impacts and risks are considered to be of an acceptable level if the adopted controls are implemented. Therefore, CGG considers the adopted controls appropriate to manage the impacts accidental hydrocarbon release to the marine environment due to a vessel collision to be of an acceptable level.

8.2.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID		
EPO 9	No release of hydrocarbons to the marine environment due to a vessel collision associated with the activity.	PS 4.1	PS 2.2	PS 4.3
		PS 2.1	PS 2.3	PS 4.4

Number	Performance Standards	Measurement Criteria
PS (refer to PS 4.1)	Adherence with requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea (SOLAS) as implemented in Commonwealth Waters through the *Navigation Act 2012* and associated Marine Orders 21, 30, 58 – safety and emergency arrangements, prevention of collisions, safe management of vessels, including: Appropriate lighting, navigation and communication to inform other users. Use of radar and 24/7 watch.	No incidents of survey or support vessels failing to comply with appropriate navigation, lighting and communication requirements under the *Navigation Act 2012* or its associated Marine Orders.
PS (refer to PS 2.1)	The AHO is advised four weeks prior to survey commencement to allow for the issue of a Notice to Mariners.	Records verify that Notice to Mariners issued by AHO prior to survey commencement.
PS (refer to PS 2.2)	AMSA JRCC is notified of survey activities 24-48 hours before operations commence, to allow for issue of AUSCOAST warnings, at survey commencement and at completion.	Available records verify AMSA JRCC notifications have been made, and that AUSCOAST warnings have been issued.
PS (refer to PS 2.3)	Notification is provided to fisheries stakeholders, four weeks prior to commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within two weeks of completion of the survey.	Consultation and notification records verify stakeholders have been informed of survey activities throughout the survey period.
PS (refer to PS 4.3)	A communications protocol is in place between the survey and support vessels and other users (e.g. known commercial fishing vessels within the Operational Area), to actively manage concurrent activities.	Records demonstrate that 48-72-hour 'look-aheads' have been provided to stakeholders that have requested to receive them.
PS (refer to PS 4.4)	At least one chase vessel is employed to assist the seismic vessel to mitigate interference associated with third party vessel operations.	Records demonstrate that one vessel (support or chase vessel) has remained with the survey vessel throughout the entire duration of the survey.

8.3 Hydrocarbon Spill – Bunkering

8.3.1 Details of Impacts and Risks

8.3.1.1 Source of Impact/Risk

Accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea, with the potential hazards of temporary and localised reduction in water quality and temporary toxicity effects to marine biota.

Bunkering of marine diesel between the support vessel and the survey vessel may occur within the Operational Area or surrounding waters for the Sauropod 3D MSS. Bunkering of the survey vessel is expected to be required approximately every 5–6 weeks during the survey.

Two credible scenarios for the loss of containment of marine diesel during bunkering operations were identified:

- Partial or total failure of a bulk transfer hose or fittings during bunkering, due to operational stress or other integrity issues could spill marine diesel to the deck and/or into the marine environment. This would be in the order of less than 200 L, based on the likely volume of a bulk transfer hose (assuming a failure of the dry break coupling and complete loss of hose volume)
- Partial or total failure of a bulk transfer hose or fittings during bunkering, combined with a failure in procedure to shutoff fuel pumps, for a period of up to five minutes, resulting in approximately 1.2 to 25 m^3 marine diesel loss to the deck and/ or into the marine environment.

8.3.1.2 Receptors

- Marine fauna
  - Cetaceans, marine reptiles, seabirds, fishes/elasmobranchs, planktonic communities.
- Water quality.

8.3.2 Impact/Risk Evaluation

Based on the modelling conducted for the 280 m^3 marine diesel spill within the Operational Area the exposure to surface hydrocarbons above the moderate 10 g/m^2 threshold is limited to the immediate vicinity of the release site, with little potential to extend beyond distances of 1 km or less. Therefore, it is considered that exposure to thresholds concentrations from a 25 m^3 surface spill from bunkering operations would be well within the surface hydrocarbon extent or 'footprint' for the vessel collision scenario in the Operational Area (refer to Figure 8-2), detailed in Section 8.1.3. Given this, specific modelling for a 25 m^3 marine diesel release was not undertaken for the Sauropod 3D MSS.

Based on the modelling results presented in Section 8.1.3, it is considered that there is no potential for contact with any marine protected areas, shallow waters or shorelines above low threshold concentrations (surface hydrocarbons 1 g/m^2; entrained hydrocarbons 10 ppb; or dissolved hydrocarbons 6 ppb) from a 25 m^3 or 200 L spill of marine diesel within the Operational Area during the survey.

The potential biological and ecological impacts to marine fauna and water quality associated with a much larger hydrocarbon spill are presented in Section 8.2. The biological consequences of such small volume releases of marine diesel on identified open water sensitive receptors relate to the potential for minor impacts to cetaceans, marine reptiles, seabirds, fishes/ elasmobranchs and planktonic communities (surface and water column biota) that are within the spill affected area. The potential impacts are considered to be very localised and short-term.

No impacts to commercial fisheries are expected to occur.

Based on the assessment presented above and the implementation of the identified controls (Section 8.3.4), it is expected that the consequence associated with an accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea will be Negligible (0). The likelihood of impacts occurring is considered to be Rare (A), resulting in a Low residual risk to sensitive receptors within the Operational Area.

8.3.3 Decision Context

The decision context for accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea has been assessed as 'Type A', given the impacts/risks are well understood, uncertainty is minimal and little or no stakeholder interest.

8.3.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Adherence with requirements of Marine Order 91: Marine pollution prevention – oil.	Yes	By ensuring a SOPEP is in place for the vessel, the likelihood of a spill entering the marine environment is reduced.	10.1
Good Industry Practice			
Bunkering equipment controls: • All bulk transfer hoses tested for integrity before use • Dry-break couplings and flotation installed on refuelling hoses • Adequate number of appropriately stocked, located and maintained spill kits aboard both survey and support vessels.	Yes	By ensuring the appropriate equipment is in place, tested and maintained appropriately, the likelihood of a spill occurring is reduced. By ensuring spill kits are in place, the likelihood of a spill entering the marine environment is reduced. Good industry practice, environmental benefit outweighs additional cost.	10.2
Survey vessel contractor procedures include requirements to be implemented during bunkering/refuelling operations, including: • A completed Permit to Work (PTW) and / or Job Safety Analysis (JSA) implemented for bunkering operations • Visual monitoring of gauges, hoses, fittings and sea surface during bunkering operations • Hose checks prior to commencement • Bunkering commences only in daylight hours. If transfer is to continue into night-time, JSA risk assessment must consider lighting and ability to determine if a spill has occurred • Bunkering not to occur in marginal weather conditions.	Yes	By ensuring the appropriate bunkering procedures are implemented, the likelihood of a spill occurring is reduced, and the likelihood of a spill entering the marine environment is also reduced. Good industry practice, environmental benefit outweighs additional cost.	10.3
Bunkering operations will be undertaken within the Operational Area (unless as required in an emergency situation).	Yes	The Operational Area does not overlap with any AMPs, therefore bunkering within the Operational Area is consistent with the management prescriptions of the AMPs. Good industry practice, environmental benefit outweighs additional cost.	10.4
Alternatives/Substitutes Considered			
Survey vessel bunkering only occurs in port.	No	The survey vessel would have to recover the towed array, leave the Operational Area and return to port for bunkering. This would increase the survey duration, and the overall cost. Eliminates the hydrocarbon spill risk from the Operational Area but transfers it to coastal waters. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
Additional Controls Considered			
No additional controls have been identified.	N/A	N/A	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable improvements have been identified	N/A	N/A	N/A
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the impacts and risks of accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Negligible (0)	Rare (A)	Low

8.3.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy Company Standards/Systems	The risk management strategy for managing the impacts and risks of accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea, is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP. Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Notification and Reporting (Section 9.12).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** N/A: No advice or guidelines have been identified that specifically address potential impacts to protected species resulting from accidental hydrocarbon release **Conservation values and objectives of the North-west Marine Parks Management Plan** No significant impacts are predicted to occur to the natural, cultural and socio-economic values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to the impacts and risks of accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea.
Legislation and Other	Legislation and Conventions	All requirements under the Navigation Act and associated Marine Orders for prevention of pollution from oil are identified as control measures.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practice is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from an accidental hydrocarbon release to the marine environment during bunkering of the survey vessel at sea meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, accidental hydrocarbon release to the marine environment during bunkering is unlikely to result in potential impact greater than very localised and short-term effects to marine fauna and water quality. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 8.3.4 are considered industry best practice and meet requirements of the Australian Marine Orders. The potential impacts and risks are considered to be of an acceptable level if the adopted controls are implemented. Therefore, CGG considers the adopted controls appropriate to manage the impacts accidental hydrocarbon release to the marine environment due to bunkering of the survey vessel at sea to be of an acceptable level.

8.3.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	
EPO 10	No unplanned loss of hydrocarbons to the marine environment from bunkering of the survey vessel at sea during the activity	PS 10.1	PS 10.3
		PS 10.2	PS 10.4

Number	Performance Standards	Measurement Criteria
PS 10.1	A SOPEP is available onboard the survey and support vessels (as appropriate to vessel class), as required by Marine Order 91 (Marine pollution prevention – oil).	Marine Assurance inspection records demonstrate a SOPEP is available onboard the survey and support vessels in compliance with Marine Order 91.
PS 10.2	Bunkering equipment controls are implemented: • All bulk transfer hoses tested for integrity before use • Dry-break couplings and flotation installed on refuelling hoses • Adequate number of appropriately stocked, located and maintained spill kits aboard both survey and support vessels.	Records confirm the vessel bunkering equipment is subject to systematic integrity checks, has dry-break couplings and flotation installed on refuelling hoses, and there are an adequate number of appropriately stocked, located and maintained spill kits aboard both survey and support vessels.

Number	Performance Standards	Measurement Criteria
PS 10.3	At sea bunkering procedures are followed, including: • A completed PTW and / or JSA implemented for bunkering operations • Visual monitoring of gauges, hoses, fittings and sea surface during bunkering operations • Hose checks prior to commencement • Bunkering commences only in daylight hours. If transfer is to continue into night-time, JSA risk assessment must consider lighting and ability to determine if a spill has occurred • Bunkering not to occur in marginal weather conditions.	Records demonstrate bunkering / refuelling undertaken in accordance with contractor bunkering procedures.
PS 10.4	Bunkering operations are undertaken within the Operational Area (unless as required in an emergency situation).	Records demonstrate that no bunkering operations have been undertaken outside of the Operational Area.

8.4 Chemical Spill: Single Point Failure

8.4.1 Details of Impacts and Risks

8.4.1.1 Source of Impact/Risk

Accidental spills of up to 1 m^3 of hydraulic fluids or chemicals may result in a localised and short-term reduction in water quality with the potential to result in toxic effects on marine fauna.

8.4.1.2 Receptors

- Marine fauna
  - Cetaceans, marine reptiles, seabirds, fishes/elasmobranchs, planktonic communities.
- Water quality.

8.4.2 Impact/Risk Evaluation

The accidental release of up to 1 m^3 of hydraulic fluids or chemicals to the marine environment may result in a localised reduction in water quality. Hydraulic fluids spilt or washed overboard have the potential to result in toxicity effects to marine fauna and fish in the immediate vicinity of the spill release location, through direct contact or accidental ingestion. Given the open water dispersive location of the Operational Area, the extent and duration of potential exposures and impacts to marine fauna and fish is expected to be highly localised and short term and limited to the vicinity of point of discharge.

Based on the assessment presented above and the implementation of the identified controls (Section 8.4.4), it is expected that the consequence associated of a single point failure resulting in a reduction in water quality and toxicity to marine fauna and fish will be Negligible (0). The likelihood of impacts occurring is considered to be Rare (A), resulting in a Low residual risk to sensitive receptors within the Operational Area

Further information about the selected control measures, the ALARP evaluation, and the evaluation of Acceptability are provided below.

8.4.3 Decision Context

The decision context for a release of hydraulic fluids or chemicals to the marine environment from a single point failure has been assessed as ‘Type A’, given the impacts/risks are well understood, uncertainty is minimal and little or no stakeholder interest.

8.4.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Adherence with requirements of Marine Order 91: Marine pollution prevention – oil.	Yes	By ensuring a SOPEP is in place for the vessel, the likelihood of a spill entering the marine environment is reduced.	10.1
Good Industry Practice			
Hydraulic fluids and chemicals will be selected in accordance with the CGG Chemical Control Procedure and will be selected to have the lowest environmental toxicity possible whilst meeting operational performance requirements.	Yes	Chemical use is controlled through the implementation of the CGG Chemical Control Procedure ensuring the use of chemicals with the lowest environmental toxicity possible meeting technical specifications. Good industry practice.	11.1
Storage, handling and use of hazardous substances (including hydraulic fluids and chemicals) shall be in accordance with the product's Safety Data Sheet (SDS).	Yes	Storage and handling in accordance with SDS, reduces the potential for deck spills. Good industry practice.	11.2
Spill kits and scupper plugs are available on-board the seismic vessel and crew are trained in their use.	Yes	Should a spill occur on deck, spill kits and scupper plugs can prevent the spill from entering the marine environment. Good industry practice.	11.3
Spills will be reported through the CGG Incident Reporting Procedure and waste materials managed in accordance with the vessel Waste/Garbage Management Plan.	Yes	All spills during the Sauropod 3D MSS will be reported through the CGG Incident Reporting Procedure. Waste materials will be managed in accordance with the vessel Waste/Garbage Management Plan. Good industry practice.	11.4
Alternatives/Substitutes Considered			
No hydraulic fluids or chemicals to be used during the seismic survey activity.	No	During the survey, the use of hydraulic oils cannot be eliminated as they are required for the safe operation of equipment. Chemical use is controlled through implementation of the CGG Chemical Control Procedure ensuring the use of chemicals with the lowest environmental toxicity possible meeting technical specifications.	N/A
Additional Controls Considered			
No additional control measures have been identified	N/A	N/A	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable improvements have been identified	N/A	N/A	N/A
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the impacts and risks of accidental chemical release to the marine environment from a single point failure. As the impact/risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Negligible (0)	Rare (A)	Low

8.4.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing the impacts and risks of accidental chemical release to the marine environment from a single point failure is compliant with CGG's HSE Policy objectives of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Notification and Reporting (Section 9.12).
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** N/A: No advice or guidelines have been identified that specifically address potential impacts to protected species resulting from accidental chemical release. **Conservation values and objectives of the North-west Marine Parks Management Plan** No significant impacts are predicted to occur to the natural, cultural and socio-economic values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to the impacts and risks of accidental chemical release to the marine environment due to bunkering of the survey vessel at sea.

Context	Factor	Demonstration
Legislation and Other	Legislation and Conventions	All requirements under the Navigation Act and associated Marine Orders for prevention of pollution are identified as control measures.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practice is demonstrated.
Ecological Sustainability Development (ESD)	ESD Application	Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from an accidental chemical release to the marine environment from a single point failure meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, accidental chemical release to the marine environment is unlikely to result in potential impact greater than very localised and short-term effects to marine fauna and water quality. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 8.4.4 are considered industry best practice and meet requirements of the Australian Marine Orders. The potential impacts and risks are considered to be of an acceptable level if the adopted controls are implemented. Therefore, CGG considers the adopted controls appropriate to manage the impacts accidental chemical release to the marine environment from a single point failure to be of an acceptable level.

8.4.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	
EPO 11	No unplanned loss of hydraulic fluids or chemicals to the marine environment from a single point failure during the activity	PS 10.1	PS 10.3
		PS 10.2	PS 10.4

Number	Performance Standards	Measurement Criteria
PS (refer to PS 10.1)	A SOPEP is available onboard the survey and support vessels (as appropriate to vessel class), as required by Marine Order 91 (Marine pollution prevention – oil).	Marine Assurance inspection records demonstrate a SOPEP is available onboard the survey and support vessels in compliance with Marine Order 91.
PS 11.1	Hydraulic fluids and chemicals are selected in accordance with the CGG Chemical Control Procedure and will be selected to have the lowest environmental toxicity possible whilst meeting operational performance requirements.	Records of pre-survey environmental checklist and compliance audit during the survey (Section 9.3.1) confirm that only chemicals approved via the CGG Chemical Control Procedure are carried on the vessel.
PS 11.2	Storage, handling and use of hazardous substances (including hydraulic fluids and chemicals) are in accordance with the product's Safety Data Sheet (SDS).	Records demonstrate survey inductions included the requirement to follow SDS when storing, handling and using hazardous substances (including hydraulic fluids and chemicals). Record of audit during the survey confirms that SDS for hydraulic fluids are available on-board and storage, handling and/or use is in accordance with the SDS.
PS 11.3	Spill kits and scupper plugs are available on-board the seismic vessel and crew are trained in their use.	Record of pre-survey environmental checklist (Section 9.3.1) confirms spill kits and scupper plugs are available on-board. Training and competency records confirm that relevant crew have been trained on the use of spill kits and scupper plugs.
PS 11.4	Spills are reported through the CGG Incident Reporting Procedure and waste materials managed in accordance with the vessel Waste/Garbage Management Plan.	If a spill has occurred during the survey, CGG Incident Reporting records demonstrate that immediate action was taken to clean up the spill and waste was managed in accordance with the vessel Waste/Garbage Management Plan.

8.5 Physical Presence: Entanglement / Collision with Marine Fauna

8.5.1 Details of Impacts and Risks

8.5.1.1 Source of Impact/Risk

The physical presence of the survey and support vessels and towed equipment within the Operational Area provides a risk of potential entanglement/collision with marine fauna. The survey and support vessels operating in the Operational Area, and the towed seismic equipment, may represent a potential entanglement / collision risk to cetaceans and other protected marine fauna, such as whale sharks and marine turtles.

Vessel movements can result in collisions between the vessel (hull, propellers and streamer array) and marine fauna, potentially resulting in serious injury that may affect life functions (e.g. movement and reproduction) or cause mortality. The factors that contribute to the frequency and severity of impacts due to collisions vary greatly due to the vessel type, vessel operation (specific activity, speed), physical environment (e.g. water depth) and the type of fauna potentially present and their behaviours.

The survey will be undertaken by a seismic survey vessel towing an underwater seismic source (at a depth of 5-10 m) and a series of hydrophone streamers (up to 12 at a depth of approximately 15 m).When acquiring data the vessel will travel along pre-determined lines within the Acquisition Area at approximately 4.5 knots. The survey vessel will be accompanied by two support vessels.

This section deals with the risk of entanglement or collision with marine fauna from the physical presence of vessels and in-water equipment (streamers and seismic source) in the Operational Area. Risks associated with the disruption/interference with other marine users are addressed in Section 7.4, and potential underwater acoustic impacts on marine fauna are addressed in Sections 7.1 to 7.2.

8.5.1.2 Receptors

- EPBC listed marine fauna, including threatened and migratory cetaceans, marine turtles and whale sharks.

8.5.2 Impact/Risk Evaluation

The risk of a vessel collision or entanglement 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 a maximum of 60 days.

As the survey vessel transits at low speeds (4–5 knots), with MFO observers on-board, the likelihood of a vessel-strike and associated injury to megafauna is considered very unlikely. Support vessels generally travel at higher speeds within the Operational Area and are considered to have a slightly higher potential for collision and damage with megafauna, relative to the survey vessel.

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. Anecdotally, there have been no reported cases of marine fauna becoming entangled in seismic equipment in Australian waters.

8.5.2.1 Cetaceans

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).

Collisions between vessels and cetaceans occur more frequently where high vessel traffic and cetacean habitat coincide (Whale and Dolphin Conservation Society (WDCS) 2006). There have been occasional recorded instances of cetacean deaths in Australian waters (WDCS 2006), though the data indicates this is more likely to be associated with container ships and fast ferries. The Whale and Dolphin Conservation Society (WDCS 2006) also indicates that some cetacean species, such as Humpback whales, can detect and change course to avoid a vessel.

Laist *et al.* (2001) identified larger vessels (container vessels and fast ferries), moving faster than ten knots may cause fatal or severe injuries to cetaceans, with the most severe injuries caused by vessels travelling at speeds greater than 14 knots. Individual cetaceans engaged in behaviours such as feeding, mating or nursing may also be more vulnerable to vessel collisions when distracted by these activities (DoEE 2017).

Several species of cetaceans are known to occur in the NWMR and have wide distributions that are associated with feeding and migration patterns linked to reproductive cycles. The Operational Area overlaps with the Pygmy blue whale distribution BIA, with the migration BIA located 95 km from the Operational Area. Occasional individuals may therefore pass through the Operational Area and surrounds during the annual migration. Acquisition of the survey may overlap the commencement of the northbound migration (April), but avoids the southbound migration period for Pygmy blue whales in the region (September to November). However, overall cetacean numbers within the Operational Area are expected to be very low during the proposed timing of the Sauropod 3D MSS (January to May). Given the low number of cetaceans expected in the Operational Area, presence of two MFOs on-board the seismic survey vessel, and the low operating speeds of vessels, the risk of entanglement or collision is considered low.

8.5.2.2 Marine Turtles

Marine turtles are at potential risk from vessel strike and entanglement with the in-water seismic equipment. Peel *et al.* (2016) reviewed vessel strike data (2000–2015) for marine turtle species in Australian waters and identified that all turtle species present in Australian waters had had an interaction with vessels. Green and loggerhead turtles exhibited the highest incident of interaction. The effect of vessel speed and turtle flee response can be significant. A study by Hazel *et al.* (2007) recorded 60% of green turtles fleeing from vessels travelling at 4 km/h, while only 4% fled from vessels travelling at 19 km/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 4 km/h (DoEE 2017).

The NWMR is considered to be significant for supporting large feeding and nesting turtle populations. Six threatened and migratory marine turtle species have the potential to occur in the Operational Area, however, the Operational Area does not overlap with any BIAs for marine turtle species. The closest foraging BIA for the flatback turtle is 55 km from the Operational Area. In addition, the closest ‘habitat critical to the survival of a species’ BIA for the flatback turtle is located approximately 55 km from the Operational Area. The marine turtle numbers within the Operational Area are expected to be low during the proposed Sauropod 3D MSS. Given the low number of marine turtles expected in the Operational Area and the low operating speeds of vessels, the risk of entanglement or collision is considered low.

8.5.2.3 Whale Sharks

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 offshore North West Shelf waters in the Operational Area during their migrations to and from Ningaloo Reef. The Operational Area does overlap with a foraging BIA for whale sharks which extends northwards from Ningaloo Reef along the 200 m isobath. The foraging BIA is used from August to November and does not overlap with the proposed acquisition period. Whale sharks are a highly migratory species, which are known to migrate between Christmas Island and Ningaloo Reef. Migration is expected to occur between January and March. It is expected that whale shark presence in the Operational Area would not comprise significant numbers, given the main aggregations are recorded in coastal waters, (MPRA 2005; Sleeman *et al.* 2010) and their presence would be transitory and of a short duration. Given the low number of whale sharks expected in the Operational Area and the low operating speeds of vessels, the risk of entanglement or collision is considered low.

8.5.2.4 Summary

Based on the assessment presented above and the implementation of the identified controls (Section 8.5.4), it is expected that in the event of entanglement or collision with marine fauna, the consequence would be Major (4), as collision/entanglement of marine fauna could result in serious injury or death. The likelihood of interaction is considered Rare (A), given the low presence of transiting individuals, avoidance behaviour of marine fauna and the low operating speed of vessels. The residual risk of entanglement/collision with marine fauna has been assessed as Low.

8.5.3 Decision Context

The decision context for the risk of potential entanglement or collision with marine fauna, has been assessed as ‘Type A’, given the risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

8.5.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
Vessels will comply, when safe to do so, with the relevant requirements of EPBC Regulations 2000 - Part 8 Division 8.1, including: • Taking action to avoid approaching or drifting closer than 50 m to a dolphin or 100 m to a whale • Not exceeding a speed of six knots within the caution zone of a cetacean (300 m).	Yes	The requirements of the EPBC regulations set out clear measures to reduce speed and avoid approaching cetaceans, which reduces the risk of collision or entanglement. MSS. For safety reasons, the distance requirements are not applied for vessels with limited manoeuvrability. It is a legislative requirement for vessels to comply with the EPBC Act and EPBC Regulations.	3.1
Good Industry Practice			
Operation of the seismic source within the Operational Area for the Sauropod 3D MSS is compliant with EPBC Act Policy Statement 2.1 Part B.1 – Additional Management Measures: Marine Mammal Observers.	Yes	Two trained and experienced marine fauna observers (MFOs) will be aboard the survey vessel. The two MFOs (in addition to briefed crew members) will alternate shifts during daylight hours (during operation of the seismic source) in order to manage fatigue and provide some redundancy in the event one MFO is temporarily unavailable. The MFOs will have adequate training and will have 12 months experience in Australian waters. Good industry practice, environmental benefit outweighs additional cost.	1.2
Any vessel strike incident to marine mammals shall be reported as soon as possible via the National Vessel Strike Database at https://data.marinemammals.gov.au/report/shi , within 72hr of collision.	Yes	Reporting ship strikes with cetaceans is requested by the DAWE's Australian Antarctic Division and allows the Australian Government and International Whaling Commission (IWC) to collate scientific data on vessel strike locations, frequencies and timings so that further research and mitigation can be considered. Good industry practice, environmental benefit outweighs additional cost.	12.1
Turtle guards installed on tail buoys or tail buoys are of a design that does not represent an entrapment risk to turtles.	Yes	A tail buoy will be fitted to the end of each streamer. Tail buoys are brightly coloured and contain a radar reflector and strobe light to be visible to other marine users. If the tail buoys are not of a design that does not represent an entrapment risk to turtles, they will be fitted with guards to prevent accidental entrapment of turtles. Good industry practice, environmental benefit outweighs additional cost.	12.2
All vessel crews have completed an environmental induction covering the requirements for cetacean vessel interactions consistent with EPBC Regulations 2000 – Part 8 Division 8.1.	Yes	Environmental inductions will be included as part of the crew induction package, including cetacean vessel interactions, consistent with EPBC Regulations 2000 – Part 8 Division 8.1. Good industry practice, environmental benefit outweighs additional cost.	12.3
Alternatives/Substitutes Considered			
Use ocean bottom nodes (OBN – receivers) instead of towed hydrophone streamers	No	To further reduce the potential for entanglement, an alternative to the use of towed streamers is the use of ocean bottom receivers. However, this was considered impractical for the following reasons: • Environmentally, OBNs placed on the seabed may reduce the risk of marine fauna becoming entangled in towed streamers. However, this alternative would not alter the risks associated with potential vessel interactions. Also, OBNs can result in unnecessary seabed disturbance particularly in areas of shallow benthic habitat. • OBNs cannot be placed securely on steep sloping seabed, making acquisition in some areas of the Operational Area difficult or impossible to implement. • OBNs would result in a significant increase in vessel activity to manage deployments and recoveries throughout the Operational Area, which would increase the potential for vessel collision and may disrupt other marine users. • Operationally, this alternative would not meet survey requirements for coverage and would also add significantly to the cost and timeframe for the survey, making it impractical. • Given that there have been no reported cases of marine fauna becoming entangled in seismic equipment, the risk is already very low and so little additional benefit would be gained.	N/A
Additional Controls Considered			
Marine fauna entangled within the in-water equipment will be returned to sea (where possible and safe to do so).	Yes	If safe and practicable to do so, marine fauna found to be entangled in towed equipment shall be recovered to reduce the risk of mortality. The environmental benefit outweighs the additional cost.	12.4
Retrieve towed equipment when not in use.	No	Consideration was given to the option of retrieving towed equipment when not in use. However, given the other controls in place to reduce the risk of interaction with marine fauna, this additional control was determined as providing limited benefit and as being disproportionate due to the significantly increased time, cost and complexity associated with implementing it, as well as increased health and safety risks from repeatedly retrieving and deploying equipment from the survey vessel.	N/A

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Survey acquisition timed to avoid turtle internesting periods	No	Not justified. Acquisition of the survey may overlap the nesting and breeding season for a number of turtle species in the region, however the Operational Area is located approximately 55 km from the closest BIA boundary. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
Survey acquisition timed to avoid the migration periods for Humpback whales	Yes	The survey will be acquired in the period January to May, which will avoid the northbound and southbound migration season for Humpback whales in the region (June to October). The environmental benefit outweighs the additional cost.	1.7
Survey acquisition timed to avoid the migration periods for Pygmy blue whales	No	Not justified. Acquisition of the survey may overlap the commencement of the northbound migration (April), but avoids the southbound migration period for Pygmy blue whales in the region (September to November). While the Operational Area overlaps with the Pygmy blue whale distribution BIA, the migration BIA is located 95 km from the Operational Area. Only occasional, transient individuals are therefore expected in the area during the proposed acquisition period. The costs are grossly disproportionate to any potential environmental benefit gained.	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
In addition to the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for cetaceans, vessels, when safe to do so, will also: • Take action to avoid approaching or drifting closer than 50 m to a turtle • Not exceeding a speed of six knots within 300 m of a turtle.	Yes	In addition to implementing avoidance measures for cetaceans, CGG has considered extending the prescribed avoidance measures to turtles. For safety reasons, the distance requirements are not applied to vessels with limited manoeuvrability. The environmental benefit outweighs the additional cost.	3.4
Vessels, when safe to do so, will also adopt consistent with the DPaW Whale Shark Management Programme (2013), including: • Taking action to avoid approaching or drifting closer than 30 m of a whale shark • Not exceeding eight knots within 250 m of a whale shark.	Yes	In addition to implementing the EPBC Regulations 2000 avoidance measures for cetaceans, CGG has extended avoidance measures to whale sharks. For safety reasons, the distance requirements are not applied for vessels with limited manoeuvrability. The environmental benefit outweighs the additional cost.	3.5
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the risks of entanglement or collision with marine fauna. As the risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Major (4)	Rare (A)	Medium

8.5.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing the physical presence of vessels and towed equipment, reflects CGG's HSE Policy goals of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Environmental Performance Monitoring and Reporting (Section 9.3).
External	Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** Proposed control measures and the low residual risk of vessel collision or entanglement are consistent with the various Conservation Advice, Conservation Management Plans, Recovery Plans and other Guidelines for whales, sharks and turtles: • Conservation Management Plan for the Blue Whale • Approved Conservation Advice for *Megaptera novaeangliae* (Humpback whale) • Conservation advice for sei and Fin whales • Recovery Plan for Marine Turtles in Australia • Whale shark – wildlife management program no. 57 (DPaW 2013) • National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (DoEE 2017)

Context	Factor	Demonstration
		Conservation values and objectives of the North-west Marine Parks Management Plan
		No impacts are expected to the natural and cultural heritage values of the Argo-Rowley Terrace, Mermaid Reef or Eighty Mile Beach AMPs.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to the risk of entanglement/collision with marine fauna from the physical presence of vessels and in-water equipment.
Legislation and Other	Legislation	The controls adopted will comply with the *Navigation Act 2012*, *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and the *Environment Protection and Biodiversity Conservation Act 1999*.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practices (where applicable).
Ecological Sustainability Development (ESD)	ESD Application	If an incident resulting in entanglement/collision with marine fauna was to occur, it would be expected to be limited to an isolated individual. Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from entanglement/collision with marine fauna meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, physical presence of vessels and in-water equipment is very unlikely to result in potential impact to marine fauna. Further opportunities to reduce the risk have been investigated above. The adopted controls described in Section 8.5.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.

8.5.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID		
EPO 12	No injury or death to marine fauna as a result of vessel collision or entanglement with in-water equipment during the Sauropod 3D MSS.	PS 3.1	PS 12.2	PS 1.7
		PS 1.2	PS 12.3	PS 3.4
		PS 12.1	PS 12.4	PS 3.5

Number	Performance Standards	Measurement Criteria
PS (refer to PS 3.1)	Seismic vessels and support vessels (taking into account the limited manoeuvrability of the former) comply with relevant requirements of EPBC Regulations 2000 - Part 8 Division 8.1, including: • Taking action to avoid approaching or drifting closer than 50 m to a dolphin or 100 m to a whale • Not exceeding a speed of six knots within the caution zone of a whale (300 m).	MFO Master Data Sheet verifies interaction between the MSS vessel and marine mammals comply with these requirements. Support vessel observations sheet verified interactions between the vessel and marine mammals comply with these requirements.
PS (refer to PS 1.2)	Operation of the seismic source within the Operational Area for the Sauropod 3D MSS is compliant with EPBC Act Policy Statement 2.1 Part B.1 – Additional Management Measures: Marine Mammal Observers. Two trained and experienced MFOs are aboard the seismic survey vessel. The two MFOs (in addition to briefed crew members) alternate shifts during daylight hours in order to manage fatigue and provide some redundancy in the event one MFO is unavailable. The MFOs have adequate training and will have 12 months experience in Australian waters.	Records demonstrate that two MFOs were aboard the survey vessel for the duration of the survey. MFO sighting records and final report. CVs and training records for the MFOs.
PS 12.1	Any vessel strike incident to marine mammals is reported as soon as possible via the National Vessel Strike Database at https://data.marinemammals.gov.au/report/shi, within 72 hr of collision.	Records verify incident has been reported via the National Vessel Strike Database.
PS 12.2	Turtle guards are installed on tail buoys or tail buoys are of a design that does not represent an entrapment risk to turtles.	Inspection records verify turtle guards are installed on header buoys and tail buoys (or buoys have been designed to not represent an entanglement risk to turtles).
PS 12.3	All vessel crews have completed an environmental induction covering the requirements for cetacean vessel interactions consistent with EPBC Regulations 2000 – Part 8 Division 8.1.	Induction records verify that all crews have completed an environmental induction.
PS 12.4	Marine fauna entangled within the in-water equipment are returned to sea (where possible and safe to do so).	MFO records verify that any marine fauna entangled within the in-water equipment are returned to sea (where possible and safe to do so).
PS (refer to PS 1.7)	Survey acquisition is timed to avoid the migration periods for Humpback whales (June to October).	Records confirm that the survey has been acquired outside the June to October Humpback whale migration season.
PS (refer to PS 3.4)	In addition to the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for cetaceans, vessels (where safe to do so) also: • Take action to avoid approaching or drifting closer than 50 m to a turtle • Not exceeding a speed of six knots within 300 m of a turtle.	MFO Master Data Sheet verifies interaction between the MSS vessel and marine mammals comply with these requirements. Support vessel observations sheet verified interactions between the vessel and marine mammals comply with these requirements.

Number	Performance Standards	Measurement Criteria
PS (refer to PS 3.5)	Vessels, when safe to do so, also adopt will measures consistent with the Whale shark – wildlife management program no. 57 (DPaW 2013), including: • Taking action to avoid approaching or drifting closer than 30 m of a whale shark • Not exceeding eight knots within 250 m of a whale shark.	MFO Master Data Sheet verifies interaction between the MSS vessel and marine mammals comply with these requirements. Support vessel observations sheet verified interactions between the vessel and marine mammals comply with these requirements.

8.6 Physical Presence: Loss of Equipment

8.6.1 Details of Impacts and Risks

8.6.1.1 Source of Impact/Risk

The risk of physical loss of equipment (e.g. seismic streamers and/or source) in the Operational Area could result in localised seabed disturbance and disruptions to other marine users, as a result of a breakage in cables or a failure in lifting equipment. The survey will be undertaken by a purpose-built seismic survey vessel towing an underwater seismic source (at a depth of 5–10 m) and a series of hydrophone streamers (up to 12). These streamers will be towed at a depth of approximately 15 m below the surface. Loss of this equipment has the potential to cause localised seabed disturbance, localised damage to benthic habitats, and disruptions to other marine users. Loss of equipment during petroleum activities is uncommon; however, it has been recorded within the industry.

Impacts associated with the unplanned loss of solid wastes (hazardous or non-hazardous) are assessed in Section 8.7.

8.6.1.2 Receptors

- Marine users: Commercial fishing and commercial shipping.
- Benthic habitats and communities.

8.6.2 Impact/Risk Evaluation

8.6.2.1 Marine Users (e.g. Commercial Fishing and Shipping)

In the unlikely event that equipment is lost, other marine users of the Operational Area may be required to make minor diversions to avoid the equipment, until it can be retrieved (if possible). The potential for such interactions will be limited to a short period of time while the equipment is retrieved (if possible). Should disruption occur, it is only expected to affect individual users and cause temporary disruption through avoidance of a highly localised area. 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 to the sort of vessels typically in the area. Therefore, anticipated impacts are expected to be low.

8.6.2.2 Benthic Habitat and Communities

Loss of equipment has the potential to cause localised seabed disturbance and localised damage to benthic habitats, arising from the streamers and associated equipment potentially sinking and being dragged along the seabed. However, the tow depth of streamers (15 m), and the application of depth control in-built into the design and planning of the activity means that the likelihood of direct impact on benthic communities during normal operations is highly unlikely.

The ancient coastline at 125 m depth contour KEF overlaps with a small portion of the Operational Area. Parts of the ancient coastline are represented as rocky escarpment, which are considered to provide significant habitat in an area predominantly made up of soft sediment (Section 4.3.2).

The Operational Area is expected to consist primarily of soft, fine unconsolidated sediments, which are typical of the broader NWMR (Section 4.2.4). As such physical impacts to the seabed from lost equipment are expected to be short-term and highly localised. Due to the presence of mostly soft sediments and lack of hard substrate, the seabed is likely to be inhabited by a low abundance and patchy distributions of filter feeders and other epifauna, characteristic of the wider NWMR (Brewer *et al.* 2007). Impacts to benthic habitats such as shelf and slope habitats, pinnacle and terrace seabed features and the ancient coastline KEF are not expected.

8.6.2.3 Summary

Based on the assessment presented above and the implementation of the identified controls (Section 8.6.4), it is expected that localised seabed disturbance, impact to benthic habitats and localised disturbance to marine users will be Minor (1). The likelihood of this consequence occurring is Rare (A) and the residual risk is considered to be Low.

8.6.3 Decision Context

The decision context for loss of equipment has been assessed as ‘Type A’, given the impacts/risks are well understood and uncertainty is minimal with little or no stakeholder interest.

8.6.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements and Good Industry Practice			
No relevant legislation has been identified.	N/A	N/A	N/A
Good Industry Practice			
Solid streamers will be used for the survey.	Yes	Solid streamers are used as a standard to prevent any possibility of discharges that could otherwise occur if fluid-filled streamers were used and became damaged. Good industry practice, environmental benefit outweighs additional cost.	13.1
The seismic vessel will operate under approved procedures for streamer deployment/retrieval and these procedures are adhered to at all times.	Yes	The procedure ensures all personnel involved in the deployment/retrieval of in-water equipment, are doing so in a safe and consistent manner. The environmental benefit outweighs the additional cost.	13.2
Streamer equipment is routinely maintained and inspected for wear and tear to ensure the equipment is fit-for-purpose.	Yes	In-water equipment is routinely checked to confirm the integrity of the equipment, and to ensure the equipment is fit-for-purpose. The environmental benefit outweighs the additional cost.	13.3
Streamers will be fitted with the following equipment: • Streamer recovery devices (self-inflating SRDs) • Surface marker buoys • Secondary retaining devices • Tail buoys	Yes	Streamers are fitted with equipment to allow for the ease in deployment and retrieval of in-water equipment. The environmental benefit outweighs the additional cost.	13.4
Support vessels will search for and retrieve lost in-water equipment (where possible and safe to do so).	Yes	Two support vessels will accompany the survey vessel. Support vessels are able to assist in the search and recovery of lost equipment. The environmental benefit outweighs the additional cost.	13.5
Marine stakeholders will be notified (VHF Channel 16) in the event of a loss of in-water equipment.	Yes	Notification to other marine users (i.e. commercial fishing and shipping) to alert them of the navigational hazard (if applicable). This is considered good industry practice.	13.6
Loss of equipment will be reported to AMSA, as soon as possible.	Yes	Notification to AMSA to alert them of the navigational hazard. This is considered good industry practice.	13.7
Alternatives/Substitutes Considered			
No practicable alternative or substitutes to the above controls have been identified.	N/A	N/A	N/A
Additional Controls Considered			
No additional controls have been identified.	N/A	N/A	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable improvements have been identified	N/A	N/A	N/A
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the risk of a loss of equipment. The residual risk has been assessed as Low. As the risk has been classified as 'Type A' and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Minor (1)	Rare (A)	Low

8.6.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing loss of equipment to the marine environment, reflects CGG's HSE Policy goals of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Environmental Performance Monitoring and Reporting (Section 9.3).

Context	Factor	Demonstration
External	Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** Marine debris causing entanglement and ingestion was recognised in 2003 as a key threatening process for marine vertebrates under the EPBC Act. Pollution generally is also identified as a threat in several conservation advices / recovery plans for EPBC-listed species potentially occurring within the Operational Area. CGG has reduced and, where possible, eliminated any adverse impacts of marine debris from the activities of the seismic survey on turtles, cetaceans, sharks and birds, noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life (Commonwealth of Australia 2018). **Conservation values and objectives of the North-west Marine Parks Management Plan** Although the Operational Area is not located within any AMPs, management of loss of equipment is consistent with the management prescriptions of North and North-west Management Plans for AMPS. No impacts are predicted to occur to the cultural and socio-economic values of the AMPs.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to the loss of equipment during the Sauropod 3D MSS.
Legislation and Other	Legislation	The controls adopted for the loss of equipment to the marine environment will comply with the *Navigation Act 2012*, *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and the *Environment Protection and Biodiversity Conservation Act 1999*.
Industry Standards	Industry Standards and Best Practices	Compliance with industry standards and best practices (where applicable).
Ecological Sustainability Development (ESD)	ESD Application	Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from loss of equipment to the marine environment meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, loss of equipment is very unlikely to result in to result in potential impact greater than localised seabed disturbance, and short-term disruption to marine users. Further opportunities to reduce the risk have been investigated above. The adopted controls described in Section 8.6.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.

8.6.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID		
EPO 13	No loss of equipment to the marine environment during the survey.	PS 13.1	PS 13.4	PS 13.6
		PS 13.2	PS 13.5	PS 13.7
		PS 13.3		

Number	Performance Standards	Measurement Criteria
PS 13.1	Solid streamers are used for the survey.	Inspection records verify solid streamers are used.
PS 13.2	The survey vessel operates under approved procedures for streamer deployment/retrieval and these procedures are adhered to at all times.	Approved procedures are available and used on-board all vessels.
PS 13.3	Streamer equipment are routinely maintained and inspected for wear and tear to ensure the equipment is fit-for-purpose.	Inspection records verify streamers are fit-for-purpose.
PS 13.4	Streamers are fitted with the following equipment: • SRDs • Surface marker buoys • Secondary retaining devices • Tail buoys.	Equipment deployed meets minimum specification requirements.
PS 13.5	Support vessels search for and retrieve lost in-water equipment (where possible and safe to do so).	Dropped objects recorded in incident report and vessel log.
PS 13.6	Marine stakeholders are notified (VHF Channel 16) in the event of a loss of in-water equipment.	Vessel log records notification on loss of equipment.
PS 13.7	Loss of equipment is reported to AMSA, as soon as practical.	Incident report/notification to AMSA.

8.7 Discharge: Loss of Hazardous or Non-Hazardous Solid Waste

8.7.1 Details of Impacts and Risks

Entanglement with, or ingestion by marine fauna may occur as a result of the unplanned loss of solid wastes (hazardous and non-hazardous waste) from the seismic and support vessels. Loss of solid waste also has the potential to cause a temporary/localised reduction in water quality and minor/temporary toxicity effects to marine biota.

Solid wastes may include non-biodegradable, non-hazardous wastes such as plastics, waste metal, glass and timber, and/or non-biodegradable hazardous wastes such as batteries and oil filters. Some solid waste generated onboard may be blown or knocked/dropped overboard.

Loss of solid wastes excludes scenarios involving detachment of operational equipment (i.e. streamers and the survey array), which is assessed in Section 8.6. Impacts associated with the discharge of putrescible wastes is assessed in Section 7.5.

8.7.1.1 Source of Impact/Risk

- Water quality.
- Ancient coastline at the 125 m depth contour KEF.
- Marine biota.
- Marine fauna.

8.7.2 Impact/Risk Evaluation

The seismic and support vessels will generate a variety of solid wastes including non-hazardous wastes (e.g. paper, plastics, waste metal and glass) and/or hazardous wastes (e.g. batteries and oil filters). Hence, there is the potential for solid wastes to be discharged to the marine environment.

Discharge of solid wastes have the potential to:

- Temporarily create a localised change in water/sediment quality resulting in localised, minor and temporary ecological impacts
- Cause injury, ingestion or entanglement by marine fauna.

8.7.2.1 Water/Sediment Quality

Impacts to water quality resulting from the unplanned loss of solid wastes are expected to be minor, temporary and highly localised. The resulting change in water quality in the water column will be highly localised and short term. Impacts to sediment quality are also expected to be minor, temporary and highly localised. Therefore, significant impacts to marine biota are not expected.

8.7.2.2 Marine Fauna

The risk associated with the loss of solid wastes to marine fauna involves direct interaction between the waste and organism, which may result in fauna mortality or injury through ingestion or entanglement.

Interaction may occur with marine fauna, including EPBC listed species such as cetaceans, marine turtles and whale sharks in the:

- Pelagic zone (floating wastes / temporarily floating wastes); and/or
- Benthic zone (wastes that descend the water column to the seabed).

Solid wastes will not be discharged to sea but rather will be stored on-board the seismic vessel and support vessels prior to transfer to a supply vessel for onshore recycling or disposal. Where practical, solid waste will be minimised, and non-hazardous waste will be either reused or recycled.

Windblown waste is likely to be a rare event as wastes will be stored in closed/covered containers. In the event of waste blown overboard, attempts would be made to recover it. There is the potential for windblown wastes to not be recovered from the marine environment, which may impact fauna via ingestion or entanglement. Ingestion or entanglement by marine fauna has the potential to result in serious injury or mortality.

Lost heavy solid wastes descending the water column will settle on the seabed, potentially causing minor disturbance to sediment and sessile benthic organisms. Benthic habitats within the Operational Area are considered to generally comprise of relatively little seabed structure or sessile epibenthos (Section 4.3.2). Any impact associated with this risk would be highly localised and proportional to the size/type of the solid waste.

Consequently, the potential impacts to marine fauna as a result of windblown waste or waste knocked/dropped overboard are unlikely and would be limited to individual occurrences.

8.7.2.3 Summary

Considering the required controls, the consequence resulting from the risk of occasional short term and localised disturbance to marine fauna and benthic habitat from the unplanned discharge of hazardous and non-hazardous solid waste is Minor (1). The likelihood of this consequence occurring is Rare (A) and the risk is considered to be Low.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability are provided below.

8.7.3 Decision Context

The decision context for loss of solid wastes has been assessed as ‘Type A’, given the impacts/risks are well understood, uncertainty is minimal and little or no stakeholder interest.

8.7.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements			
In accordance with MARPOL Annex V and Marine Order 95: • Vessels 100 GRT (or certified for 15 persons on-board) will have a Waste Management Plan • Vessels ≥400 gross tonnes (or certified for 15 persons on-board) will have a waste management logbook	Yes	Vessels engaged for the survey that are of 100 GRT or certified to carry more than 15 people will have a Waste Management Plan and vessels ≥400 gross tonnes or certified to carry more than 15 persons, will hold a Waste Management Logbook. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.	14.1
Marine Order 94 – packaged harmful substances, which requires: • Vessels carrying harmful substances in packaged form must comply with regulations 2 to 5 of MARPOL Annex III, with respect to stowage requirements A a substance may only be washed overboard if: • The physical, chemical and biological properties of the substance have been considered • Washing overboard is considered the most appropriate manner of disposal • The vessel master has authorised the washing overboard.	Yes	Vessels used for the survey will comply with regulations 2 to 5 of MARPOL Annex III and the vessel Master will comply with Marine Order 94. It is a legislative requirement for vessels to comply with AMSA Marine Orders. Good Industry Practice	14.2
Bins available for the segregation of waste as per the vessel Waste Management Plan, and bins for potentially wind-blown waste are covered (e.g. using lids or netting).	Yes	Bins will be used to segregate wastes on vessels in accordance with the vessel Waste Management Plan and covered bins will be used to prevent windblown waste. The control is considered good practice, is well defined and established standard practice by the offshore petroleum sector. While adoption of the control does not reduce the likelihood or consequence of the risk, implementation is considered to provide overall benefit to the risk.	14.3
Recycling or reuse of non-hazardous solid waste where possible.	Yes	Non-hazardous solid waste generated on-board the vessel will either be recycled where practical or reused. Good industry practice, environmental benefit outweighs additional cost.	14.4
Alternatives/Substitutes Considered			
No practicable alternative or substitutes to the above the controls have been identified	N/A	N/A	N/A
Additional Controls Considered			
No practicable alternative or substitutes to the above the controls have been identified	N/A	N/A	N/A
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No practicable alternative or substitutes to the above the controls have been identified	N/A	N/A	N/A
ALARP Statement			
The residual risk associated with the unplanned loss of solid waste has been determined to be Low. CGG considers the adopted control measures appropriate to manage the risks of a loss of solid waste. As the risk has been classified as ‘Type A’ and no reasonable additional or alternative controls were identified that would further reduce the impacts and risks, without jeopardising the objectives of the survey, the risk is considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Minor (1)	Rare (A)	Low

8.7.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing the loss of soil waste, reflects CGG’s HSE Policy goals of proactively identifying hazards, eliminating impacts where possible and where this is not possible managing the risk to ALARP.
	Company Standards/Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Environmental Performance Monitoring and Reporting (Section 9.3).
External	Natural Environment	**EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.

Context	Factor	Demonstration
		Conservation Advice, Recovery Plans, and Other Guidelines: Marine debris causing entanglement and ingestion was recognised in 2003 as a key threatening process for marine vertebrates under the EPBC Act. Pollution generally is also identified as a threat in several conservation advices / recovery plans for EPBC-listed species potentially occurring within the Operational Area. CGG has reduced and, where possible, eliminated any adverse impacts of marine debris from the activities of the seismic survey on turtles, cetaceans, sharks and birds, noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life (Commonwealth of Australia 2018). **Conservation values and objectives of the North-west Marine Parks Management Plan** Although the Operational Area is not located within any AMPs, management of discharges in accordance with the requirements of MARPOL meets the management prescriptions outlined in the North and North-west Management Plans for AMPs. Unplanned loss of solid waste will not occur in AMPs.
	Relevant Persons Expectations	No specific concerns have been raised by stakeholders relating to loss of solid waste.
Legislation and Other	Legislation	The proposed controls meet or exceed the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and associated AMSA Marine Orders made under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* for the management of discharges at sea.
Industry Standards	Industry Standards and Best Practices	The impact/risk will comply with industry standards and good practice by using bins to segregate wastes on vessels in accordance with the vessel Waste Management Plan. Covered bins with tight lids will be used to prevent windblown waste.
Ecological Sustainability Development (ESD)	ESD Application	Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from loss of hazardous or non-hazardous solid waste meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, loss of solid waste is unlikely to result in potential impact greater than localised and short-term local concern to water quality and marine biota. Further opportunities to reduce the impacts and risks have been investigated above. The adopted controls described in Section 8.7.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.

8.7.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID	
EPO 14	No releases of solid hazardous or non-hazardous waste to the marine environment during the survey.	PS 14.1	PS 14.3
		PS 14.2	PS 14.4

Number	Performance Standards	Measurement Criteria
PS 14.1	Seismic vessel and support vessels are compliant with Marine Order 95 – pollution prevention – Garbage: • Vessels 100 GRT (or certified for 15 persons on-board) will have a Waste Management Plan • Vessels ≥400 gross tonnes (or certified for 15 persons on-board) will have a waste management logbook	Records demonstrate any non-compliance with Marine Orders is documented.
PS 14.2	Seismic vessel and support vessels are compliant with Marine Orders 94 – packaged harmful substances which provides information about preventing harmful substances carried by regulated Australian vessels, from entering the marine environment, which requires: • Vessels carrying harmful substances in packaged form must comply with regulations 2 to 5 of MARPOL Annex III, with respect to stowage requirements • A vessel Master may only wash a substance overboard if: • The physical, chemical and biological properties of the substance have been considered • Washing overboard is considered the most appropriate manner of disposal • The vessel Master has authorised the washing overboard.	Records demonstrate any non-compliance with Marine Orders is documented.
PS 14.3	Hazardous and non-hazardous waste will be managed in accordance with the vessel Waste Management Plan, which requires: • Dedicated waste segregation bins. • Records of all waste to be disposed, treated or recycled onshore. • Waste streams shall be handled and managed according to their hazard and recyclability class.	Pre-Mobilisation Inspection Report confirms that a vessel Waste Management Plan is on the vessel Documented evidence that the vessel Waste Management Plan is included in induction content Records demonstrate compliance against implemented vessel Waste Management Plan.
PS 14.4	Non-hazardous solid waste is recycled or reused where possible.	Records demonstrate compliance against implemented vessel Waste Management Plan.

8.8 Introduction of Invasive Marine Species: Ballast Water and Biofouling

8.8.1 Details of Impacts and Risks

8.8.1.1 Source of Impact/Risk

Potential introduction of invasive marine species (IMS) via unmanaged vessel biofouling or the discharge of ballast water from vessels within the Operational Area.

IMS are non-indigenous marine plants or animals that have been introduced into a region beyond their natural range and have the ability to survive, reproduce and establish invasive populations. The survey and support vessels operating in the Operational Area have the potential to introduce IMS via the following mechanisms:

- Discharge of ballast water containing IMS
- Translocation of IMS through biofouling of the vessel hull, internal sea water systems (e.g. sea chests, bilges) or immersible equipment (e.g. towed seismic source and streamers).

The survey and support vessels will operate out of an Australian port (likely Port Hedland). Should a survey or support vessel arrive in Australia from overseas, it will enter Australian territory via an Australian port prior to mobilising to the Operational Area.

8.8.1.2 Receptors

- Marine ecological communities
- Ancient coastline at the 125 m depth contour KEF.

8.8.2 Impact/Risk Evaluation

IMS are widely recognised as potentially significant threats to marine ecosystems worldwide. 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). The availability of suitable habitat, such as hard substrate or artificial structures are also conducive to the settlement and establishment of IMS (Glasby *et al.* 2007; Dafforn *et al.* 2009a, 2009b; Wells *et al.* 2009).

Not all organisms that are translocated to an area outside of their natural range will survive to establish as IMS, with the majority of introduced species failing to establish (Williamson and Fitter 1996; Paulay *et al.* 2002). The successful survival and subsequent establishment of an IMS is dependent on a number of factors, including:

- Presence and potential for uptake of organisms at a point of origin prior to translocation, such as a port, harbour or within coastal waters
- Activities undertaken by the vessel (both at origin and destination) that favour successful establishment of the IMS, such as low speed or stationary vessel activities in shallow water locations
- Environmental conditions during transit and at destination compared with the point of origin, such as water temperature, salinity and light availability
- Availability of suitable habitat on which to settle, grow, reproduce and establish a population.

Once introduced, IMS may be irreversible and can have significant impacts on the marine ecosystem. Invasive organisms may have few or no predators or natural competition, resulting in IMS potentially outcompeting native species for food or habitat, preying on native species, and/or changing the nature of the environment. This may result in an alteration to the structure (species biodiversity and abundance) and the functioning of ecological communities. Introduction of IMS also has the potential to introduce pathogens to the marine environment, which can be detrimental to native organisms.

During the Sauropod 3D MSS, vessels will be moving for the majority of the time and will not be stationary for prolonged periods and so are less conducive to the translocation of IMS than stationary vessels. The water depths in the Operational Area range from approximately 95 m to 172 m. The bathymetry within the Operational Area is predominately characterised by relatively flat seabed without shallow bathymetric features. In addition, the substrate is predominantly calcareous gravel, sand and silt, which support relatively little seabed structure or sessile epibenthos. Areas of hard substrate and topographic relief supporting filter feeder communities may occur in association with the ancient coastline at the 125 m depth contour KEF. Therefore, given the nature of the survey activities, the relatively deep-water location and limited availability of suitable habitat provides relatively unfavourable environmental conditions for most IMS to become established and spread. However, in the unlikely event that IMS were introduced to the Operational Area by the survey and support vessels and were successful in establishing on substrates associated with the ancient coastline at the 125 m depth contour KEF, this could result in long-term-impacts to the these regionally significant ecological communities. Changes to ecological communities may also impact socio-economic receptors such as commercial fisheries, by affecting target fish stocks or through food chain related impacts.

Given the unfavourable water depths, environmental conditions (i.e. low light penetration at the seabed), and the limited availability of suitable habitat in the Operational Area, establishment of IMS is not expected to occur. However, any localised introduction of IMS in the Operational Area, including the ancient coastline at the 125 m depth contour KEF, may result in long-term changes to ecological communities in the form of decreased ecological diversity or ecosystem health, and potential for indirect effects to commercial fisheries. If unmanaged, the potential consequence of localised but medium-term impacts is assessed as Moderate (2).

Given the environmental conditions in the Operational Area, the mobile nature of the survey and support vessels and the implementation of the identified controls (Section 8.8.4), the consequence is considered to be Moderate (2) and the likelihood of IMS being introduced and subsequently becoming established is reduced to Rare (A), resulting in a Low level of residual risk.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability are provided below.

8.8.3 Decision Context

The decision context for the potential introduction of IMS has been assessed as ‘Type A’, given the impacts/risks are well understood, good practice is well defined, the conditions in the Operational Area are of limited environmental sensitivity with respect to IMS, and there is little or no stakeholder interest.

8.8.4 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Legislative Requirements and Good Industry Practice			
Seismic vessel and support vessels will have Department of Agriculture and Water Resources biosecurity clearance prior to mobilising to the Operational Area.	Yes	Vessels are required to submit a pre-arrival report prior to entering Australian territorial waters and obtain Department of Agriculture and Water Resources (DWAR) biosecurity clearance. Clearance confirms that the vessel meets the requirements of the *Biosecurity Act 2015*and Biosecurity Regulations 2016 for entry into Australian waters, including review of a ballast water report by a biosecurity officer. Mobilisation of the vessels to the Operational Area will only occur after clearance is confirmed. Clearance confirms that the vessel does not present a high risk to the marine environment in Australian waters and therefore reduces the likelihood of IMS being translocated to the Operational Area. The Ballast Water Report provided during reporting identifies if the vessel has or intends to discharge internationally sourced ballast water, and management will be conducted as determined by DWAR.	15.1
Vessels will also have an anti-fouling system that is compliant with the prescriptions of the International Convention on the Control of Harmful Anti-fouling systems on ships 2001, the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006* and Marine Order 98 (Marine pollution - anti-fouling systems) 2013.	Yes	Vessels will have an anti-fouling system that is compliant with the International Convention on the Control of Harmful Anti-fouling systems on ships 2001, the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006* and Marine Order 98 (Marine pollution - anti-fouling systems) 2013. An anti-fouling coating provides a level of protection to reduce the establishment of marine organisms on hulls and in niches, and therefore reduces the likelihood of IMS being introduced through biofouling.	15.2
Compliant with the Australian Ballast Water Management Requirements, vessels will manage ballast water exchange/discharge using one of the following approved methods of management including: • An approved ballast water management system • Ballast water exchange conducted in an acceptable area * • Use of low-risk ballast water (e.g. fresh potable water, water taken up on the high seas, water taken up and discharged within the same place) • Retention of high-risk ballast water on-board the vessel • Discharge to an approved ballast water reception facility. *Acceptable area is as defined in the Biosecurity (Ballast Water and Sediment) Determination 2017.	Yes	Once in the Operational Area, vessels are not anticipated to exchange/discharge ballast water. Any requirement to do so will comply with the Australian Ballast Water Management Requirements, which are consistent with international good practice and the Ballast Water Management Convention. Management of ballast water reduces the likelihood of IMS being introduced to the Operational Area by preventing the exchange of high-risk ballast water.	15.3
Vessels will have an approved Ballast Water Management Plan (BWMP) and valid Ballast Water Management Certificate (BWMC) unless an exemption applies or is obtained from DWAR.	Yes	In accordance with the Australian Ballast Water Management Requirements, vessels will have a BWMP that details the approved ballast water management method. A BWMC verifies the vessel has been surveyed to a standard compliant with the Ballast Water Convention. Management of ballast water reduces the likelihood of IMS being introduced to the Operational Area by preventing the exchange of high-risk ballast water.	15.4
Vessels will maintain complete and accurate records of ballast water exchange that complies with Section B, Regulation B.2. of the Annex to the Ballast Water Convention.	Yes	Records identify when ballast water is taken on-board; circulated or treated for ballast water management purposes; and discharged to the sea or a reception facility; and accidental or other exceptional discharges of ballast water. Ballast water records will be used to confirm that ballast water management is undertaken in accordance with the Australian Ballast Water Management Requirements, as detailed above.	15.5
Biofouling risk assessment	Yes	A biofouling risk assessment will be completed for each vessel mobilised from overseas or from other regions in Australia prior to mobilising to the Operational Area. CGG will use the Biofouling Risk Assessment Tool 'Vessel Check' developed by the WA DPIRD (or equivalent). The assessment will consider hulls, niche areas, sea water systems and immersible equipment. Mitigation will be implemented that is commensurate to the level of risk, as appropriate to ensure the vessel and equipment poses a low risk of introducing IMS. For vessels determined to have a LOW biofouling risk, the vessel is deemed suitable for use in the Sauropod 3D MSS without corrective actions. For vessels determined to have a MEDIUM or HIGH risk, the vessel contractor will need to engage a qualified independent third-party marine pest inspector to determine the corrective actions to reduce the vessel IMS risk to low. The vessel contractor must demonstrate to CGG that all corrective actions have been implemented and reassessment of the vessel prior to mobilisation determines the risk to be low. This control and implementation of any associated corrective actions will reduce the likelihood of IMS translocation and establishment from biofouling.	15.6

Control Measure	Control Adopted	Justification	Performance Standard Ref.
Alternatives/Substitutes Considered			
No discharge of ballast water from vessels.	No	Although, ballast water exchange is not expected to occur during routine survey activities, the possibility of discharge or exchange cannot be ruled out completely. Ballast water exchange and uptake may be required in unexpected circumstances where the safety of persons on-board the vessel is a necessity. Ballast water will already be managed in accordance with the Australian Ballast Water Management Requirements and the likelihood of introducing IMS via ballast water is highly unlikely. The control is not practicable to implement and is grossly disproportionate to the limited environmental benefit that would be gained in addition to existing controls.	N/A
Additional Controls Considered			
Hull cleaning and/or new antifouling coat application to vessel hull and niche areas on every occasion prior to entry into the NWMR.	No	Given the existing control measure to undertake a biofouling risk assessment, this control measure may not be commensurate to the level of risk. Should the risk assessment determine a vessel to have a medium or high IMS risk from biofouling, further inspections or cleaning may be implemented. However, the cost of undertaking inspections and hull cleaning could range from tens to hundreds of thousands of dollars. This is not practicable to implement in all cases and is disproportionate to the level of risk if the existing risk profile for a vessel is already low.	N/A
All towed seismic equipment (source and streamers) have been removed from the water, inspected and cleaned (where required) prior to deployment in the NWMR.	Yes	Transfer of immersible equipment will result in equipment being stored out of water, which reduces the potential for marine fouling to survive transport. Equipment will also be inspected and cleaned prior to deployment in Australian waters, which reduces the risk of introducing IMS and also increases performance of the equipment.	15.7
Improvements Considered to Effectiveness of Controls (Functionality, Availability, Reliability, Survivability, Independence and Compatibility)			
No further improvements have been identified that can practicably reduce the level of risk.	N/A	N/A	N/A
ALARP Statement			
CGG considers the adopted control measures appropriate to manage the impacts and risks of IMS. As the impact/risk has been classified as ‘Type A’, all legislative and good practice controls, as well as additional controls have been identified that further reduce the impacts and risks, without jeopardising the objectives of the survey, the impacts and risks are considered to be ALARP.			

Risk Ranking	Consequence	Likelihood	Risk Ranking
Residual Risk	Moderate (2)	Rare (A)	Low

8.8.5 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Internal	CGG Policy	The risk management strategy for managing the potential to introduce IMS, reflects CGG’s HSE Policy goals of proactively identifying hazards, eliminating impacts where possible and, where this is not possible, managing the risk to ALARP.
	Company Standards/ Systems	Section 9 details the relevant management system processes adopted to implement and manage impacts/risks to ALARP: • Contractor and Supplier Management (Section 9.6) • Environmental Performance Monitoring and Reporting (Section 9.3).
External	Natural Environment	**Natural environmental setting of the Sauropod 3D MSS** The water depths and environmental conditions within the Sauropod 3D MSS Operational Area present limited potential for the introduction and establishment of IMS and the residual risk is low. **EPBC Policy Statement 1.1. – Significant guidelines** The residual risk has been assessed as low and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines. **Conservation Advice, Recovery Plans, and Other Guidelines** IMS is identified as a key threat in several conservation management plans, with actions focusing on the prevention of their introduction. The proposed control measures are consistent with these actions. **Conservation values and objectives of the North-west Marine Parks Management Plan** No IMS impacts are predicted to occur to the natural values within the AMPs.
	Relevant Persons Expectations	The Department of Agriculture and Water Resources responded during stakeholder consultation and outlined the need to comply with the requirements of the *Biosecurity* Act 2015, Biosecurity Regulations 2016, and Australian Ballast Water Management Requirements. The Department also provided information on biofouling management (including biofouling guidelines 2011) The control measures adopted meet the requirements of the *Biosecurity Act* 2015, Biosecurity Regulations 2016, and the Australian Ballast Water Management Requirements and are consistent with the National Biofouling Management Guidelines.
Legislation and Other	Legislation	The controls adopted will comply with the *Biosecurity Act 2015*, Biosecurity Regulations 2016, and the Australian Ballast Water Management Requirements.
Industry Standards	Industry Standards and Best Practices	The controls adopted with regards to anti-fouling coatings, biofouling risk assessment and corrective actions are consistent with the National Biofouling Management Guidelines.

Context	Factor	Demonstration
Ecological Sustainability Development (ESD)	ESD Application	Compliance with the principles of ESD is demonstrated.

Acceptability Statement
As identified in Section 6.7.1, impacts and risks classified as 'Decision Type A' are considered acceptable if the level of residual risk is determined to be low or medium and the criteria outlined in Table 6-7 are met. The evaluation of potential risk and impacts from introduction of invasive marine species meets these requirements as outlined above. The impact assessment has determined that, given the adopted controls, the Sauropod 3D MSS is highly unlikely to result in the introduction of IMS. Further opportunities to reduce the risk have been investigated above. The adopted controls described in Section 8.8.4, are considered industry best practice and meet legislative requirements. CGG considers the adopted control measure to be appropriate to manage the activity to an acceptable level.

8.8.6 Environmental Performance Outcomes, Standards and Measurement Criteria

Number	Environmental Performance Outcomes	Relevant Performance Standard ID		
EPO 15	Prevent the introduction and establishment of IMS in the marine environment as a result of the Sauropod 3D MSS	PS 15.1 PS 15.2 PS 15.3	PS 15.4 PS 15.5	PS 15.6 PS 15.7

Number	Performance Standards	Measurement Criteria
PS 15.1	CGG verify that vessel contractors comply with pre-arrival reporting obligations defined in the *Biosecurity Act 2015* and that biosecurity clearance / low risk status is obtained from DWAR prior to mobilisation to the Operational Area.	Pre-mobilisation vessel audit confirms vessels have received documentation of DAWE release from biosecurity control or low risk status.
PS 15.2	All vessels have an anti-fouling system that complies with the requirements of Annex 1 of the International Convention on the Control of Harmful Anti-fouling systems on ships 2001, the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006* and Marine Order 98 (Marine pollution - anti-fouling systems) 2013.	Pre-mobilisation vessel audit confirms vessels have current anti-fouling certification that complies with the stated convention, Act and Marine Order.
PS 15.3	Vessels operating within Australian seas manage ballast water discharge in accordance with the Australian Ballast Water Management Requirements using one of the following approved methods of management including: • An approved ballast water management system • Ballast water exchange conducted in an acceptable area* • Use of low-risk ballast water • Retention of high-risk ballast water on-board the vessel • Discharge to an approved ballast water reception facility. *Acceptable area is as defined in the Biosecurity (Ballast Water and Sediment) Determination 2017.	Pre-mobilisation vessel audit confirms vessels have a BWMC and BWMP that provides for ballast water management in accordance with the Australian Ballast Water Management Requirements. Ballast water records confirm that ballast water management was undertaken in accordance with the Australian Ballast Water Management Requirements.
PS 15.4	Vessels have an approved BWMP and valid BWMC, unless an exemption applies or is obtained from DWAR.	Vessels have an approved BWMP and valid BWMC on-board.
PS 15.5	Vessels maintain complete and accurate records of ballast water exchange that complies with Section B, Regulation B.2. of the Annex to the Ballast Water Convention.	Records demonstrate the ballast water exchange records are maintained.
PS 15.6	A biofouling risk assessment, in accordance with WA DPIRD 'Vessel Check' (or equivalent) is completed for all MSS vessels mobilising from overseas or from other bioregions of Australia, prior to arrival within the NWMR. Where required, mitigation measures commensurate to the risk are implemented to ensure the vessel risk profile is reduced to 'Low' in accordance with WA DPIRD 'Vessel Check' (or equivalent).	Vessel-specific biofouling risk assessment (WA DPIRD 'Vessel Check' or equivalent) confirming the vessel presents a low risk and records of mitigation measures implemented (if required).
PS 15.7	The seismic source and towed streamers have been removed from the water, inspected and cleaned (where required) prior to deployment in the NWMR.	Pre-mobilisation vessel audit confirms seismic source and towed streamers have been removed from the water, inspected and cleaned (where required).

9 Implementation Strategy

CGG's implementation strategy for this EP has been developed to comply with the requirements of Regulation 14(1) of the OPGGS(E) and describes the specific measures and arrangements that will be implemented for the duration of the activity to ensure that:

- All environmental impacts and risks of the activity will be continually identified and reduced to a level that is ALARP
- Control measures detailed in the EP are effective in reducing the environmental impacts and risks of the activity to ALARP and acceptable levels
- Environmental performance outcomes and standards set out in the EP are met
- Arrangements are in place to respond to, and monitor impacts of, oil pollution emergencies
- Stakeholder consultation is maintained throughout the activity as appropriate.

The implementation strategy outlines a systematic approach that describes:

- The management systems by which the control measures identified in the risk assessment will be implemented
- The implementation of control measures will be monitored to ensure environmental risks continue to be managed to ALARP
- The ongoing stakeholder consultation process prior to and during the activity
- Monitoring, auditing and reporting of environmental performance for activities carried out under the EP
- Arrangements in place to respond to, and monitor impacts of, oil pollution emergencies.

The implementation strategy for this EP has considered lessons learnt from the implementation of previous campaigns and inspection recommendations.

9.1 Environmental Management System

The Sauropod 3D MSS will be conducted under the framework of the CGG Environment and HSE Policies (Appendix A:), CGG Environmental Management Procedure, CGG Health, Safety, Environment and Social Responsibility Operating Management System (HSE-OMS) and the survey vessel's HSE MS.

The program will also operate under a project-specific HSE plan that CGG and the vessel operator will develop for the Sauropod 3D MSS. The Project HSE Plan is a tailored document that ensures CGG's environmental management standards and intended performance outcomes are achieved at operational level throughout the activity, while identifying and enabling the selected seismic contractors' own procedures (if a contractor is used) to be utilised where appropriate; for example, for specific vessel operational controls. At all times, however, the seismic contractor will be required as a minimum to comply with all relevant requirements of CGG's HSE policies and standards. As described in CGG Environment Management Procedure, the Project HSE Plan will incorporate regulatory and client environmental requirements including procedures for the following:

- Emergency response
- Waste management
- Hazardous materials and handling
- Fuel/oil spills.

The seismic contractor's vessel HSE documentation will be reviewed for compliance with the relevant requirements described in this EP prior to the commencement of the activity. In the event of a gap between the existing plans and procedures and the requirements of this EP, a bridging document will be developed to ensure all control measures are adequately covered in the implementation of the EP and the hierarchy of control established.

9.2 Management of change

For the Sauropod 3D MSS, the following activities will trigger a Management of Change (MoC) process:

- A new scope (e.g. timing, location or changes to operational details such as vessel type, equipment, processes or procedures), which has the potential to impact on the environment not assessed for environmental impact previously or authorised in existing management plans and procedures (responsibility of the CGG Project Manager)
- Change to the existing activity, scope, equipment, process or procedures which have the potential to impact on the environment or interface with an environmental receptor (responsibility of the CGG Project Manager)
- Changes in the external environment managed and monitored by the CGG Project Manager (or delegate):
- Provision of new information that differs to that included in this EP, such as:
    - Potential changes in scientific knowledge regarding impacts and risks from seismic activities
    - New environmental sensitivities within or adjacent to the survey area
- Issue of new regulatory requirements (e.g. AMP Management Plans)
- Identification of KEFs, threatened or migratory species or critical habitats/BIAs not identified in the EP
- Identification of new stakeholder objections or claims that are assessed to have merit, including evidence of a reduction in catch when compared to historical fishing activity, as recorded in statutory Catch and Disposal Records for at least two out of the previous five years prior to the Sauropod 3D MSS, within an Adjustment Area (an area extending 10 km around the perimeter of the acquired survey area [where guns are fired at full power for the purpose of data acquisition], noting this may be smaller than the defined Acquisition Area of the survey) during and/or up to two months after the conclusion of the acquisition of the seismic survey.
- Non-conformances (audits, inspections, etc.) which identify control measures may no longer manage environmental impact/risk to ALARP or acceptable criteria. Non-conformances are monitored by the CGG offshore representative
- Incidents which identify new or increased impacts and risks arising from activities not previously identified in the accepted EP. Incidents are monitored by the CGG offshore representative.

Any change to the Sauropod 3D MSS shall be directed to the CGG offshore representative and the CGG Project Manager for initial assessment. The change shall be assessed for environmental impact/risk in accordance with the CGG risk methodology and any implications determined for the environment and associated regulatory document revisions.

A risk assessment will accompany any MoC with identified environmental impacts/risks in accordance with the CGG Risk Management and Management of Change Process (refer Section 6 and Section 9.2).

For changes (e.g. additional controls implemented) identified in the risk assessment process, if stakeholder interests, activities or functions are affected by the change, stakeholders will be advised, and feedback invited on the proposed change.

Additional controls identified as part of the MoC shall be effective in reducing the environmental impact and risk to a level which is ALARP and acceptable; and meet the nominated EPOs and EPSs set out in the accepted EP for the activity. Note: Existing EPOs and EPSs cannot be altered from those set out in the accepted EP. If EPOs/EPSs cannot be met, a recordable or reportable incident will be registered for the activity.

If a change in impacts and risks to commercial fishing is confirmed, a practical, evidence-based process for reasonable monetary adjustment will be provided to commercial fishers for loss of catch, displacement, or fishing gear loss or damage in the form of a Fishery Impacts Mitigation Plan. Good practice principles that will incorporated into a Fishery Mitigation Plan, if required, will include:

- Mitigation will be made available during the acquisition phase of the seismic survey and up to two months after the conclusion of the acquisition of the seismic survey.
- Mitigation will be available to a commercial fisher who fishes as a normal part of their commercial fishing activity within the Adjustment Area (an area extending 10 km around the perimeter of the acquired survey area [where guns are fired at full power for the purpose of data acquisition], noting this may be smaller than the defined Acquisition Area of the survey as defined in the EP). A commercial fisher must be able to demonstrate that they would have received the revenue from the landed catch that is the subject of a claim and adjustment is dependent on a commercial fisher continuing to carry out their fishing activities to the best of their ability and to mitigate and limit financial loss despite the occurrence of a seismic survey, i.e. adjustment would not available where a fisher chooses to move away from a survey and makes no attempt to fish within the survey Adjustment Area.
- The mitigation process will apply to historical fishing activity over established fishing grounds, and not to speculative fishing activity

- Mitigation claims may be lodged up to 4 months after the conclusion of the acquisition of the seismic survey
- If a commercial fisher is unable to fish in their historical fishing area within the Adjustment Area during the seismic survey and incurs costs over and above the normal running costs for a fishing trip while relocating to another historical fishing area, then costs associated with increased distance/transit time, fuel and crewing will be considered for monetary adjustment.

9.3 Environmental Performance Monitoring, Inspection, Audit and Reporting

9.3.1 Pre-survey inspection and audit

Prior to the survey, CGG will undertake:

- A vessel audit/inspection to confirm that the vessel management systems are consistent with the environmental management controls detailed in this EP. This will ensure that procedures and equipment for managing routine discharges and emissions are in place to enable conformance with the EP. The audit will be documented, and any corrective actions closed out and tracked through the CGG management system.
- A review of the risk of IMS, potentially including an inspection to confirm that the vessel does not pose an unacceptable risk of IMS.
- An audit of the on-board spill response capability of the seismic vessel against its SOPEP and relevant controls in this EP, to verify spill preparedness
- A review to ensure that the EP Assurance procedure has been communicated to relevant personnel.

9.3.2 Monitoring, auditing and management of non-conformance

CGG will maintain a quantitative record of emissions and discharges as required under Regulation 14(7) of the OPGGS(E). This record will include all emissions and discharges to the air and water and can be monitored and audited against the environmental performance standards. A summary of these results will be reported in the Sauropod 3D MSS Environmental Performance Report to be submitted to NOPSEMA three months after the completion of the Sauropod 3D MSS.

CGG will monitor the performance of the control measures during the activity in line with the Project HSE Plan and CGG Environment Management document. Environmental performance during the survey will be reviewed to ensure that:

- EPOs and EPSs are being met, reviewed and where necessary amended (to continue to reduce the environmental impacts and risks of the activity to ALARP).
- Potential non-conformances and opportunities for continuous improvement are identified and corrective actions implemented.
- All environmental monitoring requirements have been met before completing the activity.

The following arrangements will be established to review the environmental performance of the activity:

- Inspections of the vessels will be carried out before and during the survey to ensure that procedures and equipment for managing routine discharges and emissions are in place to enable conformance with the EP.
- The performance of key equipment as described in this EP (i.e. oil-in-water separator) will be checked to ensure ongoing reduction of risks and impacts to ALARP, and any potential issues (i.e. observations of poor operating condition/performance or non-conformances) are continually monitored and raised as soon as practicable
- Records of inspections against EP requirements are documented in the ECR.

CGG will develop and maintain an electronic Environmental Conformance Register for the activity, which details the environmental commitments, performance outcomes and criteria outlined in this EP. The Conformance Register is an audit tool to be used before and during the activity to demonstrate conformance of the activity with the environmental performance commitments made by CGG.

A summary of the EP commitments for the activity will be distributed aboard the survey vessel, and implementation of the environmental performance standards will be monitored by the CGG Client Site Representative.

Conformance will be monitored on a regular basis by the Client Site Representative, or delegate, via mechanisms including fortnightly audits during the activity. Conformance auditing or inspection during the Sauropod 3D MSS will be based on the Conformance Register and will target the following:

- Conformance with regulatory requirements detailed in this EP

- Management strategies and procedures to ensure EPOs and EPSs are being implemented, monitored, measured and evaluated
- Emissions and discharges are being monitored, measured and documented.

Non-conformances and opportunities for improvement will be identified and corrective actions will be tracked to completion utilising the seismic vessel's on-board action tracking system. Corrective actions will specify the remedial action required to fix the breach and prevent its reoccurrence and is delegated to the person deemed most appropriate to fulfil the action. Where more immediacy is required, non-compliances will be communicated to relevant personnel immediately and responded to as soon as possible. CGG will carry forward any areas of non-conformance identified during the Sauropod 3D MSS for consideration in future seismic campaigns to assist with continuous improvement in environmental management controls and performance outcomes.

All breaches of EPOs and EPSs in this EP are considered non-compliances and a recordable incident (refer to Section 9.12). Non-compliances may be identified during an audit, inspection, general observation or as a consequence of an incident.

9.3.3 Review

An end of survey HSE Review will be jointly conducted by CGG and the seismic contractor during the Post-survey Meeting.

This activity will enable the review of management and mitigation strategies implemented during the survey and, including reviews of performance, incident investigations, audits and field activity to identify actions for future seismic surveys, which can be implemented on a continuous improvement basis. The end of survey HSE Review will include a 'Lessons Learnt' section to facilitate incorporation of any recommended improvement actions in future seismic activities.

9.3.4 Record Management

In accordance with the Commonwealth OPGGS (E) Regulations - Regulation 27, CGG will store and maintain documents or records relevant to the EP implementation for a period of five years in a way that makes retrieval reasonably practicable.

9.4 Organisation Structure

Key roles and responsibilities for CGG and contractor (if used) personnel in relation to implementation, management and review of this EP are described in Table 9-1. It is ultimately CGG's responsibility to ensure all employees and contractors (if used) comply with the requirements of the CGG corporate HSE Policy and that the personnel are suitably trained and competent in their respective roles. Roles and responsibilities for environmental management during the activity are a combination of generic/standard professional duties, such as complying with shipboard garbage procedures, complemented by project-specific requirements arising from this EP, such as regulator-specific reporting arrangements. CGG will ensure that all employees and contractors associated with the Sauropod 3D MSS are inducted into the requirements of the corporate Environment Policy (Appendix A), particularly regarding the responsibilities associated with each role. CGG will further ensure that all personnel are suitably trained and competent in their respective roles.

A clear chain of command for the shore-based and vessel-based roles relating to the Sauropod 3D MSS is provided in Figure 9-1.

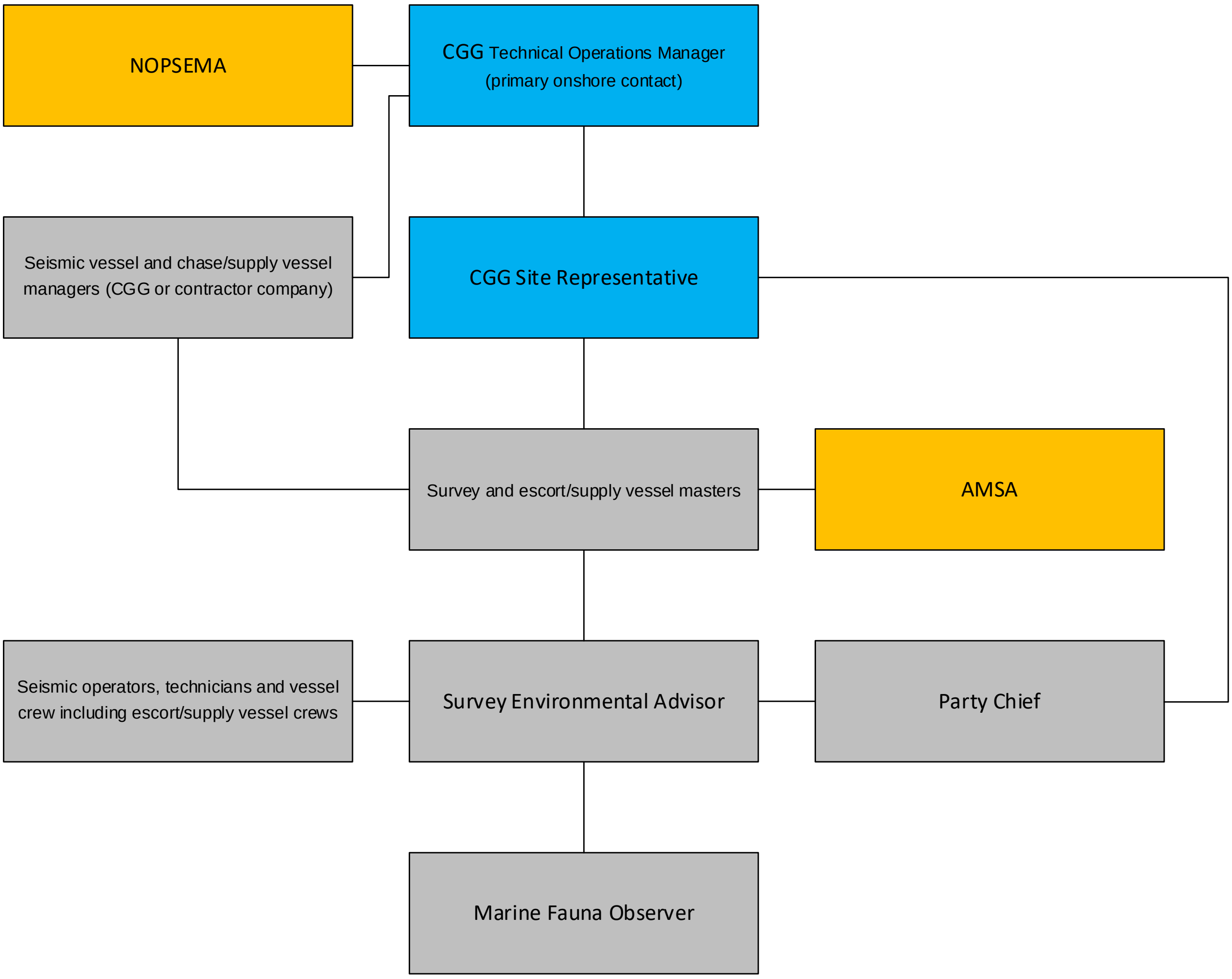


Figure 9-1 - Sauropod 3D MSS Organisation Structure

Roles and responsibilities as they relate specifically to Oil Spill Response are detailed in the Sauropod 3D MSS Oil Pollution Emergency Plan (OPEP) (Appendix G:).

During contract award and on evaluation of the contractor's management system, specific on-board positions will be identified who are responsible for specific control measure implementation.

Table 9-1 – Roles and responsibilities

Role	Responsibility
CGG Technical Operations Manager (primary onshore contact)	• Ensure the activity is undertaken as per the performance outcomes of the EP. • Provide sufficient resources to implement management measures to achieve the performance outcomes of the EP. • Manage change requests for the activity and notifying the Survey Environmental Adviser (SEA) of any scope changes in a timely manner. • Liaise with regulatory authorities as required. • With the support of the SEA, ensure that ongoing monitoring for potential changes that may have a bearing on the EP are undertaken • Review the EP as necessary and manage change requests • Ensure environmental incident reporting meets regulatory requirements. • Monitor and close out corrective actions raised from environmental inspections/audits or incidents. • Commit resources to facilitate an emergency response strategy in the event of an incident.

Role	Responsibility
	• Manage the CGG emergency response strategy in the event of an incident. • Review results of conformance audits conducted during the program and make recommendations where required. • Ensure that all reportable incidents are reported to NOPSEMA within 3 days of the incident occurring. • Ensure that all recordable incidents are reported to NOPSEMA as soon as practicable after the end of the calendar month, and not later than 15 days after the end of the calendar month. • Notify NOPSEMA of any spills in Commonwealth waters. • Ensure that a full briefing to all project personnel is provided, including details of the environmental sensitivities of the Acquisition Area and environmental management procedures and performance outcomes detailed in this EP. • Preparation of the Post-survey Environmental Review Report (PERR) and submission to NOPSEMA.
Seismic vessel and chase/supply vessel managers (CGG or contractor company)	• Vessel Quality, Health, Safety and Environmental (QHSE) performance (qualitative and quantitative) including but not limited to - Leadership by personal example and visible commitment to instil excellent QHSE behaviour and culture aboard - Establishing and reviewing the annual QHSE plan for the vessel - Ensuring the vessel's conformance with all company standards, policies and procedures - Ensuring major incidents (Lost Time Injury and/or Hi-Potential or above) are thoroughly investigated, root cause analyses performed, corrective actions completed, logged and closed out - Participation in key audits - Ownership of the vessel's HSE statistics, leading and lagging indicators and overall HSE performance - Ensuring that all relevant QHSE documentation is in place for the vessel, according to the company's QHSE Management System requirements.
Survey and escort/supply vessel masters	• Ensure the safe execution of all operations of the survey/supply/escort vessel • Overall responsibility for HSE management aboard the survey/supply/escort vessel • Ensure vessel operations are being conducted in accordance with the legislative requirements and this EP, including waste management, refuelling and emergency/oil spill response • Ensure vessel audits, inspections, emergency drills, training, HSE and inductions are undertaken • Ensure maintenance of equipment and records meet statutory requirements • Implement the vessel's SOPEP and OPEP procedures in the event of an oil spill, including first response to an incident using the resources immediately available to the vessel • Immediately notify the Client Site Representative of any incidents/activities arising from vessel operations that are likely to have a negative impact on the performance outcomes detailed in this EP • Support the Client Site Representative in ensuring that all relevant HSE documents are understood and adhered to • Report hydrocarbon or other chemical spillage to the Party Chief • Establish and maintain radio contact with other vessels in the Sauropod 3D MSS operational area and adjacent waters • Notify AMSA, the CGG Technical Operations Manager and the support vessels to report to seismic survey Vessel Manager in the event of a notifiable oil spill.
Party chief	• Ensure safe execution of all operations carried out by the seismic crew aboard the survey vessel. • Ensure that the following documents are in place and aboard – CGG Sauropod HSE Plan

Role	Responsibility
	– Emergency Response Procedures – HSE Management Procedures – Hazard Management Procedures – SOPEP and OPEP – this EP. • Ensure the seismic operations are conducted in accordance with – the CGG Environment Policy – Bridging Document between CGG, this EP and the seismic vessel contractor, if required – CGG plans, procedures and work instructions – relevant environmental legislative requirements or regulatory conditions – this EP. • Ensure the control measures adopted within this EP relating to operation of the seismic source are implemented to minimise potential environmental impacts resulting from seismic acquisition (e.g. pre-watch, soft-start procedures, stop-work procedures) • Ensure equipment used on site is inspected before use and as required during survey. • With assistance from others, inspect and maintain equipment, including environmental equipment. • Maintain all statutory test and inspection documentation for the marine equipment. • Provide a daily log of activities and environmental incidents to the Client Site Representative. • Ensure compliance with all aspects of HSE reporting and for investigations of all incidents and near misses. • Immediately notify the Client Site Representative of any incidents/activities arising from seismic operations that are likely to have a negative impact on the performance outcomes detailed in this EP.
CGG/client site representative (primary offshore contact)	• Ensure that the following documents are understood and adhered to - project HSE Plan and CGG HSE Plan - Emergency Response Procedures including survey vessel SOPEP - HSE Management Procedures - Hazard Management Procedures - Environmental Management Procedures - this EP • Facilitate clear communications between the Perth office, the CGG Technical Operations Manager, Vessel Manager and the survey vessel personnel • Ensuring all personnel have received a program environmental induction and the induction includes environmental sensitivities, control measures, specific roles and responsibilities of all vessel crew members • Ensuring day-to-day activities are monitored for conformance against this EP and the outcomes are reported to the Technical Operations Manager • Immediately alerting the Technical Operations Manager of any changes in operations which could impact negatively on environmental performance or for changes in operation which alter the environmental risk profile of the activity • Ensuring vessel inspections are undertaken in accordance with the requirements of this EP, CGG's procedures and the seismic vessel's procedures • Ensuring survey operations are carried out in accordance with the control measures and environmental performance standards adopted within this EP • Monitoring and reporting on the conformance of all EP commitments through observations and assessments of performance against the measurement criteria

Role	Responsibility
	• Assisting with review, investigation and reporting all environmental incidents are reported to the Technical Operations Manager, appropriate levels of incident investigation are undertaken and corrective actions from incidents are tracked to completion on behalf of CGG • Ensuring incidents are fully investigated and corrective actions monitored to close-out • Facilitating clear communications between the Perth office, the Technical Operations Manager, Vessel Manager and the survey vessel crew • Ensuring data and records are collected for the Post-survey Environmental Performance Report (PEPR) • Assisting the Technical Operations Manager in the preparation of the PEPR • Collating information for monthly recordable incident report and providing information to the Technical Operations Manager • Liaising with the Technical Operations Manager in the event of a change in the activity and updates the EP in accordance with the requirements of the OPGGS(E) Regulations • Performing MFO duties when the dedicated MFO is unable to, such as during short break periods • Immediately notify the Client Site Representative of any incidents/activities arising from seismic operations that are likely to have a negative impact on the performance outcomes detailed in this EP
Survey environmental advisor (SEA)	• Prepare environmental induction and vessel inspection information. • Provide a briefing to project personnel and survey vessel crew members of the environmental sensitivities of the Acquisition Area, environmental management strategies, EPO, and EPS detailed in the EP as part of the environmental induction process. • Ensure all relevant personnel have received and understood the spatial and temporal exclusions provided in the EP in relation to charts. • Assist with review, investigation and reporting of environmental incidents. • Ensure environmental inspections/audits are undertaken as per the requirements of the EP. • Maintain and advise Operations Manager of the status of the Corrective Action Register • Monitor and provide evidence of conformance to the environmental commitments as outlined in this EP and ensure the Conformance Register is updated. • Assist in preparation of external regulatory reports required for the survey, in line with environmental approval requirements and the CGG HSE incident reporting procedures. • Prepare a report of the overall environmental performance upon completion of the survey, including the results of audits and any incidents, and forward to the Project Manager. • Collate data for and assist in the preparation of the PERR.
Marine fauna observers (MFO)	• Ensure conformance with the relevant environmental performance requirements under this EP, including inspections and adequate fauna watch and implementation of EPBC Policy Statement 2.1 Part A and Part B management measures adopted for the survey. • Record any non-conformances with EPBC Act Policy Statement 2.1 management measures adopted for the survey. • Maintain and distribute records of marine mammal sightings and other species of concern and submitting daily and final survey sighting reports to the Client Site Representative and CGG Technical Operations Manager. • Submit notification of any incidents involving vessel collision and/or equipment entanglement with marine fauna, in accordance with the EPBC Regulations. • Provide environmental inductions for survey personnel (where relevant), including details of the environmental sensitivities of the Operational Area, control measures and performance outcomes and standards detailed within this EP. • Preparation of the MFO Report.

Role	Responsibility
Seismic operators, technicians and vessel crew including escort/supply vessel crews	• Conduct activities in a professional and safe manner with attention to good housekeeping procedures and work practices. • Immediately report any incidents to the Survey Vessel Master and Party Chief. • Encourage improvement in environmental performance wherever possible. • Immediately report any environmental incidents or spillages (hydrocarbons or other chemicals) to the Survey Vessel Master and Party Chief.

9.5 Training and competencies

All personnel involved with the Sauropod 3D MSS will be given a project-specific environmental induction prior to commencing work. This induction will cover environmental responsibilities relevant to the duties and responsibilities of the roles described in Section 9.4 including:

- Environmental sensitivities and conservation values in the Acquisition Area and surrounding waters
- Environmental risks and potential impacts associated with the activity
- Waste management and chemical management procedures (including the vessel GMP)
- Emergency response and spill management procedures outlined in the OPEP and vessel SOPEP
- Procedures for marine fauna interactions (including MFO duties and obligations)
- Roles and environmental responsibilities of key personnel on board the survey vessel
- The importance of following procedures and using company processes (JSAs etc.) to identify environmental risks and mitigation measures
- Environmental performance outcomes, standards and measurement criteria to be complied with under the EP
- Procedures for reporting environmental hazards, incidents, near misses and opportunities for improvement
- Opportunities for employee communication and participation
- Relevant plans and procedures (CGG and seismic/supply/escort vessel contractor owned), including where they can be obtained on board the vessel.

A record of the induction will be retained by CGG's Technical Operations Manager with the endorsement of personnel who attended. All personnel are required to sign an attendance sheet to confirm their participation in and understanding of the induction. If a contractor is used, they will conduct their own company and vessel-specific inductions independently and in addition to the project-specific HSE induction.

9.5.1 Competency and Ongoing Awareness

CGG or the seismic vessel contractor (if used) will provide marine crew who are trained and competent to undertake their respective activities on board the vessel. All marine personnel will be qualified in accordance with the International Convention on Standards of Training Certification and Watch Keeping for Seafarers (STCW95).

Only appropriately experienced MFOs (as determined by a review of their CVs) will be utilised for the Sauropod 3D MSS. Evidence of experience includes, but is not limited to:

- Completion of an approved MFO/marine mammal observer (MMO) training course (including distance estimation training)
- The lead MFO will have served a minimum of five seismic survey campaigns in Australia or New Zealand and had the responsibility to
  - Apply the EPBC Act PS 2.1 Part A and parts of Part B
  - Establish robust communications protocol between MFO and the seismic operator, navigators or gun crew
  - Train or supervise junior MFOs
  - Write the compliance and sightings report at the completion of survey
- Time as a marine fauna conservation guide, participation in paid or voluntary cetacean research surveys
- Work at sea where marine mammal identification experience was achieved – with seismic MFO experience preferred

- Visual distance estimation experience/ability including “calibration” through the help of the marine bridge crew to provide distances to objects measured via the radar
- All marine fauna detection personnel will be familiarized with relevant EP commitments, knowledge of the measures contained in EPBC Act PS 2.1 and their responsibilities for implementing them.

The MMOs will provide an information session to control room operators and other essential personnel at the start of the survey regarding their fauna observation duties and the communication protocols required with the control room operators to ensure shutdowns and power downs occur efficiently.

The following activities will serve to reinforce and maintain ongoing environmental awareness of vessel personnel for the Sauropod 3D MSS. Records will be produced for each of these meetings:

- Project kick-off meeting: Held at the start of the activity and reviews the contractual and HSE specifications for the activity, the scope of work, vessel-specific HSE plans, environmental outcomes, performance standards and measurement criteria within this EP.
- Daily progress meetings (on board): Review all survey operations and incidents of the previous day, actions are recorded within the daily progress report.
- Toolbox meetings: Attended by all personnel involved in a specific operation (i.e. operations involving major hazards and/or involving more than one person). This meeting reviews the activity and reinforces the adoption of control measures within this EP to prevent adverse environmental and safety impacts. Recorded within the daily progress report.

All personnel will be encouraged to communicate any concerns, suggest improvements to the control measures implemented for any particular task or operation during the activity and comment on any proposed changes to equipment, systems, or methods of operation of equipment, where these may have HSE implications. Opportunities for personnel (including management, relevant contractors and MMOs) to participate in improving the management of environmental risks during the activity include:

- At the time of the induction
- During daily toolbox and pre-start meetings at the commencement of each shift and prior to commencing a new task (e.g. recovery of streamer)
- Identification of hazards based on incident and near miss reporting
- Providing suggestions for improvements to the Client Site Representative at any time.

CGG crew and contractors (including all vessel personnel) will be provided information on employee communication and participation during the project environmental induction prior to commencing the activity.

9.6 Contractor and Supplier Management

Seismic contractors considered for the Sauropod 3D MSS will be assessed against, and meet the following criteria:

- Compliance with all statutory requirements
- Have an acceptable HSEQ performance record in undertaking seismic activities
- Provide evidence of resources and competency in the services to be provided
- Services, procedures and vessel hardware comply with the requirements of this EP
- Any equipment to be used in the provision of survey services meets regulatory requirements, is fit-for-purpose and has all equipment, testing and verification certificates.
- Specific requirements, which need to be assessed at tender evaluation stage includes:
- The acoustic source is confirmed to be 2,820 in^3 or less.
- Specific requirements that need to be assessed prior to vessel mobilisation to the Operational Area include:
- All vessels transiting from outside of the NWMR must be assessed for biofouling risk and have the relevant biosecurity clearance from DWAR (refer Section 8.8).

EP implementation activities with the selected seismic contractor have been described throughout Section 9.

9.7 Emergency Response

CGG's emergency preparedness and response arrangements will be included within the Project HSE Plan. In addition, the seismic vessel will be expected to have a vessel-specific Emergency Response Plan (ERP) and SOPEP. These documents will be reviewed by CGG to ensure they meet the requirements for emergency and oil spill response specified within this EP. As the Sauropod 3D MSS is vessel-based, it is considered appropriate that operational response to an emergency would be handled by CGG using their existing emergency response procedures and the vessel-specific ERP and SOPEP. The ERP, SOPEP and OPEP will be tested prior to the commencement of the survey.

CGG reviews specific activities, equipment and workplaces to identify possible emergency situations that may arise. CGG would ensure that any subcontracted vessel operator has established systems to ensure emergency plans are developed, implemented and maintained and that these plans address those incidents that are reasonably foreseeable. Information that is considered when identifying potential emergency situations include the following:

- Results of hazard identification and impact/risk assessments
- Legal requirements
- Previous incident (including accident) and emergency experience
- Emergency situations known to have occurred in similar organisations
- Information related to accident and/or incident investigations posted on the websites of regulators or emergency response agencies.
- The Project HSE Plan contains instructions for vessel emergency, medical emergency, search and rescue, reportable incidents, incident notification and contact information to ensure that:
- All potential emergencies are identified
- Emergency response plans are documented, accessible and clearly communicated
- Roles and responsibilities are clearly defined
- Adequate equipment, facilities and trained personnel are available to respond to emergency situations to mitigate adverse consequences
- Inspection and testing of critical emergency equipment is performed
- Emergency drills and exercises are conducted to assess emergency response capacity and capabilities
- Lessons learned are communicated to the appropriate people
- Adequate treatment and medical management are available for injured employees.

9.7.1 Emergency response initiation

In the event of an emergency, in the first instance the Survey Vessel Master will assume overall on-site command and act as the Emergency Response Coordinator (ERC). In the event of a Level 2 release or above, AMSA will take over control of the response in their role as Control Agency and provide direction to the ERC. All persons on board the vessels will be required to act under the ERC's directions. The Survey Vessel Master will maintain communications with the Vessel Manager and CGG Technical Operations Manager and/or other emergency services in the event of an emergency.

When an emergency occurs, the initial alert will usually be made from the emergency location itself, such as from the Vessel Master or Client Site Representative, to the Crisis Management Team (CMT) or equivalent department of the vessel operator, as well as to relevant Commonwealth and State Agencies (such as AMSA). The CMT will be mobilised upon initial contact and emergency response will be initiated. This will be carried out by working directly with the established emergency services operating in the area. The survey and support vessel(s) will have equipment on board for responding to emergencies including, but not limited to, medical equipment, fire-fighting equipment and oil spill response equipment.

Upon receiving notification of an emergency, the vessel marine crew will respond in accordance with CGG's Crisis Management Procedure, which details the responsibilities for each of the CMT roles. The ERC will maintain the direct link between the vessel and the CMT. The vessel Emergency Response Plan (ERP) would also be implemented.

In the event of an emergency, the Survey Vessel Master will notify the onshore duty manager (and CGG Technical Operations Manager), who will activate the CMT. CGG will, if necessary, be ready to provide technical and tactical resources to the emergency response. The CGG Technical Operations Manager will liaise with the CMT, provide support to the response as required and provide regular reports until the response is terminated.

Notifications to relevant Commonwealth and State Agencies will be made as defined in Section 9.12.

9.7.2 Adverse weather procedures

It is the duty of the Vessel Master to act as the focal point for all actions and communications with regards to any emergency, including response to adverse weather or sea state, to safeguard his vessel, all personnel on board and environment.

During adverse weather the Survey Vessel Master is responsible for:

- Ensuring the safety of all personnel on board
- Monitoring all available weather forecasts and predictions
- Initiating the vessel safety management system, vessel HSE procedures and/or vessel ERP
- Keeping the Party Chief and Client Site Representative fully informed of the prevailing situation and intended action to be taken
- Assessing and maintaining security, watertight integrity and stability of vessel
- Proceeding to identified shelter location(s) as appropriate.
- Other appropriate responsibilities shall be taken into consideration as dictated by the situation.

In addition to in-vessel VHF Marine Radio Weather Services, daily weather forecasting from a designated weather forecast will be provided (if available) to monitor weather within the Operational Area over the duration of the survey.

Should poor/bad weather be imminent/encountered, the Vessel Master shall implement weather monitoring to assess conditions on site. The amount of monitoring and subsequent action would be dependent on the severity of the bad weather front and resulting actions will comply with the survey contractors procedure for Severe Weather Monitoring.

The CGG Technical Operations Manager shall ensure adequate weather forecasting is available at an increased frequency as the severity escalates.

9.8 Maintaining Environmental and Legislative Knowledge

9.8.1 Prior to Survey

If the survey commences six months after the approval of the EP, then at least eight weeks prior to the survey, the CGG Technical Project Manager shall undertake pre-survey planning that will review and consider the following as a minimum:

- Stakeholder notification requirements as per Section 9.12
- New issues or concerns raised by stakeholders
- Changes to relevant legislation or regulatory guidelines
- Existing information in relation to any component of the receiving environment described in Section 4 (including BIAs, AMPs)
- Search the NOPSEMA website and consult with geophysical companies and/or titleholders to determine the presence of other seismic operations overlapping the proposed Sauropod 3D MSS
- Changes to commercial fishery licence areas, fishery status, current fishing effort and licence holders overlapping the Sauropod 3D MSS area based on:
  - Status reports and available data sources such as FRDC, IMAS for fisheries and aquatic resources
  - Information provided directly by fishers, WA DPIRD, and AFMA through the stakeholder consultation process
  - Fishing locations
  - Spawning information relevant to key indicator species
  - Newly available scientific literature
- New acoustic source technology and justification for or against its implementation
- Confirmation of emergency (oil spill) contacts.

If new information regarding the receiving environment relevant to the Sauropod 3D MSS area is present, then an internal risk assessment will be conducted as described in Section 9.2.

9.9 EP Revision and Resubmission

Any new information, changes or updates considered via the MoC process (refer Section 9.2) will also be considered against Regulation 17 of the OPGGS (E) Regulations, to determine if resubmission of the EP to NOPSEMA is required.

Relevant sub-regulations and triggers for EP resubmission under Regulation 17 include the following:

- 17(1) New Activity, defined as a change to the extent that the regulatory levy category applied to the Sauropod 3D MSS would change.
- 17(5) Significant modification of the Sauropod 3D MSS activity or to how the activity is being managed and conducted. Modification to the activity or management system that CGG consider to be significant include but are not limited to:
  - The total acoustic source volume and dB output is increased beyond that defined in this EP; or
  - The vessel fuel type changes from that described in this EP; or
  - The CGG Environmental Management System (Section 9.1) is altered to the degree that the overall Sauropod 3D MSS activity or a potential impact or risk of the activity can no longer be managed to ALARP or acceptable levels or in accordance with relevant EPOs and EPSs.
- 17(5) New stage of the activity, defined as either:
  - A change to the spatial limits of the activity (an increase in the geographical extent of the Sauropod 3D MSS Operational Area); or
  - A change to the temporal limits of the activity (an extension to the acquisition timeframe or EP timeframe specified in this EP).
- 17(6) New or increased environmental impact or risk. Only significant new or significant increased impacts or risks (following identification of additional control measures) require resubmission of the EP to NOPSEMA.
- 17(7) Change in Titleholder. A change in Titleholder requires a resubmission of the EP.
  - A resubmission of the EP may also be required if requested by NOPSEMA (Regulation 18).

  Minor revisions to the Sauropod 3D MSS EP that do not require resubmission to NOPSEMA will be made when:
  - Minor administrative changes are identified that do not impact on the environment (e.g. document references, contact details, etc.
  - A review of the activity/change and the environmental impacts and risks of the activity/change does not trigger a requirement for revision under the OPGGS (E) Regulations (Regulation 17 and Regulation 18).

Where amendments are made to the accepted EP/OPEP via the CGG MoC process, revisions made will be justified, tracked and a comprehensive record of the revision kept for each change. This includes all risk assessments associated with MoC activities.

9.10 OPEP

The Sauropod 3D MSS OPEP, considering the nature and scale of the activity and the potential spill risks involved (refer Section 8), consists of the following:

- Survey / support vessel(s) SOPEP (for vessels ≥400 gross tonnes involved in the survey or equivalent for lesser tonnage vessels) that manage the environmental impacts of a spill and vessel-based operational monitoring (agreement OPRC 90)
- CGG Sauropod 3D MSS OPEP (Appendix G), which supports the individual vessel-based SOPEPs, details the interaction between contractor-related spill response plans and CGG response arrangements.

  These response arrangements are consistent with, and supported by, the:
- National Plan for Maritime Environmental Emergencies (NATPLAN): Australian Maritime Safety Authority (AMSA) – has jurisdiction and is the Control Agency for vessel spills which affect Commonwealth waters
- State Hazard Plan for Maritime Environmental Emergencies (State Hazard Plan): The WA Department of Transport (DoT) is the Control Agency for marine oil spills in WA state waters.

The seismic and support vessels (if ≥400 gross tonnes) IMO-accepted SOPEPs, prepared in accordance with IMO guidelines for the development of shipboard oil pollution emergency plans (resolution MEPC.54 (32) as amended by resolution MEPC.86 (44)), include oil spill response arrangements and provisions for testing the SOPEP (oil pollution emergency drills), as required under Regulations 14(8AA), 14(8A) and 14(8B) to 14(8E) of the OPGGER. Typical oil spill response actions for shipboard oil spills are contained in the Sauropod 3D MSS OPEP.

CGG will ensure that support vessels ≥400 gross tonnes (that are not obligated legislatively to have a SOPEP), do have vessel-specific spill response plans (to an equivalent standard) that cover spill response arrangements. The SOPEP is designed to ensure a rapid and appropriate response to any oil spill and provide practical information required to undertake a rapid, effective response, and reporting procedures in the event of a spill.

Initial actions undertaken by a vessel in the event of a spill to limit environmental impacts, are detailed in the Sauropod 3D MSS OPEP (Appendix G:).

9.10.1 Drills and Training (OPEP/SOPEP)

The OPEP will be tested:

- Prior to the survey commencing
- Following any significant amendment of the arrangements
- If and when a new seismic vessel is engaged for the activity
- Not later than 12 months after the most recent test.

These arrangements for testing the OPEP are commensurate with the nature and scale of the worst-case oil spill scenario and the short duration of the survey.

Vessel-based SOPEP tests are undertaken by vessels routinely as per MARPOL Annex I (Regulation 15) requirements, and drill outcomes reviewed as part of the ongoing monitoring and improvement of emergency response control measures.

A desktop drill of the Sauropod 3D MSS OPEP, including the vessel SOPEP, will be conducted to assess the effectiveness of the arrangements, taking into account the nature and scale of the risk of a hydrocarbon prior to survey commencement. Specifically, the drill will test the following:

- Roles and responsibilities of those involved in oil spill response are clear and understood
- Communication sequence from the vessel master to vessel-contractor onshore management and the Control Agency, including notification of the AMSA JRCC is adequate, current and includes all relevant details
- Communication between the CGG offshore representative and CGG Technical Project Manager and subsequent notification authorities is adequate and timely
- Ensures Type 1 operational monitoring such as spill surveillance and tracking is appropriate, understood and practised
- Equipment and procedures intended for source control on-board the vessels are available for use as outlined in the vessel SOPEP.

The outcomes of the Sauropod 3D MSS OPEP drill will be documented, reviewed and improvements identified (as needed). Should any inadequacies, altered contractual arrangements or improvements to arrangements be identified via testing, these corrective actions will be registered as a non-conformance (refer to Section 9.12) and the EP/OPEP will be amended for these items via a Management of Change process (refer Section 9.2). This is the responsibility of the CGG Project Manager. The CGG Technical Project Manager is responsible for assessing any changes to the OPEP against the criteria in OPGGS (E) Regulations - Regulation 17 and where necessary, the EP/OPEP submitted to NOPSEMA as a formal revision.

9.10.2 Maintaining Currency

CGG will monitor AMSA and DoT's published plans and should the plans change, CGG will assess the implications of any changes to the OPEP arrangements as described in this EP.

Any change to the activity itself, or the potential impacts and risks associated with it, will result in a review of the EP (including the OPEP) to ensure the measures in place remain suitable and there is no significant increase in impact or risk.

9.11 Communication and Consultation

9.11.1 Internal Communications

The seismic contractor will be responsible for keeping its workforce informed about environmental issues. The party chief acts as a focal point for personnel to raise environmental issues, and consults/involves all personnel in the following:

- Issues associated with the implementation of the EP

- Any proposed changes to equipment, systems, or methods of operation of plant, where these may have environmental implications
- Any proposals associated with continuous improvement of environmental protection, including the setting of environmental objectives and training schemes.
- Regular HSE meetings will be held on the seismic vessel. The issues discussed and actions taken will be recorded. The minutes of each meeting, including action items from the meetings, will be made available to all personnel.

Other forms of internal communication include toolbox meetings, which occur before every critical or unfamiliar job. This meeting includes all personnel involved in the task and will include aspects such as spill prevention requirements, etc.

9.11.2 Ongoing Stakeholder Consultation

Stakeholder consultation will be ongoing during the planning and activity stages of the Sauropod 3D MSS.

9.11.2.1 Review of Relevant Stakeholders

CGG will continue to identify relevant persons, after acceptance of the EP. A review of relevant stakeholders will be undertaken during routine reviews of information relevant to the EP as per Section 9.3.

9.11.2.2 Stakeholder Notifications

CGG will keep relevant persons up to date with activity status by sending periodic notifications to relevant stakeholders. Key milestones that trigger a notification include:

- EP acceptance by NOPSEMA
- Prior to survey commencement
- Upon survey completion
- In the event of a significant incidents (e.g. large fuel spill)
- If there is a change to the MSS activity scope that may affect the stakeholder interests, activities or functions
- If a new or significant increase in potential impact or risk is identified that (after identification of additional control measures to manage those impacts or risks) may affect the stakeholder interests, activities or functions.

All notifications will include the relevant details of the activity including the activity title, location and contact details.

9.11.2.3 Assessment and Management of New Objections or Claims

CGG shall assess the merits of any new claims or objections made by a relevant stakeholder whereby they believe the activity will have an adverse impact on their interests, activities or functions. If the claim has merit, where appropriate, CGG may modify the management of the activity. The assessment will be done using the methodology detailed in this EP as detailed in Section 6. If new information regarding the receiving environment relevant to the Sauropod 3D MSS area is received through ongoing consultation, then an internal risk assessment will be conducted as described in Section 9.2.

If a change to the activity or controls adopted during the MSS occurs as a result of stakeholder consultation, including the provision of evidence regarding an impact or risk to commercial fishing due to the survey, the change will be managed in accordance with CGG’s Management of Change process (Section 9.2).

CGG shall endeavour to finalise the merits of any claim or objection received during the survey within one week of receipt and undertake any resulting management of change actions as soon as practicable, but preferably within the same time frame.

The assessment of merit and any resulting management of change actions will be shared with the concerned stakeholder.

For objections and claims that do not hold merit, CGG will respond to stakeholders providing reasoning and supporting information (as relevant) to support CGG’s conclusions.

9.12 Notifications and Reporting

Under Regulation 16(c) and 26 of the OPGGS(E), CGG is required to notify NOPSEMA of any recordable (An incident arising from the activity that breaches an EPO or EPS in the EP that applies to the activity that is not a reportable incident) and reportable (An incident arising from the activity that has caused, or has the potential to cause, moderate to significant environmental damage) incident within a specified timeframe. Environmental incidents will be reported to the relevant government agency by the Client Site Representative. The requirements for reporting and recording incidents are outlined in Table 9-2.

Following any recordable or reportable incident, CGG will undertake an incident investigation and this information will be communicated to all relevant personnel. All recordable and reportable incidents will be documented in the PERR by the CGG Technical Operations Manager, and including details of the event, immediate action taken to control the situation, and corrective actions to prevent re-occurrence. The CGG Technical Operations Manager and Client Site Representative will follow up actions taken to ensure that the corrective actions have been taken to close it out. When planning future activities, CGG will review the reportable and recordable incidents that have occurred previously to incorporate any lessons learned as part of CGG's continual improvement process.

Table 9-2 - Notification requirements

Requirement	Timing	Contact
Recordable Incidents		
As a minimum, the written monthly recordable incident report must include a description of: All recordable incidents which occurred during the calendar month All material facts and circumstances concerning the incidents that the operator knows or is able to reasonably find out. Any actions taken to avoid or mitigate any adverse environmental impacts of the incident Corrective actions that have been taken, or may be taken, to prevent a repeat of similar incidents occurring.	As soon as possible but before the fifteenth day of the following calendar month.	NOPSEMA - submissions@nopsema.gov.au
Reportable Incidents		
Verbal Notifications		
Vessel-sourced spill in Commonwealth waters.	Within one hour	JRCC Australia: Phone: +61 2 6230 6811 or 1800 641 792 Facsimile: 1800 622 153
Reportable incidents include, but are not limited to, those that have been identified through the risk assessment process as having an inherent impact consequence of 'significant', 'major' or 'critical', or at a minimum, the following incidents: • A level 2 spill incident • Vessel strike / entrapment or entanglement with a cetacean or marine turtle • IMS Introduction. The notification must contain: • All material facts and circumstances concerning the incident • Any action taken to avoid or mitigate the adverse environmental impact of the incident • The corrective action that has been taken or is proposed to be taken to stop, control or remedy the reportable incident.	Within two hours	Verbal: NOPSEMA – Phone 08 6461 7090. DMIRS - 0419 960 621 Written Notification: NOPSEMA - submissions@nopsema.gov.au
This must be followed by a written record of notification ASAP after notification.		NOPTA – reporting@nopta.gov.au DMIRS - petroleum.environment@dmirs.wa.gov.au

Requirement	Timing	Contact
This written notification must also be supplied to the NOPTA and DMIRS for Commonwealth water incidents.		
If an oil pollution incident occurs within or approaches an AMP, or where an oil spill response action must be taken within an AMP, the Director of National Parks (DNP) must be contacted immediately. Information which must be provided within that notification includes: • Titleholder details • Time and location of the incident (including AMP likely to be affected) • Proposed response arrangements as per OPEP • Confirmation of providing access to the relevant monitoring and evaluation reports when available, • Contact details of the emergency coordinator.	As soon as possible and prior to response action being taken, as far as reasonably practicable	Verbal: Director of Marine Parks – 0419 293 465 (24hr Marine Compliance Officer)
Notify DAWE of any death or injury of a listed threatened species; all cetacean species; listed migratory species or listed marine species.	Within seven days	Phone: +61 2 6274 111 Email: EPBC.Permits@environment.gov.au
Written Incident Reports		
Verbal notification of a reportable incident to NOPSEMA (Commonwealth waters) must be followed by a written report. As a minimum, the written incident report will include: • The incident and all material facts and circumstances concerning the incident • Actions taken to avoid or mitigate any adverse environmental impacts • The corrective actions that have been taken, or may be taken, to prevent a recurrence of the incident • The action that has been taken or is proposed to be taken to prevent a similar incident occurring in the future.	Within three days of notification of incident (NOPSEMA) Within seven days after submission to NOPSEMA (NOPTA).	NOPSEMA - submissions@nopsema.gov.au NOPTA – reporting@nopta.gov.au
Vessel strike with cetacean is reported to the DAWE.	Within 72 hours of incident	Upload information to: https://data.marinemammals.gov.au/report/shipstrike

9.12.1 External Routine Notification and Reporting Requirements

Review of statutory and stakeholder requirements with respect to routine external notification and reporting is provided in Table 9-3. These actions are the responsibility of the CGG Project Manager (or delegate).

Table 9-3 – External Routine Notification and Reporting Requirements

Requirement	Timing	Contact
Routine Performance Reporting		
OPGGS (E) Regulations - Regulation 26C Submit an EP Performance/Compliance Report to NOPSEMA. This reports compliance against each of the EPOs and EPSs as outlined in this EP.	Within three months of survey completion.	NOPSEMA - submissions@nopsema.gov.au

Requirement	Timing	Contact
Provide cetacean observation data to the DAWE. This report will include: • The location, date and start-up time of the survey • Name, qualifications and experience of MFOs involved in the survey • The location, times and reasons when observations were hampered by poor visibility or high winds • The location and time of any start-up delays, shut-downs or stop-work procedures instigated as a result of whale sightings • The location, time and distance of any cetacean sightings • The date and time of completion of the survey.	Within two months of activity completion.	Upload information to: https://data.marinemammals.gov.au/csa
Activity Notifications		
EP Accepted and Activity Update		
Notification to all relevant stakeholders advising of EP acceptance and provide an update on survey commencement.	Within ten days of the date the EP has been accepted.	All relevant stakeholders listed in the Consultation Log.
Provision of OPEP to DoT and AMSA following EP acceptance and prior to survey commencement.	Prior to survey commencement.	Contact details listed in Consultation Log.
Survey Commencement		
Notify AHO for Notice to Mariners.	At least four weeks prior to commencement.	AHO - datacentre@hydro.gov.au
Notify fisheries stakeholders of survey commencement. The notification shall include: • Survey location • Time frame (anticipated start date and likely duration) • Vessel details (vessel names, call signs, IMO vessel numbers, radio and satellite phone communication details) • Website details for 48 hr look-aheads • Telephone and email contact details for claims, objections, queries or concerns.	At least four weeks prior to commencement.	Fisheries stakeholders listed in Consultation Log.
Notify DMIRS of survey commencement.	At least ten days prior to commencement.	DMIRS - petroleum.environment@dmirs.wa.gov.au.
Notify NOPSEMA of survey commencement.	At least ten days prior to commencement.	NOPSEMA - submissions@nopsema.gov.au
Notify AMSA for Auscoast Warnings This notification will include: when operations start and end, name, callsign and maritime mobile service identity (MMSI)), satellite communications details (including inmarsat-c and satellite telephone numbers), area of operation, requested clearance from other vessels and any other information that may contribute to safety at sea.	At least 24-48 hours prior to survey commencement.	JRCC - rccaus@amsa.gov.au Ph: 1800 641 792 or +61 2 6230 6811

Requirement	Timing	Contact
Survey Cessation		
Notify AMSA to cease Auscoast Warnings	Upon vessel demobilisation.	JRCC - rccaus@amsa.gov.au Ph: 1800 641 792 or +61 2 6230 6811
Notify NOPSEMA with survey completion date	Within ten days of survey completion.	NOPSEMA - submissions@nopsema.gov.au
Notify DMIRS with survey completion date	Within ten days of survey completion.	DMIRS - petroleum.environment@dmirs.wa.gov.au.
Notify fisheries stakeholders of survey cessation	Within ten days of survey completion.	Fisheries stakeholders listed in the Consultation Log.
End of EP		
Notification of EP completion to NOPSEMA.	End of EP operation.	NOPSEMA - submissions@nopsema.gov.au

10 References

[ABARES] Torres Strait Finfish Fishery. 2021. https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/torres-strait-finfish-fishery Accessed on 05 July 2021

[AGDD] Australian Government Department of Defence, 2021. Unexploded ordnance. Accessed from https://www.defence.gov.au/UXO/Where/Default.asp. Accessed on 10 June 2021.

[AMMC] Australian Marine Mammal Centre, 2019. Australian Marine Mammal Centre. Available at http://www.marinemammals.gov.au/. Accessed on 16 May 2019.

[AMSA] Australian Maritime Safety Authority, 2013. Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities.

[BoM] Bureau of Meteorology, 2021a. Climate Statistics of Australian Locations, Bureau of Meteorology, Canberra, ACT. Available at http://www.bom.gov.au/climate/averages/tables/cw_004019.shtml. Accessed 25 May 2021.

[BoM] Bureau of Meteorology, 2021b. Daily Maximum Temperature – Rowley Shoals, Bureau of Meteorology, Canberra, ACT. Available at http://www.bom.gov.au/jsp/ncc/cdio/wData/wdata?p_nccObsCode=122andp_display_type=dailyDataFileandp_stn_num=200713andp_startYear=. Accessed 25 May 2021.

[BoM] Bureau of Meteorology, 2021c. Monthly Rainfall – Wallal Downs. Bureau of Meteorology, Canberra, ACT. Available at http://www.bom.gov.au/jsp/ncc/cdio/wData/wdata?p_nccObsCode=139andp_display_type=dataFileandp_stn_num=004068. Accessed 25 May 2021.

[BoM] Bureau of Meteorology, 2021d. Tropical Cyclones Affecting Port Hedland. Bureau of Meteorology, Canberra, ACT. Available at http://www.bom.gov.au/cyclone/history/wa/pthed.shtml. Accessed 25 May 2021.

[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, pp. 145.[CSIRO] Commonwealth Scientific and Industrial Research Organisation 2015. Marine Benthic Substrate Data – CAMRIS – Marsed, CSIRO Data Collection, 10.4225/08/551485612CDEE.

[DAF] Queensland Department of Agriculture and Fisheries 2021. East Coast Spanish Mackerel Working Group communique https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/fishery-working-groups/spanish-mackerel-fishery-working-group/communiques/17-18-may-2021

[DAWE] Department of Agriculture, Water and Environment, 2021a. Sousa sahulensis — Australian Humpback Dolphin. Available at http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=50. Accessed on 10 June 2021

[DAWE] Department of Agriculture, Water and Environment, 2021b. Sterna dougallii — Roseate Tern.

Accessed from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?showprofile=Y&taxon_id=817. Accessed on 10 June 2021.

[DAWE] Department of Agriculture, Water and Environment, 2016. Indo-pacific Humpback Dolphin BIA. Accessed from https://maps.atlas.parksaustralia.gov.au/index.html?intro=false&z=4&ll=137.15359,-35.52756&l0=cmr_cmr%3AAU_DOEE_bia_2016_BlueandPygmyBlueWhale,ea_ea-be%3AWorld_Bright-Earth-e-Atlas-basemap,g_SATELLITE,g_ROADMAP&v0=,,f,f&_ga=2.44602086.359892719.1565584136-1576342056.1565584136. Accessed on 10 June 2021

[DAWE) Department of Agriculture, Water and Environment, n.d. Underwater Cultural Heritage Act 2018. Accessed from https://www.environment.gov.au/heritage/underwater-heritage/underwater-cultural-heritage-act. Accessed on 10 June 2021.

[DEC] Department of Environment and Conservation, 2007. Rowley Shoals marine Park Management Plan 2007-2017, Management Plan No 56. Prepared by the Department of Environment and Conservation on behalf of the Marine Parks and Reserves Authority (MPRA), Perth, Western Australia.

[DEH] Department of Environment and Heritage, 2005. Whale Shark (*Rhincodon typus*) Recovery Plan Issues Paper. Commonwealth Department of Environment and Heritage. 26 pp.

[DEWHA] Department of the Environment, Water, Heritage and the Arts, 2008a. The North-west Marine Bioregional Plan: Bioregional Profile. A description of the Ecosystems, Conservation Values and Uses of the North-west Marine Region. Australian Government, Canberra.

[DEWHA] Department of the Environment, Water, Heritage and the Arts, 2008b. Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle). Canberra: Department of the Environment, Water, Heritage and the Arts. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1768-conservation-advice.pdf. In effect under the EPBC Act from 08-Jan-2009.

[DEWHA] Department of the Environment, Water, Heritage, and the Arts 2008c. 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 pp.

[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.

[DoE] Department of the Environment and Energy, 2015e. Biologically Important Areas of Regionally Significant Marine Species. COPYRIGHT Commonwealth of Australia, Australian Government. Available from http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B2ed86f5a-4598-4ae9-924f-ac821c701003%7D

[DoE] Department of the Environment, 2014. Recovery Plan for the Grey Nurse Shark (*Carcharias taurus*). Canberra, ACT: Department of the Environment. Available from: http://www.environment.gov.au/resource/recovery-plan-grey-nurse-shark-carcharias-taurus. In effect under the EPBC Act from 14-Aug-2014.

[DoE] Department of the Environment, 2015a. Conservation Management Plan for the Blue Whale – A Recovery Plan under the Environment Protect and Biodiversity Conservation Act 1999. Canberra: Department of the Environment. Available at http://www.environment.gov.au/biodiversity/threatened/publications/recovery/blue-whale-conservation-management-plan. In effect under the EPBC Act from 03-Oct-2015.

[DoE] Department of the Environment, 2015b. Sawfish and River Sharks Multispecies Recovery Plan. Canberra, ACT: Commonwealth of Australia. Available from: http://www.environment.gov.au/biodiversity/threatened/publications/recovery/sawfish-river-sharks-multispecies-recovery-plan. In effect under the EPBC Act from 07-Nov-2015.

[DoE] Department of the Environment, 2015c. Conservation Advice *Calidris ferruginea* curlew sandpiper. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/856-conservation-advice.pdf. In effect under the EPBC Act from 26-May-2015.

[DoE] Department of the Environment, 2015d. Conservation Advice *Numenius madagascariensis* eastern curlew. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/847-conservation-advice.pdf. In effect under the EPBC Act from 26-May-2015.

[DoEE] Department of Environment and Energy, n.d. The Ramsar Convention on Wetlands. Available at https://www.environment.gov.au/water/wetlands/ramsar Accessed 13 May 2019i

[DoEE] Department of the Energy and Environment, n.d. Conservation Advices. Available from: https://www.environment.gov.au/biodiversity/threatened/conservation-advices. Accessed 23/05/2019c

[DoEE] Department of the Energy and Environment, n.d. Recovery Plans. Available from: https://www.environment.gov.au/biodiversity/threatened/recovery-plans. Accessed 23/05/2019b

[DoEE] Department of the Environment and Energy, 2017. Recovery Plan for Marine Turtles in Australia. Canberra, ACT: Commonwealth of Australia.

[DoEE] Department of the Environment and Energy, 2018. Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans. Canberra, ACT: Commonwealth of Australia. In effect under the EPBC Act from 21-Jul-2018.

[DoEE] Department of the Environment and Energy, 2019a. Species Profile and Threats Database. Available at http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl. Accessed on 4 April 2019.

[DoEE] Department of the Environment and Energy, 2019b. Australian National Shipwreck Database. Available at https://www.environment.gov.au/heritage/historic-shipwrecks/australian-national-shipwreck-database. Accessed 13 May 2019.

[DoEE] Department of the Environment and Energy, n.d. Australia's National Heritage List. Available at https://www.environment.gov.au/heritage/places/national-heritage-list Accessed 20 May 2019h

[DoEE] Department of the Environment and Energy, n.d. Biologically important areas of regionally significant marine species. Commonwealth of Australia. Available from: https://www.environment.gov.au/marine/marine-species/bias. Accessed 29/05/2019d

[DoEE] Department of the Environment and Energy, n.d. Marine Bioregional Plans. Commonwealth of Australia. Canberra. Available from: https://www.environment.gov.au/marine/marine-bioregional-plans Accessed 29/05/2019a

[DoEE] Department of the Environment and Energy, n.d. Species Profile and Threats Database - Canyons linking the Argo Abyssal Plain and Scott Plateau. Available at https://www.environment.gov.au/sprat-public/action/kef/view/8;jsessionid=7BE137C6FB158E60179C4EA5D6B2D97A Accessed 13/05/2019e

[DoEE] Department of the Environment and Energy, n.d. Species Profile and Threats Database - Mermaid Reef and Commonwealth waters surrounding Rowley Shoals. Available at https://www.environment.gov.au/sprat-public/action/kef/view/11;jsessionid=01AD87551D0DE1B0248C8722BE137004 Accessed 13/05/2019f

[DoEE] Department of the Environment and Energy, n.d. Species Profile and Threats Database – Key Ecological Features. Available from https://www.environment.gov.au/sprat-public/action/kef/search Accessed 20.05.2019g

[DPaW] Department of Parks and Wildlife, 2013. Whale shark – wildlife management program no. 57

[DoF] Department of Fisheries, 2012. State of the Fisheries report. https://www.fish.wa.gov.au/About-Us/Publications/Pages/State-of-the-Fisheries-report.aspx

[DoF] Department of Fisheries, 2013. Spanish mackerel. https://www.fish.wa.gov.au/Species/Spanish-Mackerel/Pages/default.aspx

[DoF] Department of Fisheries, 2016. INTEGRATED FISHERIES MANAGEMENT RESOURCE REPORT PEARL OYSTER (Pinctada maxima) RESOURCE. Fisheries Management paper No. 281. Document number ISSN 0819-432.

[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 20 May 2019.

[DPIRD] Department of Primary Industries and Regional Development, 2019c. 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. Available from http://www.fish.wa.gov.au/Documents/management_papers/fmp285.pdf

[DPIRD] Department of Primary Industries and regional Development, 2020 State of the Fisheries report. https://www.fish.wa.gov.au/About-Us/Publications/Pages/State-of-the-Fisheries-report.aspx

[DPLH] Department of Planning, Lands and Heritage, 2019. Aboriginal Heritage Inquiry System. Available at https://www.dplh.wa.gov.au/information-and-services/aboriginal-heritage/aboriginal-heritage-search Accessed 13 May 2019.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2011. Approved Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake). Canberra, ACT: Department of Sustainability, Environment, Water, Population and Communities. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/1115-conservation-advice.pdf. In effect under the EPBC Act from 15-Feb-2011.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012a. Marine bioregional plan for the North Marine Region. Commonwealth of Australia.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012b. Species group report card – boney fishes. Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia Capital Territory.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012c. Species group report card – Dugong. Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia Capital Territory.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2012d. Species group report card – reptiles. Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia Capital Territory.

[DSEWPaC] Department of Sustainability, Environment, Water, Population and Communities, 2013. Recovery Plan for the White Shark (*Carcharodon carcharias*). Department of Sustainability, Environment, Water, Population and

Communities. Available from: http://www.environment.gov.au/biodiversity/threatened/recovery-plans/recovery-plan-white-shark-carcharodon-carcharias. In effect under the EPBC Act from 06-Aug-2013 as *Carcharodon carcharias*.

[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 and Development Corporation. 2019. Status of Australian Fish Stocks Reports. Available at https://www.fish.gov.au/. Accessed 13 May 2019.

[FRDC] Fisheries Research and Development Corporation, 2020. Silverlip Pearl Oyster (*Pinctada maxima*). Available at https://fish.gov.au/report/279-Silverlip-Pearl-Oyster-2020?jurisdictionId=4. Accessed on 28 June 2021.

[FRDC] Fisheries Research and Development Corporation 2021. Spanish Mackerel (2020) https://www.fish.gov.au/report/393-Spanish-Mackerel-2020

[IAGC] International Association of Geophysical Contractors. 2017. Plankton Study Speculative and Needs Better Data. News Release, June 22, 2017. 2 pp.

[IPIECA] International Petroleum Industry Conservation Association, 2004. A guide to Oiled Wildlife Response Planning, International Petroleum Industry Conservation Association, No. 13.

[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.

[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.

[NMSC] The Australian National Marine Safety Committee, 2010. Marine Incidents during 2009. Preliminary Data Analysis. Available at http://www.nmsc.gov.au

[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, 116 pp.

[NOAA] National Oceanic and Atmospheric Administration, 2021a. WOA 2013 V2 Data Access: Statistical mean of temperature on 1° grid for all decades. National Oceanic and Atmospheric Administration, United States Department of Commerce, Maryland.

[NOAA] National Oceanic and Atmospheric Administration, 2021b. WOA 2013 V2 Data Access: Statistical mean of salinity on 1° grid for all decades. National Oceanic and Atmospheric Administration, United States Department of Commerce, Maryland.

[NSF] National Science Foundation (U.S.), Geological Survey (U.S.), 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, U.S.A.

[NSW DPI] NSW Department of Primary Industries. 2014. NSW Department of Primary Industries submission on PEP11 seismic survey proposal 2014/15. 15 pp.

[PSMA] Department of the Prime Minister and Cabinet Australia, 2019. PSMA Geocoded National Address File (G-NAF) Administrative Boundaries, CadLite, Features of Interest, G-NAF, G-NAF Lite, G-NAF Live, Land Tenure, Postcode Boundaries and Transport and Topography. PSMA Australia Limited, ACT.

[RPS] RPS Group, 2010. Marine Mammals Technical Report – Wheatstone Project Technical Appendix O12. RPS Planning and Environment Pt Ltd, Perth, Western Australia.

[RPS] RPS Group, 2019. 3D Oil WA-527-P. Oil Spill Modelling. Final Report No. MAQ0793J, 29 May 2019. 70 pp.

Threatened Species Scientific Committee, 2008. Listing Advice for Pristis zijsron (Green Sawfish). Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/68442-listing-advice.pdf. In effect under the EPBC Act from 07-Mar-2008.

Threatened Species Scientific Committee, 2009. Commonwealth Listing Advice on *Pristis clavata* (Dwarf Sawfish). Department of the Environment, Water, Heritage and the Arts. Canberra, ACT: Department of the Environment, Water, Heritage and the Arts. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/68447-listing-advice.pdf. In effect under the EPBC Act from 20-Oct-2009.

Threatened Species Scientific Committee, 2015a. Conservation Advice *Balaenoptera borealis* sei whale. Canberra: Department of the Environment. Available at http://www.environment.gov.au/biodiversity/threatened/species/pubs/34-conservation-advice-01102015.pdf. In effect under the EPBC Act from 01-Oct-2015.

Threatened Species Scientific Committee, 2015b. Conservation Advice *Balaenoptera physalus* Fin whale. Canberra: Department of the Environment. Available at http://www.environment.gov.au/biodiversity/threatened/species/pubs/37-conservation-advice-01102015.pdf. In effect under the EPBC Act from 01-Oct-2015.

Threatened Species Scientific Committee, 2015c. Conservation Advice *Megaptera novaeangliae* Humpback whale. Canberra: Department of the Environment. Available at http://www.environment.gov.au/biodiversity/threatened/species/pubs/38-conservation-advice-10102015.pdf. In effect under the EPBC Act from 01-Oct-2015.

Threatened Species Scientific Committee, 2015d. Conservation Advice *Rhincodon typus* whale shark. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/66680-conservation-advice-01102015.pdf. In effect under the EPBC Act from 01-Oct-2015.

Threatened Species Scientific Committee, 2015e. Conservation Advice *Papasula abbott*i Abbott's booby. Canberra: Department of the Environment. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/59297-conservation-advice-01102015.pdf. In effect under the EPBC Act from 01-Oct-2015.

Threatened Species Scientific Committee, 2016 - Conservation advice *Calidris canutus* red knot. Canberra: Department of the Environment. Available at: http://www.environment.gov.au/biodiversity/threatened/species/pubs/855-conservation-advice-05052016.pdf. In effect under the EPBC Act from 05-May-2016

[WDCS] Whale and Dolphin Conservation Society, 2006. Vessel collisions and cetaceans: What happens when they don't miss the boat. Whale and Dolphin Conservation Society. United Kingdom.

Ainslie, M.A., 2008. Review of published safety thresholds for human divers exposed to underwater sound. TNO Defence, Security and Safety Report. TNO-DV 2007 A598.Austin, D. and Pollum, R. 20169. The IUCN Red List of Threatened Species 2019. Available at http://www.iucnredlist.org/. Accessed 13 May 2019.

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.

André, M., Kaifu, K., Solé, M., van der Schaar, M., Akamatsu, T., Balastegui, A., Sánchez, A.M. and Castell, J.V. 2016. Contribution to the understanding of particle motion perception in marine invertebrates. pp. 47–55, in Popper, N.A., Hawkins, A. (eds.), The effects of noise on aquatic life II. Springer, New York, USA.

Australian Museum. 2019. Ruby Snapper, *Etelis* carbunculus (Cuvier, 1828). Viewed online on 20 March 2019 at https://australianmuseum.net.au/learn/animals/fishes/ruby-snapper-etelis-carbunculus-cuvier-1828/.

Baker, C., Potter, A., Tran, M. and Heap, A.D. 2008. Sedimentology and Geomorphology of the North West Marine Region of Australia, Geoscience Australia Record 2008/07, Geoscience Australia, Canberra, Australian Capital Territory.

Bannister, A., Kemper, C.M., and Warnecke, R.M.1996. The Action Plan for Australian Cetaceans. Australian Nature Conservation Agency, Canberra, Australian Capital Territory.

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, P.F. and Marsh, L.M. 1986. Part I: History of Investigation and Description of the Physical Environment, in Berry, P. (Ed.), Fauna Surveys of the Rowley Shoals, Scott Reef and Seringapatam Reef, North-western Australia. Records of the Western Australian Museum, Supplement No. 25, pp.1-25.

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. streaked shearwater Calonectris leucomelas. Available at http://datazone.birdlife.org/species/factsheet/streaked-shearwater-calonectris-leucomelas/text. Accessed 16 May 2019.

Birdlife International 2019b. lesser frigatebird Fregata ariel. Available at http://datazone.birdlife.org/species/factsheet/lesser-frigatebird-fregata-ariel/text. Accessed 16 May 2019.

Boeger, W.A., Pie, M.R., Ostrensky, A. and Cardoso, M.F., 2006. The Effect of Exposure to Seismic Prospecting on Coral Reef Fishes. Brazilian Journal of Oceanography 54(4): 235-239.

Booman, C., Dalen, J., Leivestad, H., Levsen, A., van der Meeren, T. and Toklum, K., 1996. Effekter av luftkanonskyting på egg, larver og yngel. Undersøkelser ved Havforskningsinstituttet og Zoologisk laboratorium, UIB. [In Norwegian with English Summary]. 89 pp.

Bradshaw, C.J.A., Mollet, H.F. and Meekan, M.G. 2007. Inferring Population Trends for the World's Largest Fish and Mark-Recapture Estimates of Survival, Journal of Animal Ecology, vol. 76, no. 76, pp. 480-489.

Bray, D.J. 2020. *Etelis* carbunculus in Fishes of Australia, accessed 14 May 2020, http://136.154.202.208/home/species/1238

Bray, D.J. and Thompson, V.J. 2017. Fishes of Australia. Available at http://fishesofaustralia.net.au/. Accessed 13 May 2019.

Brewer, D., Lyne, V., Skewes, T. and Rothlisberg, P., 2007. Trophic Systems of the North-West Marine Region, CSIRO Marine and Atmospheric Research, Report to the Department of the Environment, Water, Heritage and the Arts. CSIRO Marine and Atmospheric Research, Cleveland, Australia.

Brown, A.M., Bejder, K., Pollock, K.H. and Allen, S.J. 2014. Abundance of coastal dolphins in Roebuck Bay, Western Australia: Updated results from 2013 and 2014 sampling period. A report to WWF Australia, Murdock University Cetacean Research Unit, Murdoch University, Western Australia.

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.

Burbidge, A., Woinarski, J. and Harrison, P. 2014. The Action Plan for Australian Mammals 2012. CSIRO Publishing, Victoria

Burgess, H.G. and Branstetter, S. 2009. *Carcharhinus limbatus* – The IUCN Red List of Threatened Species. Available at https://www.iucnredlist.org/species/3851/10124862. Accessed 11 April 2019.

Cailliet, G.M., Cavanagah, 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., and Domingo, A. 2009. *Isurus oxyrinchus* – IUCN Red List of Threatened Species. Available at https://www.iucnredlist.org/species/39341/2903170#population. Accessed 15 May 2019.

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.

Chapman, C. and Hawkins, A. 1969. The importance of sound in fish behaviour in relation to capture by trawls. Fisheries and Aquaculture Report 62 (3): 717–729.

Chilvers, B.L., Delean, S., Gales, N.J., Holley, D.K., Lawler, I.R., Marsh, H. and Preen, A.R. 2004. Diving behaviour of dugons, Dugong dugon, Journal of Experimental Marine Biology and Ecology, vol. 304, no. 2, pp. 203-224.

Christian, J.R., Mathieu, A., Thompson, D.H., White, D. and Buchanan, R.A., 2003. Effect of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Funds Project No. 144. Fisheries and Oceans Canada, Calgary, Canada.

Colman, J.G. 1997. A Review of the Biology and Ecology of the Whale Shark. The Fisheries society of British Isles, Journal of Fish Biology, vol. 51, no. 6, pp. 1219-1234.

Commonwealth of Australia, 2009. National Biofouling Management Guidance for the Petroleum and Exploration Industry, http://www.marinepests.gov.au/marine_pests/publications/Documents/Biofouling_guidance_petroleum.pdf. Viewed 25 April 2019.

Commonwealth of Australia, 2010. Ningaloo Coast World Heritage Nomination. Commonwealth of Australia, Canberra, Australian Capital Territory. 360 pp.

Commonwealth of Australia, 2015. Wildlife Conservation Plan for Migratory Shorebirds. Canberra, ACT: Department of the Environment. Available at: http://www.environment.gov.au/biodiversity/publications/wildlife-conservation-plan-migratory-shorebirds-2016. In effect under the EPBC Act from 15-Jan-2016.

Commonwealth of Australia, 2021. Inquiry report - Making waves: the impact of seismic testing on fisheries and the marine environment. Available at: https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/SeismicTesting/Report

Commonwealth of Australia, n.d. Australian Heritage Database - Mermaid Reef - Rowley Shoals, Broome, WA, Australia. Commonwealth of Australia. Available at https://www.environment.gov.au/cgi-bin/ahdb/search.pl?mode=place_detail;search=state%3DWA%3Blist_code%3DCHL%3Blegal_status%3D35%3Bkeyword_PD%3D0%3Bkeyword_SS%3D0%3Bkeyword_PH%3D0;place_id=105255 Accessed 14 May 2019.

Dafforn, K. A., Glasby, T. M., and Johnston, E. L., 2009a. Links between estuarine condition and spatial distributions of marine invaders. Diversity and Distributions 15(5): 807–821.

Dafforn, K. A., Johnston, E. L., Glasby, T. M., 2009b. Shallow moving structures promote marine invader dominance. Biofouling 25:3, 277-287.

Dalen, J. and Knutsen, G. 1987. Scaring effects in fish and harmful effects on eggs, larvae and fry by offshore seismic explorations. pp. 93–102 in Merklinger, H.M (ed.), Progress in underwater acoustics. Plenum Publishing Corporation, New York, USA.

Day, R.D., McCauley, R.D., Fitzgibbon, Q.P., Hartman, K. and Semmens, J.M., 2016a. Exposure to seismic air gun signals causes physiological harm and alters behaviour 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.M., Fitzgibbon, Q.P. and Semmens, J.M. 2016b. Assessing the impact of marine seismic surveys on southeast Australian scallop and lobster fisheries. FRDC Project No 2012/008. University of Tasmania, Hobart, Tasmania.

Day, R.D., McCauley, R.M., 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.

del Hoyo, J., Elliot, A. and Sargatal, J. 1992. Handbook of the Birds of the World, Vol. 1: Ostrich to Ducks. Lynx Edicions, Barcelona, Spain.

del Hoyo, J., Elliot, A. and Sargatal, J. 1996. Handbook of the Birds of the World, Vol. 3: Hoatzin to Auks. Lynx Edicions, Barcelona, Spain.

Director of National Parks, 2018. North-west Marine Parks Network Management Plan 2018. Director of National Parks. Canberra.

Done, T.J., Williams, D.McB., Speare, P.J,. Davidson, J., DeVantier, L.M., Newman, S.J. and Hutchins, J.B., 1994. Surveys of coral and fish communities at Scott Reef and Rowley Shoals. Australian Institute of Marine Science, Townsville.

Donovan, A., Brewer, D., van der Velde, T., and Skewes, T. 2008. Scientific descriptions of four selected key ecological features (KEFs) in the north-west bioregion: final report. A report to the Department of the Environment, Water Heritage and the Arts. CSIRO Marine and Atmospheric Research, Hobart.

Double, M.C. Jenner, K.C.S., Jenner, M-N., Ball, I., Childerhouse, S., Laverick, S. and Gales, N. 2012. Satellite tracking of northbound Humpback whales (*Megaptera novaeangliae*) off Western Australia. Australian Marine Mammal Centre. Available at: http://www.wamsi.org.au/sites/wamsi.org.au/files/Final%20report%20-%20Satellite%20tracking%20WA%20Humpback%20whales%202011.pdf

Double, M.C., Andrews-Goff, V., Jenner, K.C.S., Jenner, M-N., Laverick, S.M., Branch, T.A. and Gales, N.J. 2014. Migratory Movements of Pygmy Blue Whales (*Balaenoptera musculus brevicauda*) between Australia and Indonesia as revealed by Satellite Telemetry, PLoS One, vol. 9, no. 4.

Ebert, D.A., Fowler, S. and Compagno, L. 2013. Sharks of the World. A Fully Illustrated Guide. Wild Nature Press, Plymouth, United Kingdom.

Edmonds, N.J., Firmin, C.J., Goldsmith, D., Faulkner, R.C. and Wood, D.T., 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: 5–11.

Engås, A. and Løkkeborg, S. 2002. Effects of seismic shooting and vessel-generated noise on fish behaviour and catch rates. Bioacoustics 12(2-3): 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.

Environment Australia, 2000. Mermaid Reef Marine National Nature Reserve Plan of Management. Environmental Australia, Canberra.

Environment Australia, 2002. Ningaloo Marine Park (Commonwealth Waters) Management Plan, Environment Australia, Canberra, Australian Capital Territory.

Etkins, D.S., 1997. The Impact of Oil Spills on Marine Mammals, OSIR Report 13 March 1997 Special Report.

Falkner, I., Whiteway, T., Przeslawski, R. and Heap, A.D. 2009. Review of Ten Key Ecological Features (KEFs) in the Northwest Marine Region, Geoscience Australia Record 2009/13. A report to the Department of the Environment, Water, Heritage and the Arts, Geoscience Australia, Canberra, Australian Capital Territory.

Fanta, E., 2004. Efeitos da sísmica com Cabo Flutuante em peixes tropicais de areas recifais. Relatório Tėcnico (CTAIBAMA 298857) Universidade Federal do Paraná, Departamento de Biologia Celular, Grupo de Estudos de Impacto Ambienta. August 4, 2004 [Effects of Floating Cable Seismic on Tropical Fish in Reef Areas. Technical Report prepared by the Environmental Impact Study Group (GEIA) of Cellular Biology Department, University of Paraná, Curitiba, Brazil]. 54 pp.

Fewtrell, J. and McCauley, R. 2012. Impact of air gun noise on the behaviour of marine fish and squid. Marine Pollution Bulletin 64 (5): 984-993.

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. 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.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). Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 pp.

Fletcher, W.J. and Santoro, K. (eds). 2012. Status Reports of the Fisheries and Aquatic Resources of Western Australia 2011/12: The State of the Fisheries. Department of Fisheries, Western Australia.

Ford, J.K.B., Ellis, G.M., Matkin, D.R., Balcomb, K.C., Briggs, D. and Morton, A.B. 2005. Killer whale Attacks on Minke Whales: Prey Capture and Antipredator Tactics, Marine Mammal Science, vol 21, no. 4, pp 603-618.

French, D.P., Schuttenberg, H.Z. and Isaji, T., 1999. Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida power and light. In: Proceedings - AMOP 99 Technical Seminar, June 2-4, 1999, Calgary, Alberta, Canada, pp. 243-270.

French-McCay, D., Rowe, J.J., Whittier, N., Sankaranarayanan, S. and Etkin, D.S. 2004. Estimate of potential impacts and natural resource damages of oil. Journal of Hazardous Materials 107(1), 11–25.

French-McCay, D.P., 2003. Development and application of damage assessment modelling: example assessment for the North Cape oil spill. Marine Pollution Bulletin 47(9), 9–12.

French-McCay, D.P., 2004. Spill impact modelling: development and validation. Environmental Toxicology and Chemistry 23(10), 2441–2456.

Froese, R. and Pauly, D (Ed.) 2019. Fishbase. Available at http://www.fishbase.org/. Accessed 13 May 2019.

Gagnon, M.M. and Rawson, C.A., 2010. Montara Well Release: Report on necropsies from a Timor Sea green sea turtle. Perth, Western Australia, Curtin University, vol. 15.

Gambell, R. (1968). Seasonal Cycles and Reproduction in Sei Whales of the Southern Hemisphere. Discovery Reports. 35:31-134.

Gascoyne Development Commission. 2012. Economic Development Opportunities for the Gascoyne Region associated with the Resource Sector Investment and Expansion. Gascoyne Pilbara Project, January 2012. SGS Economics and Planning, pp. 95.

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., Newman, S.J., and Wakefield, C.B. 2018. Western Australian Marine Stewardship Council Report Series No. 11: Summary of the stock structure information used for determining spatial management of the index species for the scalefish resources of northern Western Australia. Department of Primary Industries and Regional Development, Western Australia. 32pp.

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., Gales, N., and Frydman, S., 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.

Gilmour, J., Cheal, A., Smith, L., Underwood, J., Meekan, M., Fitzgibbon, B. and Rees, M., 2007. Data compilation and analysis for Rowley Shoals: Mermaid, Imperieuse and Clerke reefs. A report to the Department of Environment and Water Resources, Australian Institute of Marine Science, Perth.

Gilmour, J., Speed, C.W. and Babcock, R., 2016. Coral reproduction in Western Australia. PeerJ 4:e2010; DOI 10.7717/peerj.2010.

Glasby, T. M., Connell, S. D., Holloway, M. G., Hewitt, C. L., 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions. Marine Biology 151: 887–895.

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.

Green, B. S., and Gardner, C. 2009. Surviving a sea-change: survival of southern rock lobster (*Jasus edwardsii*) translocated to a site of fast growth. ICES Journal of Marine Science 66: 656–664.

Guinea, M. 2013. Monitoring Program for the Monata Well Release Timor Sea Monitoring Study S6 Sea Snakes / Turtles. Available at http://www.environment.gov.au/system/files/pages/bcefac9b-ebc5-4013-9c88-a356280c202c/files/surveys-sea-snakes-turtles.pdf. Accessed 16 May 2019.

Guinea, M.L. 1995. The sea turtles and sea snakes of Ashmore Reef Reserve. Northern Territory University, Darwin.

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.

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.

Hawkins, A.D. and Popper, A.N., 2017. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science doi:10.1093/icesjms/fsw205.

Hawkins, A.D., Roberts, L. and Cheesman, S. 2014. Responses of free-living coastal pelagic fish to impulsive sounds. Journal of the Acoustical Society of America. 135(5): 3101-3116.

Hazel, J., Lawler, I.R. and Hanmann, M. 2009. Diving at the shallow end: Green turtle behaviour in near-shore foraging habitat, vol. 371, no. 1, pp. 84-92.

Heatwole, H. and Cogger, H.G. 1993. Family Hydrophiidae in Glasby, C.G., Ross, G.J.B. and Beesley, P.L. (Ed.) Fauna of Australia Volume 2A – Amphilbia and Reptilia. Australian Government Publishing Service, Canberra, pp. 439.

Hedley, SL. Bannister, JL. and Dunlop, RA. 2011. Abundance estimates of Breeding Stock ‘D’ Humpback Whales from aerial and land-based surveys off Shark Bay, Western Australia, 2008. Journal of Cetacean Research and Management, Special Issue 3: 209-221.

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.J., Pinceratto, E. and Smith, L.D. 1997. Big Bank Shoals of the Timor Sea: an environmental resources atlas. Australian Institute of Marine Science and BHIP Petroleum, Victoria, pp. 115.

Holliday, D.V., Pieper, R.E., Clarke, M.E. and Greenlaw, C.F. 1987. The effects of airgun energy releases on the eggs, larvae and adults of the northern anchovy (*Engraulis mordax*). API Publication 4453. Report by Tracor Applied Sciences for American Petroleum Institute, Washington D.C, USA.

Hooper, J.N.A. and Ekins, M., 2004. Collation and validation of museum collection databases related to the distribution of marine sponges in Northern Australia., Unpublished report to the National Oceans Office, Hobart.

Horwood, J.W. 1987. The Sei Whale: Population Biology, Ecology and Management. Croom Helm Ltd, New York.

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.

Howey-Jordan LA, Brooks EJ, Abercrombie DL, Jordan LKB, Brooks A, *et al.* (2013) Complex Movements, Philopatry and Expanded Depth Range of a Severely Threatened Pelagic Shark, the Oceanic Whitetip (Carcharhinus longimanus) in the Western North Atlantic. PLoS ONE 8(2): e56588. doi:10.1371/ journal.pone.0056588

Hueter, R.E., Tyminski, J.P., Morris, J.J., Abierno, A.R. and Valdes, J.A. 2016. Horizontal and vertical movements of longfin mako (*Isurus paucus*) tracked with satellite-linked tags in the northwestern Atlantic Ocean. Fishery Bulletin 115(1): 101–116.

James, N.P., Bone, Y., Kyser, T.K., Dix, G.R. and Collins, L.B. 2004. The importance of changing oceanography in controlling late Quaternary carbonate sedimentation on a high-energy, tropical, oceanic ramp, North-western Australia, Sedimentology 51: 1179–1205.

Jarman, S.N. and Wilson, S.G., 2004. DNA-based species identification of krill consumed by whale sharks, Journal of Fish Biology 65: 586–591.

Jenner, K.C.S., Jenner, M-N.M., and McCabe, K.A. 2001. Geographical and Temporal Movements of Humpback Whales in Western Australian Waters, APPEA Journal, vol. 441, no. 1, pp. 749-765.

Kato, H. 2002. Bryde's Whales *Balaenopetra edeni* and *B. brydei*, in Perrin, W.F., Wrsig, B., and Thewissen, H.G.M. (Ed.), Encyclopaedia or Marine Mammals, Academic Press, pp. 171-177.

Kennish, M.J., 1997. Practical handbook of Estuarine and Marine Pollution. Boca Raton, FL: CRC Press.

Kordjazi, Z., Frusher, S., Buxton, C. D., and Gardner, C. 2015. Estimating survival of rock lobsters from long-term tagging programmes: how survey number and interval influence estimates. ICES Journal of Marine Science 72: 244–251.

Koshleva, V. 1992. The impacts of air guns used in marine seismic explorations on organisms living in the Barents Sea. Fisheries and Offshore Petroleum Exploitation, 2nd International Conference, Bergen, Norway, 6-8 April 1992.

Kostyuchenko, L. 1973. Effects of elastic waves generated in marine seismic prospecting on fish eggs in the Black Sea. Hydrobiological Journal 9: 45–48.

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S., and Podesta, M. (2001). Collisions between ships and whales. Mar. Mamm. Sci. 17, 35–75. doi: 10.1111/j.1748-7692.2001.tb00980.x

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

Last, P.R. and Stevens J.D. 2009. Sharks and Rays of Australia. CSIRO Publishing, Melbourne, pp. 550

Lewis, P. and Jones, R., 2018. Statewide Large Pelagic Finfish Resource Status Report 2017, in Gaughan, D.J. and Santoro, K. (Ed.) 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.

Lewis, S. E., Sloss, C. R., Murray-Wallace, C. V., Woodroffe, C. D. and Smithers, S. G. 2013. Postglacial sea-level changes around the Australian margin: a review. Quaternary Science Reviews, 74 115-138.Limpus, C. 2008. A Biological Review of Australian Marine Turtles, Queensland Government.

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 (2009). A biological review of Australian marine turtle species. 6. Leatherback turtle, *Dermochelys coriacea* (Vandelli). Queensland: Environmental Protection Agency. Lindsey, T.R. 1986. The Seabirds of Australia. Angus and Robertson, Australia.

Limpus, C.J. 2004. A Biological Review of Australian Marine Turtles. The State of Queensland, Environmental Protection Agency, Australia.

Limpus, C.J. 2007. A Biological Review of Australian Marine Turtles. The State of Queensland, Environmental Protection Agency, Australia.

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. and Miller, J.D. 2008. A Biological Review of the Australian Marine Turtles 2. Green turtle Chelonia mydas (Linnaeus). The State of Queensland, Environmental Protection Agency, Australia.

Lukoschek, V., Guinea, M. and Milton, D. 2010. *Aipysurus apraefrontalis* – the IUCN Red Listed of Threatened Species. Available at https://www.iucnredlist.org/species/176770/7301138 . Accessed 14 May 2019.

Lutcavage, M.E., Lutz, P.L., Bossart, G.D. and Hudson, D.M., 1995. Physiologic and clinicopathological effects of crude oil on loggerhead sea turtles, Archives of Environmental Contamination and Toxicology (28): 417–422.

Mackie, M., Buckworth, R.C. and Gaughan, D.J., (2003). Stock assessment of narrow-barred Spanish mackerel (Scomberomorus commerson) in Western Australia. Department of Fisheries.

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.

Marchant, S. and Higgeins, P.J. (Ed.) 1990. Handbook of Australia, New Zealand and Antarctic Birds. Volume 1: Ratites to Ducks. Oxford University Press, Melbourne, Victoria

Marchesan, M. Spotto, M. Verginella, L. and Ferrero, EA. 2006. 'Behavioural Effects of Artificial Light on Fish Species of Commercial Interest', Fisheries Research, vol. 73, pp. 171-185.

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, vol. 11, no. 125, 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. 2014. Biology and Stock Status of Inshore Demersal Scalefish Indicator Species in the Gascoyne Coast Bioregion. Fisheries Research Report No. 228. Department of Fisheries.

Marsh, H., Eros, C., Penrose, H. and Hugues, J. 2002. Dugong – Status Report and Action Plans for countries and territories, UNEP Early Warning and Assessment Report Series 1, pp 162.

Marshall, A., Kashiwagi, T., Bennett, M.B., Deakos, M., Stevens, G., McGregor, G., Clark, T., Ishiara, H. and Sato, K. 2018. *Mobila alfredi* – IUCN Red List of Threatened Species. Available at https://www.iucnredlist.org/species/195459/126665723. Accessed on 15 May 2019.

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.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.

McCauley R.D. and Jenner, C. 2010. Migratory patterns and estimated population size of Pygmy blue whales (*Balaenoptera musculus brevicauda*) traversing the Western Australian coast based on passive acoustics. Paper SC/62/SH26 presented to the IWC Scientific Committee (unpublished).

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. and Duncan, A.J. 2011. Sea Noise Logger Deployment, Wheatstone and Onslow, April 2009 to November 2010: Great whales, fish and man-made noise sources. CMST tech. Report R2011-23, Curtin University of Technology, Perth, Western Australia.

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 and Evolution 1: 1-8.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. *et al.*, 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. *et al.*, 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., Salgado Kent, C. and Archer, M. 2008. Impacts of seismic survey pass-bys on fish hearing and caged fish behaviour, Scott Reef Lagoon, Western Australia. Prepared for ERM and Woodside Energy, CMST Report No. 2008-52, Curtin University, Perth, Australia.

McKinney, D. 2009. A survey of the scleractinian corals at Mermaid, Scott, and Seringapatam Reefs, Western Australia. Records of the Western Australian Museum Supplement No. 77, pp. 105–143.

McPherson, C., MacGillivray, A., and Hager, E. (2018). Validation of airgun array modelled source signatures. The Journal of the Acoustical Society of America 144(3), 1846 doi:10.1121/1.5068132

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., Bradshaw, C., Press, M., McLean, C., Richards, A., Quasnichka, S. and Taylor, J. 2006. Population size and structure of whale sharks (*Rhincodon typus*) at Ningaloo Reef Western Australia, Marine Ecology-Progress Series, 319, pp.275-285.

Miller, I.R. 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 7(1-2), 63-70.

Milton, S.L. and Lutz, P.L., 2003. Physiological and genetic responses to environmental stress. In: Lutz, P.L., Musick, J.A. and Wyneken, J. (eds.), The Biology of Sea Turtles. CRC Press, Boca Raton, pp. 164–198.

Moein, S.E., Musick, J.A., Keinath, J.A., Barnard, D.E., Lenhardt, M.L. and George, R., 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.

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.

Moran, M., Edmonds, J., Jenke, J., Cassells, G. and Burton, C. 1993. Fisheries biology of emperors (Lethrinidae) in north-west Australian coastal waters. Final Report to the Fisheries Research and Development Corporation (FRDC) Project No. 89/20, Fisheries Department of Western Australia, Western Australia pp. 58.

Morgan, D.L., Whitty, J.M, and Philips, N.M. 2009. Endangered sawfishes and river sharks in Western Australia. Report prepared for Woodside Energy Limited. Centre for fish and Fisheries Research, Murdoch University,

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 B 281: 20132683.

Musick, J.A., Stevens, J.D., Baum, J.K., Bradai, M., Clò, S., Fergusson, I., Grubbs, R.D., Soldo, A., Vacchi, M. and Vooren, C.M. 2009. *Carcharhinus plumbeus*. The IUCN Red List of Threatened Species 2009: e.T3853A10130397. http://dx.doi.org/10.2305/IUCN.UK.2009-2.RLTS.T3853A10130397.en. Downloaded on 22 May 2019.

Nedelec, S.L., Campbell, J., Radford, A.N., Simpson, S.D. and Merchant, N.D., 2016. Particle motion: the missing link in underwater acoustic ecology. Methods in Ecology and Evolution doi: 10.1111/2041-210X.12544.

Newman, S., Buckworth, R., Mackie, M., Lewis, P., Bastow, T., & Ovenden, J. (1998). Spatial subdivision of adult assemblages of Spanish mackerel, Scomberomorus commerson (Pisces: Scombridae) from western, northern and eastern Australian waters through stable isotope ratio analysis of sagittal otolith carbonate. The stock structure of Northern and Western Australian Spanish mackerel. Final Report, Fisheries Research & Development Corporation Project, 159.

Newman, D.J., Smith, K.A., Skepper, C.L. and Stephenson, P.C. 2008. Northern Demersal Scalefish Managed Fishery, ESD Report, Series No. 6, June 2008. Department of Fisheries, Western Australia.

Newman, S. Trinnie, F., Saunders, T. and Wakefield, C. (2018d). Rankin Cod (2018). Available at: http://fish.gov.au/report/206-Rankin-Cod-2018, Accessed 24/05/2020.

Newman, S., Ferridge, R., Syers, C. and Kallinowski, P., 2018b, in Gaughan, D.J. and Santoro, K. (Ed.) Statewide Marine Aquarium Fish and Hermit Crab Resources 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., Wakefield, C., Lunow, C., Saunders, T. and Trinnie, F. (2018c). Red Emperor (2018). Available at: http://fish.gov.au/report/222-Red-Emperor-2018, Accessed 24/05/2020.

Newman, S., Wakefield, C., Saunders, T. and Trinnie, F. (2018e). Bluespotted Emperor (2018). Available at: http://fish.gov.au/report/227-Bluespotted-Emperor-2018, Accessed 24/05/2020.

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 2017–2018: 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.J., Wakefield, C., Skepper, C., Boddington, D., Jones, R. and Smith, E. 2018a. 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.

Odell, D.K. and MacMurray, C., 1986. Behavioral response to oil. In: Vargo, S., Lutz, P.L., Odell, D.K., van Vleet, T. and Bossart, G., (eds.), Study of effects of oil on marine turtles: Final report, U.S. Dept. of the Interior, Minerals Management Servive, Gulf of Mexico OCS Region, New Orleans, L.A. OCS Study MMS 86-0070.

Oil and Gas UK, 2014. Guidance on risk related decision making (Issue No. 2). United Kingdom Offshore Operators Association, London.

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(7): 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 79:272-284.

Parry, G.D., Heislers, S., Werner, G.F., Asplin, M.D. and 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.

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.

Parvin, S., 2005. Limits for underwater noise exposure of human divers and swimmers. Subacoustech. Presented at the National Physics Laboratory Seminar on Underwater Acoustics, Teddington, UK.

Patterson, H., Larcombe, J., Nicol, S. and Curtotti, R., 2018. Fishery status reports 2018, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

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.

Paxton, A.B., Taylor, J.C., Nowacek, D.P., Dale, J., Cole, E. Voss, C.M. and Peterson, C.H. 2017. Seismic survey noise disrupted fish use of a temperate reef. Marine Policy 78: 68-73.

Payne, J. F., Coady, J. and White, D. 2009. Potential effects of seismic air gun discharges on monkfish eggs (*Lophius americanus*) and larvae. National Energy Board, Canada.

Payne, J.F. 2004. Potential effect of seismic surveys on fish eggs, larvae and zooplankton. CSAS Research Document 2004/125. Canadian Science Advisory Secretariat, Department of Fisheries and Oceans, Canada.

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.

Pearce, A., Buchan, S., Chiffings, T., D'Adamo, N., Fandry, C., Fearns, P., Mills, D., Phillips, R. and Simpson, C. 2003. A review of the oceanography of the Dampier Archipelago, Western Australia, Museum of Western Australia, Perth, Western Australia.

Pearson, W.H., Skalski, J.R. and Malme, C.I. 1992. Effects of sounds from a geophysical survey device on behaviour of captive rockfish (*Sebastes* spp.). Canadian Journal of Aquatic Science 49(7): 1343–1356.

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., Ierodiaconou, D and Hays G.C. 2014. Protected species use of a coastal marine migratory corridor connecting marine protected areas, vol. 161, no. 6, pp. 1455-1466.

Peverell, S. 2007. Dwarf Sawfish *Pristis clavata*. Marine Education Society of Australia. Available at http://www.mesa.edu.au/seaweek2008/info_sheet05.pdf. Accessed 11 April 2019.

Peverell, S., Gribble, N., and Larson, H. 2004. Sawfish, in National Oceans Office, Descriptions of Key Species Groups in the Northern Planning Area. Commonwealth of Australia, Hobart, Tasmania.

Peverell, S.C. 2005. Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on sawfish ecology, Environmental Biology of Fishes, vol. 73, no. 4, pp. 391-402.

Popper, A., 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. 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. Journal of the Acoustical Society of America 143 (1): 470-488.

Popper, A.N. and Hawkins, A.D., 2019. An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of Fish Biology 2019: 1-22.

Popper, A.N., Carlson, T.J., Gross, J.A., Hawkins, A.D., Zeddies, D.G., Powell, L. and Young, J., 2016. Effects of seismic air guns on pallid sturgeon and paddlefish. In: Popper, A.N. and Hawkins, A.D. (eds.). The Effects of Noise on Aquatic Life II. Volume 875. Springer, New York. pp 871-878.

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.D., Sand, O. and Sisneros, J.A. 2019. Examining the hearing abilities of fishes. Journal of the Acoustical Society of America, 146(2): 948-955.

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.

PPTEP 2013. Montara Environmental Monitoring Program, Report of Search. PTTEP Australia, Western Australia. Available at http://www.au.pttep.com/wp-content/uploads/2013/10/2013-Report-of-Research-Book-vii.pdf. Accessed 16 May 2019

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., 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.

Quijano, J. E. and McPherson, C.R., 2020. 3D Oil Sauropod 3-D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures. Document 01781, Version 1.1. Technical report by JASCO Applied Sciences for Environmental Resources Management.

Radford, C.A., Montgomery, J.C., Caiger, P. and Higgs, D.M. 2012 Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. Journal of Experimental Biology 215: 3429–3435.

Reeves, R.R., B.D. Smith, E.A. Crespo, and G. Notarbartolo di Sciara, eds. (2003). Dolphins, Whales and Porpoises: 2002-2010 Conservation Action Plan for the World's Cetaceans. Switzerland and Cambridge: IUCN/SSC Cetacean Specialist Group. IUCN, Gland.

Richardson, A.J., Matear, R.J. and Lenton, A., 2017. Potential impacts on zooplankton of seismic surveys. CSIRO, Australia. 34 pp.

Richardson, W.J., Greene, C.R., Malme, C.I. and Thomson, D.H., 1995. Marine Mammals and Noise. Academic Press, San Diego, 576 pp.

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. Available at https://www.iucnredlist.org/species/60225/3095898. Accessed 11 April 2019.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B. & Winker, H. 2019b. *Carcharhinus longimanus*. The IUCN Red List of Threatened Species 2019: e.T39374A2911619. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39374A2911619.en. Downloaded on 10 June 2021.

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.

Sætre, R. and Ona, E., 1996. Seismic investigations and harmful effects on fish eggs and larvae. An assessment of the possible effects on the level of recruitment. Fisken og Havet, Havforskningsinstituttet, Bergen (Norway), 1996, no. 8, 25 pp.

Salgado Kent, C., 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. April 2016. Project CMST 1218; Report 2015-13. 184 pp.

Salgado Kent, C.P., Gavrilov, A.N., Recalde-Salas, A., Burton, C.L.K., McCauley, R.D. and Marley, S. 2012. Passive acoustic monitoring of baleen whales in Geographe Bay, Western Australia, Proceedings of Acoustics, Nov 21-23, 2012. Acoustical Society of Australia, Freemantle, Western Australia.

Salmon, M., Witherington, B.E., 1995. Artificial lighting and seafinding by loggerhead hatchlings: evidence for lunar modulation. Copeia 931–938.

Santos Ltd 2019. Keraudren Seismic Survey Environment Plan Summary. Santos Ltd, Perth, Western Australia. Document number QE-91-RI-20012.04

Santos Ltd 2020. Keraudren Extension Seismic Survey Environment Plan. Santos Ltd, Perth, Western Australian. Document number SO-91-BI-20006.01

Santos Ltd. 2018. Bethany 3D Marine Seismic Survey Environment Plan Summary. A6657652. Report prepared by Santos Ltd., Perth, Western Australia.

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.J. 2018. Goldband Snapper (2018). Accessed online on 20 March 2019 at https://www.fish.gov.au/report/221-Goldband-Snapper-2018

Scholik, A.R. and Yan, H.Y. 2001. Effects of underwater noise on auditory sensitivity of a cyprinid fish. Hearing Research 152:17–24.

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.

Semeniuk, V., Chalmer, P.N. and Le Provost, I. 1982. The marine environments of the Dampier Archipelago, Journal of the Royal Society of Western Australia 65: 97–114.

Simmonds, J.E. and MacLennan, D. 2005. Fisheries acoustics: theory and practice. Second edition. Blackwell Science, Oxford, United Kingdom.

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.

Sivle, L. D., Forland, T. N., Hansen, R. R., Andersson, M., Grimsbø, E., Linne, M., & Karlsen, H. E. (2017). Behavioural effects of seismic dose escalation exposure on captive mackerel (Scomber scombrus). Rapport fra havforskningen.

Sleeman, J. C., M.G. Meekan, B.J. Fitzpatrick, C.R. Steinberg, R. Ancel and C.J.A. Bradshaw (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., 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.

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, BL, Bowles, AE, Ellison, WT, Finneran, JJ, Gentry, RL, Greene Jr., CR, Kastak, D, Ketten, DR, Miller, JH, Nachtigall, PE, Richardson, WJ, Thomas, JA and Tyack, PL. 2007. Marine mammal sound exposure criteria: Initial scientific recommendations. Aquatic Mammals, vol. 33, iss. 4, pp. 411-509.

Spaulding, M.L., Kolluru, V.S., Anderson, E. and Howlett, E., 1994. Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill. Spill Science and Technology Bulletin 1(1), 23–35.

Spaulding, M.S., Mendelsohn, D., Crowley, D., Li, Z. and Bird, A., 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Stevens, J.D., McAuley, R.B., Simpfendorfer, C.A., and Pillans, R.D. 2008. Spatial distribution and habitat utilisation of sawfish (*Pristis* spp) in relation to fishing in northern Australia, A report to the Department of the Environment, Water, Heritage and the Arts. CIRO and Western Australian Department of Fisheries.

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* (Freen Sawfish). CSIRO Marine Research, Hobart, Tasmania.

Tang, K.W., Gladyshev, M.I., Dubovskaya, O.P., Kirillin, G. and Grossar, H-P., 2014. Zooplankton carcasses and non-predatory mortality in freshwater and inland sea environments. Journal of Plankton Research, 36: 597–612.

Taylor, J.G., 2007. Ram filter-feeding and nocturnal feeding of whale sharks (*Rhincodon typus*) at Ningaloo Reef, Western Australia, Fisheries Research 84(1): 65–70.

Thomson, P. 2015. The ocean's microscopic unsung heroes. UWA Oceans Institute, Oceans Online, Issue 5. Available at http://www.oceans.uwa.edu.au/community/oceans-online/the-oceans-microscopic-unsung-heroes. Accessed 2 May 2019

Thorburn, D., Morgan, D., Gill, H., Johnson, M., Wallace-Smith, H., Vigilante, T., Croft, I. and Fenton, J. 2004. Biology and cultural significance of the freshwater sawfish (*Pristis microdon*) in the Fitzroy River Kimberley, Western Australia. Report to the Threatened Species Network.

Tourism Western Australia, 2019. Attraction – Rowley Shoals. Available at https://www.westernaustralia.com/en/Attraction/Rowley_Shoals/56b2678f2cbcbe7073ae16b8#/. Accessed 15 May 2019.

Turnpenny, A.W.H. and Nedwell, J.R. 1994. The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys. Report by Fawley Aquatic Research Laboratories Ltd, Hampshire, United Kingdom for United Kingdom Offshore Operators Association, London, United Kingdom.

Underwood, J.N., Smith, L.D., van Oppen, M.J.H. and Gilmour, J., 2009. Ecologically relevant dispersal of a brooding and a broadcast spawning coral at isolated reefs: implications for managing community resilience, Ecological Applications, vol. 19, no. 1, pp. 18-29.

van Duinkerken, D. 2010. Movements and site fidelity of the reef manta ray, *Manta alfred*i, along the coast of southern Mozambique. Mater Thesis, Utrecht University, Utrecht, Netherlands.

van Herwerden, L., Aspden, W.J., Newman, S.J., Pegg, G.G. Briskey, L. and Sinclair, W. 2009. A comparison of the population genetics of *Lethrinus miniatus* and *Lutjanus sebae* from the east and west coasts of Australia: evidence for panmixia and isolation, Fisheries Research, 100 (2): 148–155.

Veron, J.E.N. 1986. Part II: Reef-building corals, in Berry, P. (Ed.), Fauna Surveys of the Rowley Shoals, Scott Reef and Seringapatam Reef, North0-western Australia. Records of the Western Australian Museum, Supplement No. 25, pp. 27-35.

Veron, J.E.N. 1993. Part 2: Hermatypic Corals of Ashmore Reef and Cartier Islands, in Berry. P. (Ed.), Marine Fauna Surveys of Ashmore Reef and Cater Island, North-western Australia. Records of the Western Australian Museum, Supplement No. 44, pp. 13-20.

Walker D.I. and Prince, R.I.T. 1987. The Distribution and Biogeography of Seagrass Species on the Northwest Coast of Australia, Aquatic Biology vol. 29, no. 1, pp. 19-32.

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.

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.

Weigmann, S. 2016. Annotated checklist of the living sharks, batoids and chimaeras (Chondrichthyes) of the world, with a focus on biogeographical diversity. Journal of Fish Biology 88(3): 837-1037.

Weinhold, R.J. and Weaver, R.R., 1972. Seismic air guns effect on immature coho salmon. Preprint for the 42nd Annual Meeting of the Society of Exploration Geophysicists. Alaska Department. of Fish and Game. 16 pp.

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.

Whitty, J.M., Morgan, D.L., Thorburn, D.C., Fazeldean, T. and Peverell, S.C. 2008. Tracking the movements of Freshwater Sawfish (*Pristis microdon*) and the Northern River Sharks (Glyphis sp. C): including genetic analysis of *P. microdon* across northern Australia. A report to the Department of the Environment, Water, Heritage and the Arts. Centre for Fish and Fisheries Research, Murdoch University.

Williamson, M. and Fitter, A. 1996. 'The Characteristics of Successful Invaders', Biological Conservation, vol. 78, pp. 163-170.

Wilson S.G., Carlton, J.H. and Meekan, M.G. 2003. Spatial and temporal patterns in the distribution and abundance of macrozooplankton on the southern North West Shelf, Western Australia, Journal of Estuarine Coastal and Shelf Science, 56: 897–908.

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, vol. 148, no. 55, pp. 1157-1166.

Witherington, BE. and Martin, RE. 2003. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. Florida Fish and Wildlife Conservation Commission FMRI Technical Report TR-2 3rd Edition Revised: 74pp.

Woodside Energy Ltd. 2011. 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.

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.

Yamamoto, T., Takahashi, A., Katsumata, N., Sato, K. and Trathan, P.N. 2010. At-Sea Distribution and Behavior of Streaked Shearwaters (Calonectris leucomelas) During the Nonbreeding Period, the Auk, vol. 127, no. 4, pp. 871-881.

Young, C.N., Carlson, J.K. The biology and conservation status of the oceanic whitetip shark (*Carcharhinus longimanus*) and future directions for recovery. Rev Fish Biol Fisheries 30, 293–312 (2020). https://doi.org/10.1007/s11160-020-09601-3

Appendix A: CGG Environment Policy

Care+Protect

CGG

Environmental & Climate Policy

The health of the environment and climate is critical to the well-being of people and communities globally. In order to best protect the environment, climate and the communities where we globally operate:

- We always act responsibly and abide by all applicable environmental laws;
- We continue to advance our data collection capabilities to best measure, monitor and continuously reduce our impact;
- We commit to improving our power usage efficiency, increasing the low-carbon content of our energy supply, and reducing our Green House Gas (GHG) emissions;
- We continue to advance our technology and services to enable our Clients to best reduce the impact of their activity;
- We encourage and support our businesses, all employees and locations globally to find and take specific actions that support the health of the environment, climate and the communities where we operate.

Paris, January 2020

Sophie ZURQUIYAH
Chief Executive Officer

GRP_HSE_POY_04E

Appendix B: Protected Matters Search Tool Report

Australian Government

Department of Agriculture, Water and the Environment

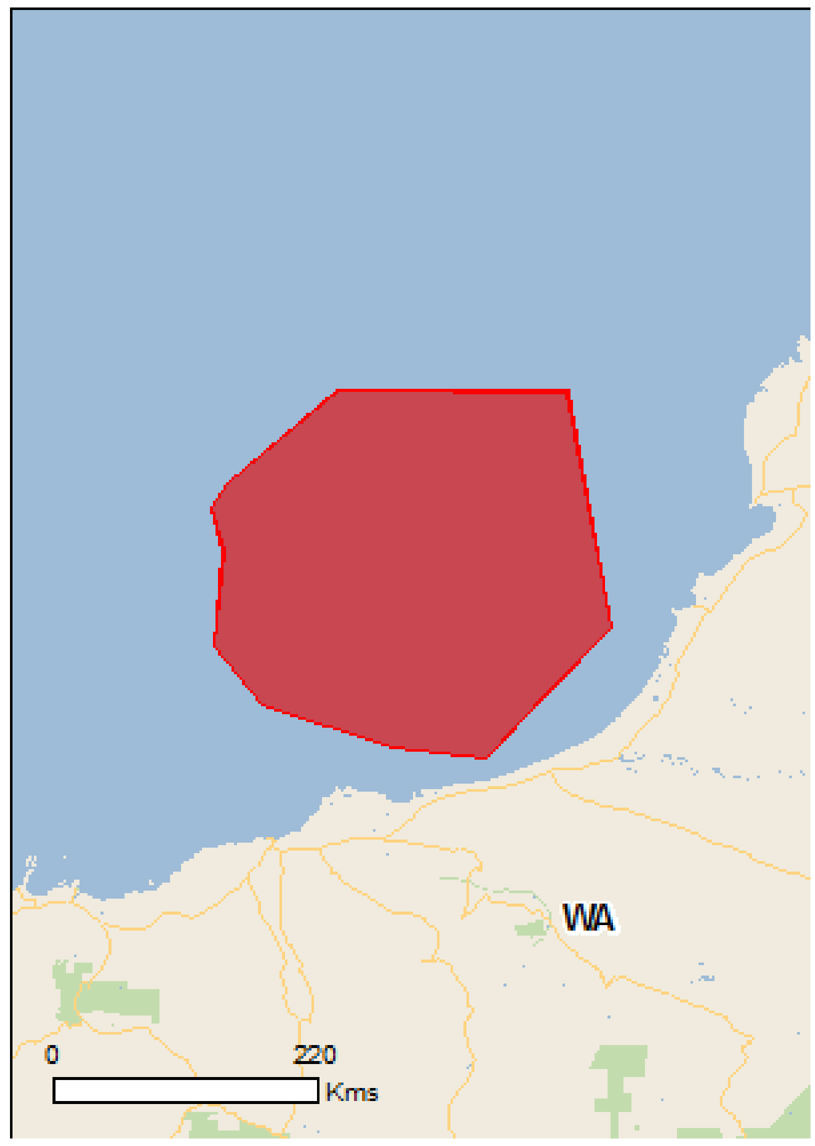
EPBC Act Protected Matters Report

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.

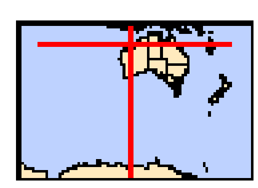
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 11/05/21 14:21:06



Coordinates

Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	19
Listed Migratory Species:	45

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:	1
Listed Marine Species:	85
Whales and Other Cetaceans:	26
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	4

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-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	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	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	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
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sternula albifrons Little Tern [82849]		Breeding known to occur

Name	Threatened	Type of Presence
		within area
Sula leucogaster Brown Booby [1022]		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	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat 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	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat 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
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	Congregation or

Name	Threatened	Type of Presence
		aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may 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

Name	Threatened	Type of Presence
		area

Other Matters Protected by the EPBC Act

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Mermaid Reef - Rowley Shoals	WA	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		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
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
Hirundo rustica Barn Swallow [662]		Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding likely to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
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

Name	Threatened	Type of Presence
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Cosmocampus banneri Roughridge Pipefish [66206]		Species or species habitat may occur within area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
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

Name	Threatened	Type of Presence
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		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
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Migration route known to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within

Name	Status	Type of Presence
		area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Australian Marine Parks [Resource Information]

Name	Label
Argo-Rowley Terrace	Multiple Use Zone (IUCN VI)
Argo-Rowley Terrace	Special Purpose Zone (Trawl) (IUCN VI)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Mermaid Reef	National Park Zone (IUCN II)

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Mermaid Reef and Commonwealth waters	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

-17.1559 120.8212,-17.1457 119.1159,-17.8143 118.2949,-17.9826 118.1763,-18.2909 118.2615,-18.9529 118.1922,-19.3736 118.5484,-19.6713 119.5193,-19.7482 120.2186,-18.8224 121.144,-17.1559 120.8212

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

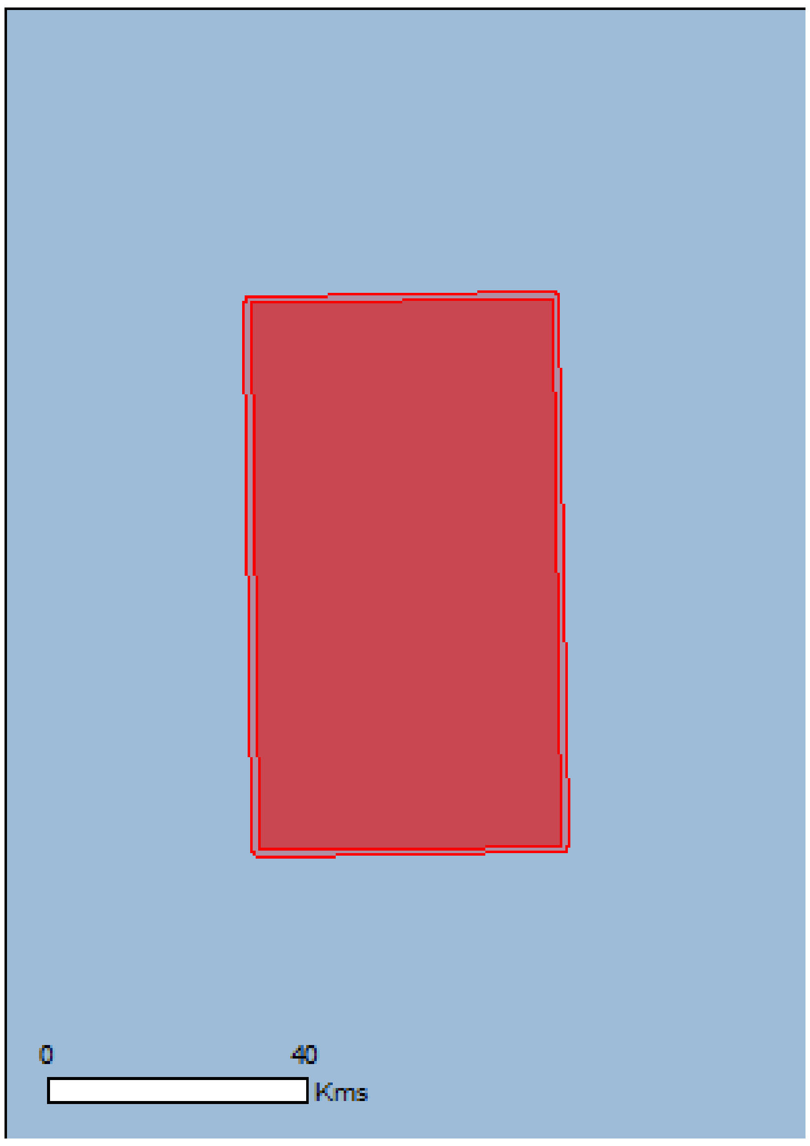
EPBC Act Protected Matters Report

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.

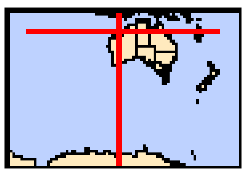
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 10/06/21 14:03:50



Coordinates

Buffer: 1.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	16
Listed Migratory Species:	34

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:	56
Whales and Other Cetaceans:	25
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	1

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known 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 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
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area
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 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
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat likely to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis 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

Name	Threatened	Type of Presence
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Tursiops aduncus (Arafura/Timor Sea populations)		
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may 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 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
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 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

Name	Threatened	Type of Presence
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area
Fish		
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 flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		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
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 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

Name	Threatened	Type of Presence
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
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
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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 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
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Species or species habitat likely to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat 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 likely to occur within area

Name	Status	Type of Presence
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale [74]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Stenella coeruleoalba Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area

Name	Status	Type of Presence
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-18.03028 119.99,-18.74778 120.0025,-18.75417 119.58472,-18.03639 119.57389,-18.03028 119.99

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: Stakeholder Consultation

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
DAWE – Biosecurity (Marine Pests)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Marine Pests	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	5/7/21 3:47PM	Email	Stakeholder thanks for email and provides contact information for urgent enquiries.	N/A No objection or claim made.	NA	NA
Marine Pests	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	8/07/21 9:37AM	Email	Stakeholder thanks for enquiry and provides biosecurity requirements on behalf of the Australian Government, including: -offshore installation projects must apply to the department at least one month prior to project commencement. -review the department's Offshore Installations webpage and associated Offshore Installations Biosecurity Guide -review Australian ballast water and biofouling requirements and pre-arrival reporting using MARS. -the project's support vessels will need to be registered and managed using MARS, -support aircraft will need to be arranged in compliance with aircraft biosecurity reporting requirements. For the department to undertake an assessment they require the above information at least a month before the start of any project works. -Stakeholder has asked for link to the NOPSEMA details to confirm details and direct engagement with department regarding biosecurity issues relating to the project.	These claims are merited due to Bio securities role as a government regulatory authority: 1) offshore installation projects must apply to the department at least one month prior to project commencement. 2) review the department's Offshore Installations webpage and associated Offshore Installations Biosecurity Guide and notify the department where your project which may have conveyance interactions with Australian territory, or to discuss a biosecurity assessment, email seaports@agriculture.gov.au. 3) Review Australian ballast water and biofouling requirements and pre-arrival reporting using MARS. The project's support vessels will need to be registered and managed using MARS, where they are travelling between the project site and Australian ports for resupply/refuelling/waste management. 4) Provide the link to the NOPSEMA details. Report directly with department for the management of the biosecurity risk.	CGG will adopt all of these control measures in response to the request from biosecurity division: • Seismic vessel and support vessels will have Department of Agriculture and Water Resources biosecurity clearance prior to mobilising to the Operational Area. • Vessels will also have an anti-fouling system that is compliant with the prescriptions of the International Convention on the Control of Harmful Anti-fouling systems on ships 2001, the requirements of the Protection of the Sea (Harmful Antifouling Systems) Act 2006 and Marine Order 98 (Marine pollution - anti-fouling systems) 2013. • Compliant with the Australian Ballast Water Management Requirements, vessels will manage ballast water exchange/discharge using one of the following approved methods of management. • Vessels will have an approved Ballast Water Management Plan (BWMP) and valid Ballast Water Management Certificate (BWMC) unless an exemption applies or is obtained from DWAR. • Vessels will maintain complete and accurate records of ballast water exchange that complies with Section B, Regulation B.2. of the Annex to the Ballast Water Convention. • A biofouling risk assessment will be completed for each vessel mobilised from overseas or from	CGG notes that the seismic survey vessel is not considered an offshore installation. The survey and support vessels will operate out of an Australian port (likely Port Hedland). Should a survey or support vessel arrive in Australia from overseas, it will enter Australian territory via an Australian port prior to mobilising to the Operational Area. CGG confirms that the below controls will be in place for the activity: • Seismic vessel and support vessels will have Department of Agriculture and Water Resources biosecurity clearance prior to mobilising to the Operational Area. • Vessels will also have an anti-fouling system that is compliant with the prescriptions of the International Convention on the Control of Harmful Anti-fouling systems on ships 2001, the requirements of the Protection of the Sea • Compliant with the Australian Ballast Water Management Requirements, vessels will manage ballast water exchange/discharge using one of the following approved methods of management. • Vessels will have an approved Ballast Water Management Plan (BWMP) and valid Ballast Water Management Certificate (BWMC) unless an exemption applies or is obtained from DWAR. • Vessels will maintain complete and accurate records of ballast water exchange that complies with Section B, Regulation B.2. of the Annex to the Ballast Water Convention. • A biofouling risk assessment will be completed for each vessel mobilised from overseas or from other regions in Australia prior to mobilising to the Operational Area. • Vessels will be registered and managed using MARS as appropriate, where they are travelling between the project site and Australian ports for resupply/refuelling/waste management • CGG will provide a link to the NOPSEMA site where the EP is published for public comment when it becomes available.

Stakeholder Code / Organisation	From Titleholder Date	From Titleholder Document	From Titleholder Mode	From Stakeholder Date	From Stakeholder Mode	Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
								other regions in Australia prior to mobilising to the Operational Area. CGG will use the Biofouling Risk Assessment Tool 'Vessel Check' developed by the WA DPIRD • Vessels will be registered and managed using MARS as appropriate, where they are travelling between the project site and Australian ports for resupply/refuelling/waste management • CGG will provide a link to the NOPSEMA site where the EP is published for public comment when it becomes available.	
Marine Pests	14/07/21 1:39AM	Response to consultation	Email	16/07/21 11:22AM	Email	Stakeholder thanks for email and provides confirmation re survey: -No further reporting required -Where the survey vessel submits pre-arrival reporting for any arrival at an Australian port then it cannot then interact with other international vessels. -If the survey vessel is remaining an international vessel but there are support vessels travelling between an Australian port and the survey vessel outside the ATS then that poses a biosecurity risk and these interactions must be reported.	These claims are merited due to biosecurity's role as a government regulatory authority: -Where the survey vessel submits pre-arrival reporting for any arrival at an Australian port then it cannot then interact with other international vessels. -If the survey vessel is remaining an international vessel but there are support vessels travelling between an Australian port and the survey vessel outside the ATS then these interactions must be reported.	No additional control measures to those already communicated to Marine Pests are proposed to be adopted. CGG currently unsure of the vessels movements prior to undertaking the project, and will report to the department as required as soon as this information is known.	CGG currently unsure of the vessels movements prior to undertaking the project, however, will report to the department as required as soon as this information is known.
Marine Pests	30/7/21 10:55AM	Response to consultation	Email	No response received.					
DAWE - Fisheries	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
DAWE - Fisheries	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
CF01	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
AUSTFISH PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
AUSTFISH PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Email	No response received.					

Stakeholder Code / Organisation	From Titleholder Date	Document	Mode	From Stakeholder Date	Mode	Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
Australian Border Force	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Australian Border Force	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
Commonwealth Fisheries Association (CFA)	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
CFA	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
Australian Fisheries Management Authority (AFMA)	28/05/21 6:10PM	Invitation to Consultation E002	Email	4/06/21 1:04PM	Email	Stakeholder thanks for email and provides contact advice to consult with: -Fishers who have entitlements to fish within the proposed area. - Directly with Commonwealth concession holders in the North West Slope Trawl Fishery -The Western Australia Fishing Industry Council (WAFIC).	Claim that the Northwest Slope Trawl Fishery has entitlements to operate within the Sauropod 3D operational area and request that CGG consult with fishers that have entitlements to fish within the proposed area, including the Northwest Slope Trawl Fishery (NWSTF) and WAFIC. This claim is merited due to AFMA's role in Commonwealth fishery regulation. CGG has invited consultation on this project from WAFIC however is not consulting with the NWSTF.	WAFIC has been sent an invitation for consultation and consultation will continue throughout the development of the EP and activity.	CGG has invited consultation on this project from WAFIC however is not consulting with the NWSTF. The NWSTF operates off north-western Australia between the 200 m isobath and the outer boundary of the Australian Fishing Zone, whereas the Sauropod 3D Operational Area is inside the 200 m isobath. Therefore, fishers from the NWSTF do not have entitlements to fish within this area. Figure of fishery management areas with survey area overlay will be included to demonstrate.
AFMA	11/06/21 9:57AM	Response to consultation	Email	11/06/21 12:41PM	Email	Stakeholder request clarification whether the activities of the NWSTF are considered to be within the scope of the EP.	No objections or claims, request for clarification.	NA	CGG advises that one licence holder is already being consulted with as they also hold licences that operate within the Operational Area. CGG has sent a consultation package to the remaining operators as the licence area of the NWSTF with approximately 10 km north of the operational area.
AFMA	25/06/21 3:17PM	Response to consultation	Email	28/06/21 8:56AM	Email	Stakeholder thanks for response.	No Objections or claims.	NA	If you have any further questions, please let us know.
AFMA	28/06/21 5:13PM	Response to consultation	Email	No response received.					
Australian Hydrographic Office (AHO)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Australian Institute of Marine Science (AIMS)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
AIMS	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
Australian Marine Oil Spill Centre (AMOSC)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
AMOSC	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
AMSA	28/05/21 6:02PM	Invitation to Consultation E001	Email	31/05/21 08:33AM	Email	Stakeholder thanks for email and provides maritime safety information including: -Australian Hydrographic Office at datacentre@hydro.gov.au no less than four weeks before operations, with details relevant to the operations. -Notify AMSA's Joint Rescue Coordination Centre (JRCC) by e-mail to rccaus@amsa.gov.au (Phone: 1800 641 792 or +61 2 6230 6811) for promulgation of radio-navigation warnings at least 24-48 hours before operations commence. -JRCC will need to be advised when operations start and end. -Plan to provide updates to both the Australian Hydrographic Office and the JRCC on progress and, importantly, any changes to the intended operations. -Exhibit appropriate lights and shapes to reflect the nature of operations -Vessels should also ensure their navigation status is set correctly in the ship's AIS unit.	Request by AMSA for standard notifications to AHO no less than four weeks before operations with details relevant to operations, and the JRCC 24-28 hours before operations commence, and for the duration of the project.	CGG will adopt all of the proposed controls requested by AMSA.	The requested controls for notifications and updates will be included in the EP, that the survey vessels will use the appropriate lights and shapes and that a vessel traffic plot showing Automatic Identification System data will be used for EP planning.
AMSA	11/06/21 9:57AM	Response to consultation	Email	No response received.					
Australian Southern Bluefin Tuna Industry Association (ASBTIA)	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
ASBTIA	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
BARDSLEY FISHERIES PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
BILYARA HOLDINGS PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
BREFJEN NOMINEES PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
Cervan Marine Pty Ltd	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
Cervan Marine Pty Ltd	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	31/05/21 11:27AM	Request to send consultation document	Webform submission	1/6/21 8:40AM	Email	Stakeholder provided alternate contact details and requests the information is sent there.	N/A - Advice / request for further information only. No objection or claim made.	N/A	CGG will email the provided contact.
CSIRO	1/06/21 12:11PM	Invitation to Consultation E001	Email	No response received.					
CSIRO	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
Conservation Council of WA (CCWA)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
CCWA	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
COYRECUP LAKE PTY LTD; OLD BROWN DOG PTY LTD	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
COYRECUP LAKE PTY LTD; OLD BROWN DOG PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
CF02	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
CF03	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
DAWE (DAWE) - Director of National Parks	28/05/21 8:02PM	Invitation to Consultation E001	Email	05/07/21 11:57AM	Email	Stakeholder provides advice on considerations for EP including: - Australian marine parks and their representativeness. - Identify 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	N/A - Advice only. No objection or claim made.	N/A	CGG confirms that we have considered the content of NOPSEMA's Guidance Note: Petroleum Activities and Australian Marine Parks dated June 2020 and have included the DNP notification requirements in the event of an oil spill into the EP. We will consider the Argo-Rowley Terrance, Eighty Mile Beach and Roebuck Marne Parks and their representativeness in the development of the EP.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
						reduce them to as low as reasonably practicable. - Demonstrate that the activity will not be inconsistent with the management plan. -Take into consideration the North-west Marine Parks Network Management Plan 2018 -The DNP should be made aware of oil/gas pollution incidences which occur within a marine park or are likely to impact on a marine park as soon as possible. Notification should be provided to the 24-hour Marine Compliance Duty Officer on 0419 293 465.			
DAWE - DNP	7/07/21 11:02AM	Response to consultation	Email	No response received.					
Department of Defence	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Department of Defence	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
Department of Industry, Science, Energy and Resources (DISER)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
DISER	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
Australian Communication s and Media Authority (Subsea Cables)	21/06/21 3:15PM	Response to consultation	Email	No response received.					
Subsea Cables	28/05/21 6:02PM	Invitation to Consultation E001	Email	17/06/21 07:11AM	Email	Stakeholder provides advice to contact stakeholders in regards to submarine cables in project vicinity.	N/A No objection or claim made.	N/A	As a relevant stakeholder subsea cables will continue to be provided project updates.
Department of Mines, Industry Regulation and Safety (DMIRS)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
DMIRS	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	19/07/21 10:41am	Email	Stakeholder asks for the following: -Pre-start notification confirming the start date of the proposed activities. -Cessation notification to inform the Department upon completion of the activities.	These claims are merited due to the Department of Mines, Industry Regulation and Safety's role as a government regulatory authority: 1) Provide DMIRS with a pre-start notification confirming the start date	CGG will adopt all of the proposed controls requested by DMIRS: • provide DMIRS with a pre-start notification confirming	1) CGG will provide DMIRS with a pre-start notification confirming the start date of the proposed activities and provide DMIRS with a cessation notification to inform the Department upon completion of the activities and include these in the notification requirements of the EP

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
						-Review DMIRS's Consultation Guidance Note.	of the proposed activities. Provide DMIRS with a cessation notification to inform the Department upon completion of the activities. 2) Review consultation Guidance Notes for information pertaining to the reporting of incidents to DMIRS	the start date of the proposed activities • provide DMIRS with a cessation notification to inform the Department upon completion of the activities.	2) CGG will consider DMIRS's Consultation Guidance Note with regard to reporting of incidents to DMIRS as required by Regulation 26AA.
DMIRS	21/07/21 9:45AM	Response to consultation	Email	21/07/21 9:47AM	Email	Automated email received.	N/A No objection or claim made.	N/A	N/A
Department of Primary Industries and Regional Development (DPIRD) - Fisheries	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
DPIRD	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
CF04	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
FAT MARINE PTY LTD	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
FAT MARINE PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
CF05	29/05/21 9:00AM	Invitation to Consultation E002	Post	1/07/21 8:54PM	Email	-Stakeholder states he is an active fisher in the vicinity of the survey and has been previously negatively impacted by seismic surveys. -Stakeholder states the Sauropod survey area is north of several mackerel schooling reefs and states mackerel are sensitive to seismic activity. -States previous survey created a dead zone around 40 nm either side of the survey area in which no fish were present and expects impacts on reefs in survey vicinity following season. -Expresses financial loss due to previous seismic survey activity and expects compensation will be required due to a major impact on reefs in the vicinity of the seismic survey. - Mackerel are pelagic fish and are very mobile. They also appear to be very	These objections and claims are merited due to the stakeholder's role as a commercial fisherman: 1) Spanish mackerel disappeared completely and failed to repopulate reefs following previous seismic surveys 2) Mackerel are pelagic fish and are very mobile. They appear to be very sensitive to seismic noise and will rapidly depart an area where this activity is occurring.	No new measures adopted as the controls in the EP are considered sufficient to address concerns raised by the stakeholder.	1)Short-term movement by mobile pelagic species away from a survey area is not unexpected and cannot be attributed solely to the seismic activity. The behaviour and distribution of mackerel is also affected by various factors such as water temperature (Mackie et al. 2003) and it is understood that there has been a moderate depletion of the stock because of a decline in catch rates in recent years (FRDC 21). The low catches in Western Australia are attributed to 'widespread environmental changes' and the status report notes that other Australian states have also recorded declining catches (DPIRD 2020). The decline in catches described could be the result of these factors. 2) Short-term movement by mobile pelagic species away from a survey area is not unexpected. Pelagic fishes are most likely to exhibit a behavioural response (avoidance) by moving away from an operating seismic source that approaches within a few tens or hundreds of metres of them (Wardle et al.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
						sensitive to seismic noise and will rapidly depart an area where this activity is occurring. Fishers are now beginning to suffer a cumulative affect on our fishing viability due to seismic surveys. -Expresses My grave concerns for long term impact on mackerel, which will lead relocation in areas inaccessible by distance or license boundaries.			2001). Research shows that mackerel in this region don't move more than 100 km along the coast (DOF 2013), and whilst it is possible that fish may be displaced from a survey footprint to adjacent areas, the total number of fish within the fishery stock remains unchanged and mortality is highly unlikely.
							3) Previous seismic surveys created a dead zone for 40 nm in which no fish were present and a similar impact is expected from the Sauropod survey		3) 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. Effects on fish behaviour are expected to be temporary as the seismic vessel traverses each survey line, and fish are expected to move away as the airgun array approaches. The impact assessment in the Environment Plan has reviewed the best available scientific literature on the effects of seismic noise emissions on fish behaviour. The southern edge of the survey area is approximately 5 km from the nearest historically fished area which has experienced only low fishing pressure. This is the only historically fished area that will receive noise capable of influencing fish behaviour.
							4) I cannot be expected to constantly take such drastic cuts to catch and continue to survive financially.		4) Effects on fish behaviour are expected to be temporary as the seismic vessel traverses each survey line, and fish are expected to move away as the airgun array approaches. Please also see responses to point 1 and 3 regarding expected impact to fish stocks.
							5) We are suffering a cumulative affect on fishing viability.		5) The Keraudren Extension 3D MSS, overlaps the acquisition area of the Sauropod MSS. The 2021 portion of the survey could be completed approximately six months prior to the earliest commencement date of the Sauropod 3D MSS (i.e. by 31 July 21). Therefore, cumulative impacts are not expected. Mitigation measures will include as a minimum: •Development of a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area •Minimum separation distance of 40 km shall be maintained between the Sauropod 3D MSS seismic sources and other operating seismic sources.
							6) I expect the Sauropod survey will impact upon my fishing and I will require compensation.		6) Whilst a compensation or 'make-good' process can be an appropriate mechanism for compensating fishers who are impacted by a seismic survey, either by displacement or from a loss of catch, compensation has to be assessed on a case-by-case basis. At this stage CGG has determined that compensation for commercial fishers is not an appropriate control or mitigation measure for the Sauropod 3D MSS, given the nature and scale of the activity, and the minimal impacts expected to the commercial fishing industry.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
							7) a long-term impact is likely occurring in which mackerel may relocate to areas I am unable to access either by distance or license boundaries.		7) Research shows that mackerel in this region don't move more than 100 km along the coast during their lifecycles (DOF 2013, Newman et al. 1998). Effects on fish behaviour are expected to be temporary as the seismic vessel traverses each survey line, and fish are expected to move away as the airgun array approaches however this movement is understood to be within the Area 2 licence boundaries and within viable operational distances.
CF05	8/07/21 13:09	Response to consultation	Email	25/07/21 8:12PM	Email	I don't think you took my concerns or your potential environmental impact seriously. I don't believe the merits of my objections and claims have been appropriately assessed or resolved. There is a likely unacceptable impact on the marine environment and socio-economic values on fishing as the information provided was not incorporated, considered and evaluated in your response. Some of the references you have used are outdated and/or not relevant to WA stock status. Stakeholder requests confirmation that the information gathered through the consultation process has been incorporated, considered and Evaluated in the Environmental Plan and my objections and claims have been resolved as far as reasonably practical. Mackerel are pelagic and will vacate the vicinity of a noise source which has financial impacts to fishers. The stakeholder states their fishing business have been successful excepting the past three seasons, during which seismic surveys have been occurring. I am against being squeezed out of business by a newcomer to this area who appear to be somewhat cavalier towards Other established businesses.	These objections and claims are merited due to the stakeholders role as a commercial fisherman: 1) I don't believe the merits of my objections and claims have been appropriately assessed or resolved	No new measures adopted as the controls in the EP are considered sufficient to address concerns raised by the stakeholder.	1) Please be assured that CGG did properly assess the merit of your objections and claims, including consideration of relevant literature and the location of the proposed survey relative to the actively fished area of the mackerel fishery. CGG will continue to consult with yourself as you are considered a relevant person for this activity and will continue to assess the merits of any objections and claims made through the regulatory stakeholder consultation process to resolve them as far as reasonably practicable.
							2) There is a likely unacceptable impact on the marine environment and socio-economic values on fishing		2) Given the scope and location of the seismic survey relative to environmental sensitivities and fishing grounds and the measures we will be implementing to manage potential impacts we do not believe that there will be any unacceptable impacts resulting from the proposed activity. The proposed controls for the activity are considered industry best practice and meet legislative requirements and CGG considers the adopted controls appropriate to manage the impacts of noise disturbance from the seismic source to be of an acceptable level.
							3) the information provided was not incorporated, considered and evaluated in your response.		3) CGG does not agree that the information was not properly considered or incorporated into the response. That the information you provided has been included in the EP risk assessment of seismic sound on fishes and commercial fisheries and for assessment of cumulative impact of seismic surveys. CGG is open to further discussion about the survey and potential impacts on your fishery and will consider any further information or evidence you can provide on this issue.
							4) Some of the references you have used are outdated and/or not relevant to WA stock status.		4) References to these fisheries was provided to demonstrate that recent declines in mackerel stocks have not been isolated to Western Australia, and to support the statement that the behaviour and distribution of mackerel is also affected by various factors such as water temperature. In doing so we believe that we have used the most recent available references but if you have more recent information relevant to this topic, in particular concerning the decline in mackerel stocks, please let us know.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
							5) confirmation that the information gathered through the consultation process has been incorporated, considered and Evaluated in the Environmental		5) CGG can confirm that information relating to fishing that has been gathered through the consultation process has been considered and where appropriate incorporated into the rest of the EP if not already present.
							6) Please provide confirmation that my objections and claims resolved as far as reasonably practical.		6) CGG will continue to consult with yourself as you are considered a relevant person for this activity and will continue to assess the merits of any objections and claims made through the regulatory stakeholder consultation process to resolve them as far as reasonably practicable.
							7) Mackerel are pelagic and will vacate the vicinity of a noise source which has financial impacts to fishers, as seen in previous surveys.		7) CGG agrees that short-term movement by mobile pelagic species away from the survey area is not unexpected and may potentially lead to short-term localised impacts to catches, however the decline in catch statistics that you provide cannot be attributed solely to seismic activity. Seismic activity has occurred extensively across the northwest shelf for more than the last three years and therefore it would be expected that the recent declines you have experienced, if attributable to seismic activity, would have been experienced before this period (rather than in synchrony to a strong environmental parameter (water temperature) that is well known to have an influence on this species). A recent study conducted on the North West Shelf by AIMS did not find any evidence that seismic activity interrupts demersal fish fauna (Meekan et al 2021). This study did not find evidence of effects on the abundance, behaviour or movement of demersal fishes, and believe it unlikely that the proposed seismic survey will cause unacceptable impact to commercial fisheries in the region.
CF05	3/08/21 7:02PM	Response to Consultation	Email	No response received.					
CF05	7/9/21 11:30AM	Meeting with WAFIC and CF05				Request that name of sender is included in future correspondence. Query what assessment has been made of cumulative impacts in the EP and what controls are implemented to make ALARP? The EP seems to only focus on short term impacts, need to focus more on long term impact. CF05 has not seen impacts from the 2016 heatwave to catches, reduction in catches correlates to the occurrence of seismic activity in the region.	These objections and claims or queries are merited due to both stakeholders roles within the commercial fishing industry: 1) (request for information, not an objection or claim) What assessment has been made of cumulative impacts and what controls are implemented to make impacts ALARP?	New control adopted in response to claims by CF05 and WAFIC: “Implementation of a management of change process that includes a specific trigger to review new evidence in relation to impacts and risks to commercial fishing from the survey, and the review of the need to enhance existing controls”. Good practice principles that will included in a Fishery Impact	Responses provided by CGG within the meeting: Confirmation that information from this meeting will be included in the EP and name of sender will be included in future correspondence. 1) The assessment is made based on the location of the activity vs the fishing area and the assessment of past catches. The impact assessment considers the fishery (catch) separately to the fishes and spawning. Catch history from the last 5 years is compared with the fishery area and the location of previous surveys. Of all of the fisheries considered the MMF is discussed however the *prawn fisheries have a larger impact so they are the one assessed, to provide a conservative basis for all fisheries with effort in the region.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
						Stakeholder doesn't think the period between the survey ending and the end of the season is long enough. Concern is if fishers catch drops then DPIRD will implement management controls which leads to a financial implication to fishers. Is the recreational mackerel fishery in WA also seeing impacts due to seismic surveys? Grey mackerel are elusive and not a good indicator of the fishery status. There have not been many humpback whales observed in the area compared to previous years and queries on the methods of detection for whales outside daylight hours. How does CGG not support use of the NERA protocol when CGG is in the group developing it? CGG is not admitting that the Sauropod Seismic survey will have an impact on the fishery. Surveys adjacent to the reefs means there is no aggregation on the reefs. There are 3-4 important reefs in the Sauropod area. Has CGG done sound modelling for this activity? More research needs to be done on the impact of seismic to fisheries. What is the impact to juveniles as they can't swim away for a survey? The concern is for the long-term of the fishery. Reduction in catch impacts the value of the fishing license Request for a map of previous surveys over the fishery. The survey is only going to impact on the eastern end of the stakeholders typical fishing ground. Is a window for the survey based on the vessel availability? Providing effort history in an area is difficult as if there are no fish in the area they won't return there. Is CGG open to exploring a mechanism to discuss this further? Must consider the impact beyond the operational area. Can CGG provide a copy of the Gippsland adjustment protocol?	2) Claim that EP seems to only focus on short term impacts, need to focus more on long term impact.	Mitigation Plan, if required, include: • Mitigation will be made available during the acquisition phase of the seismic survey and up to two months after the conclusion of the acquisition of the seismic survey. • Mitigation will be available to a commercial fisher who fishes as a normal part of their commercial fishing activity within the Adjustment Area (an area extending 10 km around the perimeter of the acquired survey area [where guns are fired at full power for the purpose of data acquisition], noting this may be smaller than the defined Acquisition Area of the survey as defined in the EP). A commercial fisher must be able to demonstrate that they would have received the revenue from the landed catch that is the subject of a claim and adjustment is dependent on a commercial fisher continuing to carry out their fishing activities to the best of their ability and to mitigate and limit financial loss despite the occurrence of a seismic survey, i.e. adjustment would not be available where a fisher chooses to move away from a survey and makes no attempt to fish within the survey Adjustment Area. • The mitigation process will apply to historical fishing activity over established fishing grounds, and not to speculative fishing activity • Mitigation claims may be lodged up to 4 months after the conclusion of the acquisition of the seismic survey. • If a commercial fisher is unable to fish in their historical fishing area within the Adjustment Area during the	2) The EP considers not only the impact to fish behaviour but to fish spawning and juvenile life stages of fish including mackerel. The EP considers the recent research by The Australian Institute of Marine Science (AIMS), as part of the North West Shoals to Shore Research Program, who undertook a study of the potential behavioural effects of seismic sound exposure on red emperor, another key demersal species that occurs in the Operational Area and in the wider region. The results from this study show that there were no short-term (days) or long-term (months) effects of exposure on the composition, abundance, size structure, behaviour, or movement of key fisheries species (Meekan et al. 2021). 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). A discussion of this body of literature is included in the EP in Section 7.
							3) Claim that the reduction in catches correlates to the occurrence of seismic activity in the region not to heatwaves		3) DPIRD has stated that the drop in MMF catches is due to heat waves, firstly in 2011 which resulted in the west coast stock moving further south than usual. A more recent heatwave in 2016 also impacted QLD and NT stocks and, because it occurred during the mackerel spawning period, is implicated with the decline in catch experienced since 2018.
							4) Claim that the period between the survey ending and the end of the season is not long enough for fishers to work once mackerel return to the area.		4) The peak period of annual Spanish mackerel fishing effort in the Pilbara sector is July to October whereas annual effort is lowest from December to March (Mackie et al. 2010). The survey is 60 days between Jan and May, which is two months prior to the peak period and therefore not expected to impact the fishery, particularly given the minimal overlap of the seismic survey with fishing grounds.
							5) Claim that reduced catch due to the survey can lead to management controls being implemented by DPIRD which will impact the value of licences.		5) A stock assessment by DPIRD is 'underway', however COVID and resourcing is holding things up. Management controls being implemented by DPIRD is outside the control of CGG.
							6) (request for information, not an objection or claim) Is the recreational mackerel fishery in WA also seeing impacts due to seismic surveys?		6) Yes there are indications recreational catch is reduced.
							7) (request for information, not an objection or claim) How does CGG not support use of the NERA		7) CGG is one of 11 companies that are being consulted regarding the protocol. CGG has developed and used their own mitigation protocol in Gippsland.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
						It is good to know that concerns are being heard. Mackerel fishers use daily logbooks and fish at 6 kn. WAFIC is not able to resource providing a daily lookahead service for the survey. CF05 is not fishing in the Sauropod area so does not need lookaheads.	protocol when CGG is in the group developing it?	seismic survey and incurs costs over and above the normal running costs for a fishing trip while relocating to another historical fishing area, then costs associated with increased distance/transit time, fuel and crewing will be considered for monetary adjustment.	Loss of catch is relatively simple to mitigate. Displacement is a complex issue and is not addressed well in the current NERA protocol. Also the NERA protocol has evidently not been reviewed by NOPSEMA.
							8) Claim that CGG does not acknowledge that the seismic survey will have an impact on the fishery.		8) CGG agrees that pelagic fishes are likely to exhibit a behavioural response (avoidance) by moving away from an operating seismic source that approaches within hundreds of metres of them, therefore behavioural movement as a result of the survey is agreed to. However, the MMF fishery does not have catch history within the Acquisition Area of the Sauropod activity, and only limited historical effort within 10 km of the Acquisition area (an area that could be conservatively considered the ensonified area for behavioural impacts) therefore CGG does not believe that the MMF fishery are likely to be impacted by the survey.
							9) (request for information, not an objection or claim) Has CGG done sound modelling for this activity?		9) Sound modelling has been conducted for the activity and CGG will supply the modelling report to WAFIC.
							10) (request for information, not an objection or claim) What is the impact to juveniles as they can't swim away?		10)Spanish mackerel are a fast-growing species and small individuals including juveniles tend to school and appear to be more mobile than larger fish (Mackie et al. 2010). They are therefore also expected to move away from the seismic sound source.
							11) Claim that a reduction in catch will impact the value of the licence, resulting in long-term impacts to the stakeholder financially.		11) No impact on catches is predicted as a consequence of the seismic survey.
							12) (request for information, not an objection or claim) Request for a map of previous surveys over the fishery.		12) A map of the location of previous surveys can be supplied to WAFIC.
							13) (request for information, not an objection or claim) Is a window for the survey based on the vessel availability?		13) The window is not based on vessel availability alone although that is an important factor.
							14) Claim that providing effort history in an area is difficult as if there are no fish in the area they won't return there.		14) In the event of a claim the only valid means of evidencing an impact is via comparison of current fishing data with historic fishing data.
							15) Claim that CGG must consider the impact beyond the operational area in any compensation cases.		15) CGG agrees that the impact area beyond the operational area, as was done for previous CGG surveys, and should be considered and should be based on noise model as an objective measure. This will be discussed further with NOPSEMA as there is currently little guidance.
									Responses provided by CGG following the meeting:

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
									References to prawn fisheries during the meeting was in error, this should have been in reference to the Pilbara Demersal Scalefish Fisheries. Documentation requested was provided (Sound modelling, full EP, extract of the EP with sound impact assessment)Detail around the adopted adaptive management control measure was related to the stakeholders in a second email following the meeting.
CF05	13/09/21 9:53AM and 2:50PM	Meeting minutes and supplementary documents	Email	No response received.					
CF05	14/10/21 11:58AM	Additional response from meeting on 7/9/21	Email	No response received.					
CF06	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
INPEX Browse E&P Pty Ltd	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
INPEX Browse E&P Pty Ltd	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
KAI NOMINEES PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
KFM LEASING PTY LTD; GNTM PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
Kimberley Land Council (KLC)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
KLC	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
CF07	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
LENDEN NOMINEES PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
M G KAILIS PTY. LTD.; MG KAILIS PTY LTD	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
M G KAILIS PTY. LTD.; MG KAILIS PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
CF08	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
CF09	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
National Native Title Tribunal (NNTT)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
NNTT	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
NORTHERN WILDCATCH SEAFOOD AUSTRALIA PTY LTD; NDSF LICENCES HOLDING COMPANY PTY LTD	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
NORTHERN WILDCATCH SEAFOOD AUSTRALIA PTY LTD; NDSF LICENCES HOLDING COMPANY PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
Pathfinder Energy Pty Ltd	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Pathfinder Energy Pty Ltd	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
Pearl Producers Association of WA (PPA)	28/05/21 6:10PM	Invitation to Consultation E002	Email	28/05/21 6:11PM	Email	Stakeholder is no longer the Executive Officer for the Pearl Producers Association (PPA) and has provided another contact.	N/A - Advice / request for further information only. No objection or claim made.	NA	Email was already sent to the specified stakeholders, no further emails will be sent. Stakeholder register was updated.
PPA	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
CF10	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
PGS Australia Pty Ltd	31/05/21 11:22AM	Request to send consultation document	Webform submission	31/05/21 22:34AM	Email	Automated email received.	N/A - Advice / request for further information only. No objection or claim made.	NA	Consultation package sent.
PGS Australia Pty Ltd	31/05/21 11:59AM	Invitation to Consultation E001	Email	No response received.					
PGS Australia Pty Ltd	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
CF11	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
RAPTIS FISHING LICENCES PTY LTD	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
RAPTIS FISHING LICENCES PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
Recfishwest	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
Recfishwest	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	28/07/21 4:00PM	Email	Provided additional contact for further emails	N/A	N/A	No response required. CGG will update contact information in the stakeholder register.
CF11	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
CF12	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
SABEA FISHING CO PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
SAGACITY PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
Santos WA Northwest Pty Ltd	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Santos WA Northwest Pty Ltd	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
Searcher Seismic	N/A			22/09/21 12:44PM	Email	Searcher is planning to conduct a seismic survey in the vicinity of the proposed Sauropod survey between 1 January 2022 and end July 2023 for 70 days. Can you please provide shapefiles of the Sauropod activity areas so that Searcher can assess positioning and potential cumulative impacts?	No objections or claims, request for information and advising the location and timing of a proposed seismic survey.	CGG will send through the requested documentation to Searcher. The Possum Acquisition Area overlaps the Sauropod Acquisition Area by approximately 95 km^2 and the survey may be acquired from January 2022 to the end of July 2023. The Possum EP has not been submitted to NOPSEMA and therefore CGG will not include the survey in the cumulative impact assessment of the Sauropod EP. If and when the Possum EP is submitted to NOPSEMA CGG will assess the cumulative impact of that survey to the Sauropod survey through either the EP development process or the MoC process as part of the ongoing environmental management of the impacts and risks of the activity. There are several existing adopted controls in the EP that CGG will implement in the event that new information regarding the surrounding environment is received post-EP acceptance, including: • Ongoing consultation process "If new information regarding the receiving environment relevant to the Sauropod 3D MSS area is received through ongoing consultation, then an internal risk assessment will be conducted as described in Section 9.2." • Management of change trigger "Changes in the external environment managed and monitored by the CGG Project Manager (or delegate)" In the event that the Possum EP is submitted to NOPSEMA and CGG is advised through the ongoing consultation process, the following controls will be implemented to manage potential impacts: • PS 1.5 "CGG will engage with proponents identified as having potential concurrent seismic activities prior to commencing the Sauropod survey and develop a concurrent operations plan for any concurrent surveys identified within 40 km of the Acquisition Area." • PS2.4 "A minimum separation distance of 40 km shall be maintained between the Sauropod 3D MSS seismic sources and other operating seismic sources."	CGG will provide the requested information to Searcher.

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
Searcher Seismic	1/10/21 2:32PM	Response to consultation	Email	No response received.					
SEA HARVEST FISHING COMPANY PTY LTD; Running Wild Fishing Co.	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
SEA HARVEST FISHING COMPANY PTY LTD; Running Wild Fishing Co.	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
SEAFRESH HOLDINGS PTY LTD; SHARK BAY NOMINEES PTY LTD; FABRON HOLDINGS PTY LTD; SHARK BAY SEAFOODS PTY LTD	28/05/21 6:10PM	Invitation to Consultation E002	Email	No response received.					
SEAFRESH HOLDINGS PTY LTD; SHARK BAY NOMINEES PTY LTD; FABRON HOLDINGS PTY LTD; SHARK BAY SEAFOODS PTY LTD	5/07/21 3:39PM	Follow up on Invitation to Consultation E004	Email	No response received.					
SPANIARD FISHING PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
TGS-NOPEC Geophysical Company Pty Ltd	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
TGS-NOPEC Geophysical Company Pty Ltd	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
The Wilderness Society WA	28/05/21 6:02PM	Invitation to Consultation E001	Email	28/05/21 6:02PM	Email	Automated response.	N/A No objection or claim made.	NA	NA
The Wilderness Society WA	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	5/07/21 3:46PM	Email	Automated response.	N/A No objection or claim made.	NA	NA

Stakeholder Code / Organisation	From Titleholder Date	From Titleholder Document	From Titleholder Mode	From Stakeholder Date	From Stakeholder Mode	Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
Tourism Western Australia	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
Tourism Western Australia	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					
CF13	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
VIENCY PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
WA Department of Transport - Marine (DoT WA)	28/05/21 6:02PM	Invitation to Consultation E001	Email	10/06/21 3:26PM	Email	Stakeholder advises that if there is a risk of a spill impacting State waters from the activity, to ensure that the Department of Transport is consulted	N/A - Advice / request for further information only. No objection or claim made.	NA	Email response to DOTWA with the oil spill risk assessment and draft Oil Pollution Emergency Plan (OPEP). CGG Sauropod 3D MSS OPEP sent with table outlining relevant sections within OPEP.
DoT WA	21/07/21 9:53AM	Response to consultation	Email	21/07/21 9:54AM	Email	Stakeholder automatic email response received.	N/A No objection or claim made.	NA	NA
DoT WA	21/07/21 9:53AM	Response to consultation	Email	28/07/21	Email	Thank you for providing the CGG Oil Pollution Emergency Plan. We will respond with any comments/queries.	N/A No objection or claim made.	NA	NA
DoT WA	21/07/21 9:53AM	Response to consultation	Email	10/8/21 9:22AM	Email	Given that the risk to State Waters is very low a full review has not been deemed necessary. If you could please send us an accepted version of the OPEP for our records that would be appreciated.	N/A - Advice / request for further information only. No objection or claim made.	NA	CGG will provide a copy of the accepted OPEP when it is available.
WEST COAST CRABS PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
Western Australian Fishing Industry Council (WAFIC)	28/05/21 6:10PM	Invitation to Consultation E002	Email	17/06/21 11:49AM	Email	Stakeholder outlines risks associated with survey: • Mobile invertebrates – Moderate • Immobile invertebrates – High • Finfish demersal – High • Pelagic – Negligible – 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. -Based on the risks above, assessment of the impacts at the population level for key species should be undertaken and included in the EP.	These claims are merited due to WAFIC's role as a commercial fishery industry representative: 1) Fishers have advised WAFIC that they are encountering a significant change in catchability of mackerel species following seismic survey activity which is having a direct impact on the economic viability of commercial fishers and potential fish stocks for those species. 2) Assessment of the impacts at the population level for key species should be undertaken and included in the EP. 3) Risk mitigation and risk control measures should be implemented to ensure all impacts are managed and detailed evidence based analysis has	CGG will adopt the following measures in response to the objections and requests made by the stakeholder -Population-level impact assessment for key fishery species will be included in the EP. - Risk mitigation and risk control measures will be implemented in the EP - Consult with the PPA with regards t impact on pearl oyster brood stock from the seismic survey - Include the results of the AIMS Shoals to Shore research (the Meekan and Speed paper) when available.	Summary of responses below: 1) Short-term movement by mobile pelagic species away from the survey area is not unexpected. Literature review and references provided. 2) Population-level impact assessment for key fishery species will be included in the EP. 3) Regulation 13(5)(c) of the OPGGS (E) Regulations require that where significant effects are identified, details of the control measures that

Stakeholder Code / Organisation	From Titleholder Date	From Titleholder Document	From Titleholder Mode	From Stakeholder Date	From Stakeholder Mode	Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
						-Risk mitigation and risk control measures should also be implemented to ensure all impacts are managed and detailed evidence based analysis has considered fish species and the timing of the survey to minimise impacts to both commercial fishing operations and the fish species both during and post survey. -the proposed timing (wild capture) and area falls in within the distribution of Pinctada maxima, and therefore WAFIC has significant concerns regarding the potential impacts to pearling stocks and pearling operations (including the risk to divers). CGG should include the outcomes of the AIMS study, which will be released soon before proceeding with the EP. - In the information sheet, it states that the fishing effort is low, please provide confirmation that the interpretation of low fishing effort is not due to confidentiality provisions under the Fish Resources Management Act 1994 .	considered fish species and the timing of the survey to minimise impacts to both commercial fishing operations and the fish species both during and post survey.		will be used to reduce the impacts and risks of the activity to as low as reasonably practicable (ALARP) and an "acceptable level", must be included in the EP. CGG has considered previous impact and risk assessments for similar activities, review of relevant published studies.
							4) WAFIC has concerns regarding the potential impacts to pearling stocks and pearling operations (including the risk to divers) as the proposed timing and area falls in within the distribution of *Pinctada maxima*.		4) Silver-lipped pearl oyster (Pinctada maxima) brood stock may occur within the Operational Area and EMBA and has been taken into consideration in the EP however the PPA has previously advised that they do not have concerns for the depths over which the survey area covers and there is no operation in these water depths.
							5) CGG should include the outcomes of the AIMS study, which will be released soon before proceeding with the EP		5) We will include it in the EP if it is available in time.
							6) Please confirm that the interpretation of low fishing effort in the area is not due to confidentiality provisions under the Fish Resources Management Act 1994.		6) CGG requested annual catch and effort data (Fish Cube data) from DPIRD for WA managed fisheries understood to operate within or near to the Operational Area. Data was assessed to identify where the greatest fishing effort in each fishery occurred and the relative importance of waters within the Operational Area.
WAFIC	1/07/21 11:49AM	Response to consultation	Email	16/07/21 15:54	Email	Stakeholder requests confirmation that the information gathered through the consultation process relating to fishing (including environmental and the socio-economic values of fishing) has been incorporated, considered and evaluated in the EP and that objections and claims have been resolved as far as reasonably practicable. -References you have used are outdated and/or not relevant to WA stock status. -Please confirm if you are making a commitment to the Commercial Fishing Industry Adjustment protocols for this EP?	These claims and requests for further information are merited due to WAFIC's role as a commercial fishery industry representative: 1) Confirm that the information you have gathered through the consultation process relating to fishing (including environmental and the socio-economic values of fishing) has been incorporated, considered and evaluated in the EP.	Controls adopted and implemented in first consultation. The AIMS study World first seismic sound experiment conducted off NW Australia (Meekan et al 21) is now available, the outcomes of which will be included in the EP.	Detailed responses were provided, summary below: 1) CGG confirms that information relating to fishing that has been gathered through the consultation process has been considered and where appropriate incorporated into the EP, if not already present. A response to all correspondence received from fishing stakeholders has also been provided. Example of pearl oyster inclusion provided.
							2) Please confirm that objections and claims have been resolved as far as reasonably practicable.		2) CGG believes that the objections and claims presented to date by WAFIC have been resolved as far as reasonably practicable. However, as part of CGG's commitment to ongoing consultation, CGG will continue to consult with relevant persons.
							3) References you have used are outdated and/or no relevant to WA stock status for example referring to the Queensland and Torres Strait fishery.		3) References to these fisheries were required to demonstrate that recent declines in mackerel stocks have not been isolated to Western Australia, including statements made by the DPIRD linking the stock declines in WA to other states in Australia. If you have more recent literature, can you please provide it?
							4) Please confirm if you are making a commitment to the NERA Commercial Fishing Industry Adjustment protocols for this EP.		4) Whilst a compensation or 'make-good' process can be an appropriate mechanism for compensating fishers who are impacted by a seismic survey, CGG is not considering using the draft NERA Protocols in the

Stakeholder Code / Organisation	From Titleholder			From Stakeholder		Stakeholders Response Summary	Assessment of the Merited Objections and Claims	Controls/ measures adopted or proposed to adopt	Summary of titleholder response
	Date	Document	Mode	Date	Mode				
									EP as the Protocols need to be reviewed and accepted by NOPSEMA prior to their use as a control measure in the EP. Our own review of the Protocols indicate that the Protocols have not been developed with proper consideration of similar previous ones and that it is lacking detail needed to ensure that there are minimal issues in its implementation.
WAFIC	27/07/21 10:38AM	Response to consultation	Email	10/8/21 to 6/9/21	Numerous Email	Various emails between stakeholder and CGG arranging a meeting between WAFIC, CGG and CF05.	No objections or claims.	N/A	Various emails between stakeholder and CGG arranging a meeting.
WAFIC	7/9/21 11:30AM	Meeting with WAFIC and CF05				Please see meeting summary and merit assessment listed in consultation summary for stakeholder CF05.			
WAFIC	13/09/21 9:53AM and 2:50PM	Meeting minutes and supplementary documents	Email	No response received.					
WAFIC	14/10/21 11:58AM	Additional response from meeting on 7/9/21	Email	No response received.					
WESTERN WILD FISHERIES HOLDINGS PTY LTD	29/05/21 9:00AM	Invitation to Consultation E002	Post	No response received.					
World Wildlife Fund for Nature (WWF)	28/05/21 6:02PM	Invitation to Consultation E001	Email	No response received.					
WWF	5/07/21 3:46PM	Follow up on Invitation to Consultation E003	Email	No response received.					

Appendix D: Underwater Sound Modelling

3D Oil Sauropod 3-D Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

Submitted to:

Jared Davidson
Environmental Resources Management

Authors:

Jorge Quijano
Craig McPherson

11 June 2020

P001483-002
Document 01781
Version 1.1

JASCO Applied Sciences (Australia) Pty Ltd.
Unit 1, 14 Hook Street
Capalaba, Queensland, 4157
Tel: +61 7 3823 2620
www.jasco.com

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.

Suggested citation:

Quijano, J.E. and C.R. McPherson. 2020. *3D Oil Sauropod 3-D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures*. Document 01781, Version 1.1. Technical report by JASCO Applied Sciences for Environmental Resources Management.

Contents

Figures

Tables

Executive Summary

JASCO Applied Sciences performed a numerical estimation study of underwater sound levels associated with the planned 3D Oil Sauropod 3-D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on key regional receptors including fish, cetaceans, turtles, benthic invertebrates, and plankton. Modelling considered a 3090 in^3 seismic source in a flip-flap-flop configuration, towed at a 6 m depth behind a single vessel.

A specialised airgun array source model was used to predict the acoustic signature of the seismic source, and complementary underwater acoustic propagation models were used in conjunction with the modelled array signature to estimate sound levels over a large area around the source. Single-impulse sound fields were predicted at defined locations within the Acquisition Area, and accumulated sound exposure fields were predicted for one representative scenario for likely survey operations over 24 hours.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. Particle motion metrics were predicted at four modelled sites. 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.

Cetacean injury and behaviour

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 6.47 and 8.36 km (Site 2 and Site 1, water depths of 125 66 m respectively).
- 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. The table below summarises the maximum distances for PTS, along with the relevant metric.
- The 24-h SEL is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours considering that an animal is consistently exposed to such noise levels at a fixed position. The corresponding 24-h SEL radii for low-frequency cetaceans were larger than those for peak pressure criteria, but they represent an unlikely worst-case scenario. More realistically, marine mammals (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius for 24-h SEL criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with injury (either PTS or TTS) if it remained in that location for 24 hours.

Table 1. Summary of maximum cetacean PTS onset distances for 24-h SEL modelled scenarios.

Relevant hearing group	Metric associated with longest distance to PTS onset	R_{max} (km)
Low-frequency cetaceans	SEL_{24h}†	0.63
Mid-frequency cetaceans	PK	<0.02
High-frequency cetaceans	PK	0.23

† The model does not account for shutdowns.

Turtles

- The PK turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance greater than 20 m from the centre of the array. Because the array is not a point source (approximately 14 × 8 m), the actual ranges from the edge of the airgun array is small.

- The distances to where the NMFS criterion (NSF 2011) for behavioural effects in turtles of turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) (Moein et al. 1995, McCauley et al. 2000a, McCauley et al. 2000b) could be exceeded are summarised in Table 2.

Table 2. Distances to turtle behavioural response criteria.

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Min	Max
175†	1.00	1.20
166‡	3.28	5.10

† Threshold for turtle behavioural response to impulsive noise (Moein et al. 1995, 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 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 the 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	Injury criteria	Water column		Seafloor	
		Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.06	PK	0.08
	TTS	SEL_{24h}	2.81	SEL_{24h}	2.79
Fish: Swim bladder not involved in hearing Swim bladder involved in hearing	Injury	PK	0.13	PK	0.19
	TTS	SEL_{24h}	2.81	SEL_{24h}	2.79
Fish eggs, and larvae	Injury	PK	0.13	PK	0.19

Crustaceans and Bivalves, Sponges and Coral, and Plankton

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; it was reached at ranges between 468 and 709 m depending on the modelled site.
- Bivalves: the distance where a particle acceleration of 37.57 ms^{-2} at the seafloor could occur was determined for comparing to results presented in Day et al. (2016a). The maximum horizontal distance to this particle acceleration level was 9.1 m.
- Sponges and coral: The PK sound level at the seafloor directly underneath the seismic source was estimated at all modelling sites considered for seafloor fish receptors and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); it was found that the level was not reached at any of the four considered sites.
- Plankton: The distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at two modelling sites through full-waveform modelling using FWRAM; the results ranged from 5.32 km to 7.93 km.

1. Introduction

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned 3D Oil Sauropod 3-D Marine Seismic Survey (MSS) in permit WA-527-P to assist in understanding the potential acoustic impact on key regional receptors including fish, cetaceans, benthic invertebrates, plankton, and turtles. Modelling considered a 3090 in^3 seismic source in a flip-flap-flop configuration, towed at a 6 m depth behind a single vessel.

JASCO's specialised Airgun Array Source Model (AASM) was used to predict the acoustic signature of the array. AASM accounts for individual airgun volumes and array geometry. 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 defined locations within the Acquisition Area, and accumulated sound exposure fields were predicted for one representative scenario for likely survey operations over 24 h. A conservative sound speed profile that would be most supportive of sound propagation conditions for the period of the survey was defined and applied at each of the modelling locations.

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. Particle motion metrics were predicted at the modelled locations along the broadside directions associated with the highest levels.

2. Modelling Scenarios

Four standalone single impulse sites and one likely scenario for survey operations over 24 hours to assess accumulated SEL were defined. The locations of all modelling sites are provided in Table 4, with all sites and the acquisition lines shown in Figure 1 along with the survey boundaries. The modelling assumed that the survey vessel sailed along the survey lines at ~4.4 knots, with an impulse interval of 12.5 m. The considered survey acquisition lines took ~10.18 h (each) to traverse with ~5.2 h of turn time required between the lines, accounted for 13280 impulses. During line turns the seismic source was not in operation.

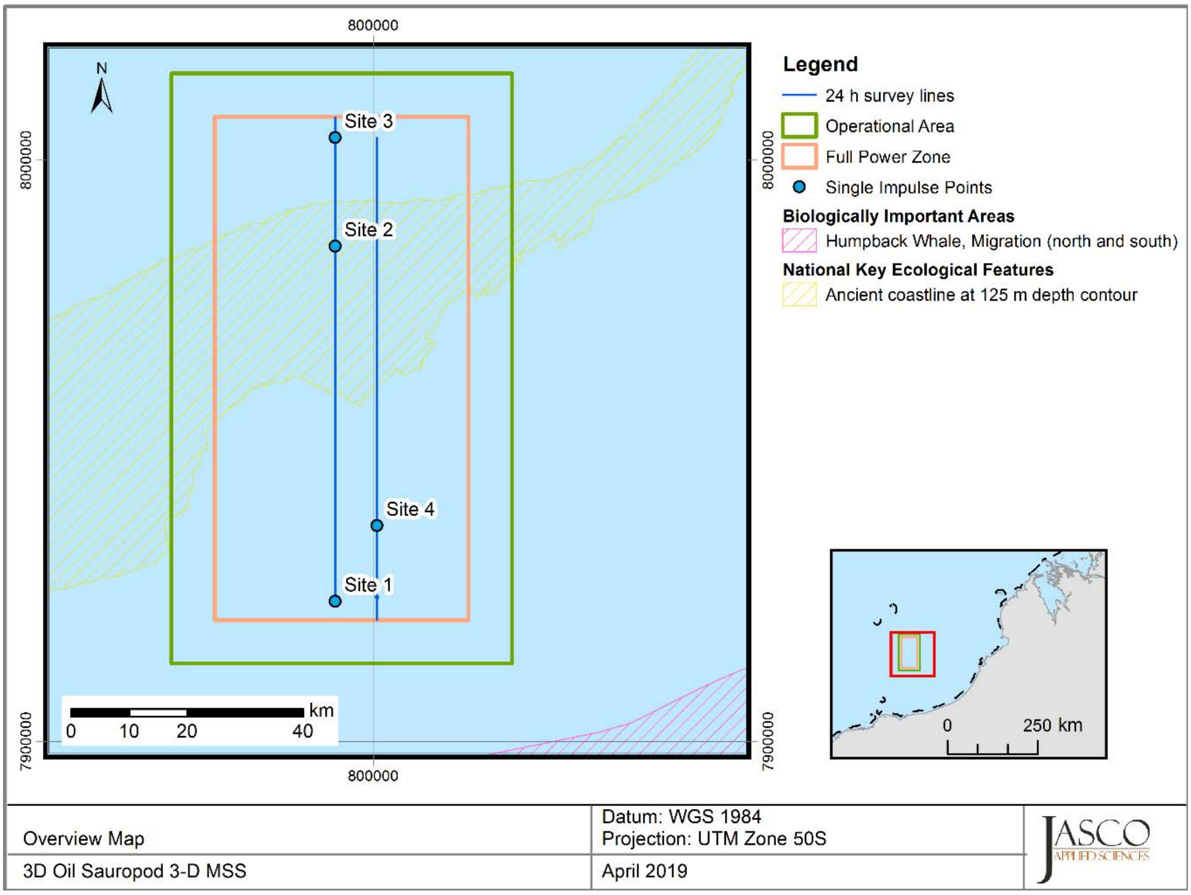


Figure 1. Overview of the modelling sites, acquisition lines, and features for the 3-DSauropod 3-D MSS modelling.

Table 4. Location details for the modelling sites.

Site	Latitude (S)	Longitude (E)	UTM (WGS1984) Zone 50S		Water depth (m)	Representative tow direction (°)
			X (m)	*Y* (m)		
1	18° 45' 14.3694"	119° 46' 58.6168"	793425	7924100	66	0 & 180
2	18° 12' 08.6755"	119° 46' 26.6060"	793425	7985200	125	
3	18° 02' 00.9264"	119° 46' 17.0335"	793425	8003900	161	
4	18° 38' 07.1558"	119° 50' 57.1375"	800625	7937133	107	

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 18405.2:2017 (2017b).

Whether acoustic exposure levels might injure or disturb marine mammals is an active research topic. Since 2007, several expert groups have investigated an SEL-based assessment approach for injury, with a handful of key papers published on the topic. The number of studies that investigated the level of disturbance to marine animals by underwater noise 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 3.1–3.2 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 interim U.S. National Marine Fisheries Service (NMFS) (2014) of 160 dB re 1 µPa SPL (L_p) for impulsive sound sources.
3. Sound exposure guidelines for fish, fish eggs and larvae, and turtles (Popper et al. 2014).
4. A threshold for turtle PTS of 232 dB re 1 µPa (PK) (Finneran et al. 2017), and a behavioural response of 166 dB re 1 µPa SPL (L_p) (NSF 2011), as applied by the U. S. NMFS, along with a sound level associated with an increased level of response 175 dB re 1 µPa (SPL) (Moein et al. 1995, McCauley et al. 2000a, McCauley et al. 2000b, NSF 2011).
5. 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.
6. Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and particle acceleration at the seafloor to help assess effects of noise on crustaceans and bivalves, through comparing to results in Day et al. (2016a) and Payne et al. (2008).
7. 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 cetaceans, fish, turtles, fish eggs, and fish larvae and benthic invertebrates.

3.1. Cetaceans

The criteria applied in this study to assess possible effects of airgun noise on cetaceans are summarised in Table 5 and detailed in Sections 3.1.1 and 3.1.2, with frequency weighting explained in Appendix A.3.

Table 5. Unweighted SPL, SEL_{24h}, and PK thresholds for acoustic effects on cetaceans.

Hearing group	NMFS (2014)	NMFS (2018)			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
Mid-frequency cetaceans		185	230	170	224
High-frequency cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p–denotes sound pressure level period and has a reference value of 1 µPa.
L_{pk}, flat–peak 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 µPa²s.
Subscripts indicate the designated marine mammal auditory weighting.

3.1.1. Behavioural response

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds. Their review found that most marine mammals exhibited varying responses between 140 and 180 dB re 1 µPa SPL, but inconsistent results between studies makes choosing a single behavioural threshold difficult. Studies varied in their lack of control groups, imprecise measurements, inconsistent metrics, and that animal responses depended on study context, which included the animal's activity state. To create meaningful quantitative data from the collected information, Southall et al. (2007) proposed a severity scale that increased with increasing sound levels.

NMFS has historically used a relatively simple sound level criterion for potentially disturbing a marine mammal. For impulsive sounds, this threshold is 160 dB re 1 µPa SPL for cetaceans (NMFS 2014) which has been applied for this report.

3.1.2. Injury and hearing sensitivity changes

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To assist in assessing the potential for impairment in cetaceans, this report applies the criteria recommended by NMFS (2018), considering both PTS and TTS. Appendix A.2 provides more information about the NMFS (2018) criteria.

3.2. Fish, Turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and turtles, work begun by a panel convened by NOAA two years earlier. The resulting guidelines included specific thresholds for different levels of effects and for different groups of species (Popper et al. 2014). These guidelines defined quantitative thresholds for three types of immediate effects:

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

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. These effects are not assessed in this report. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure varies depending on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Turtles, fish eggs, and fish larvae are considered separately.

Table 6 lists relevant effects thresholds from Popper et al. (2014). In general, any adverse effects of seismic sound on fish behaviour depends on the species, the state of the individuals exposed, and other factors. We note that, despite mortality being a possibility for fish exposed to airgun sounds, Popper et al. (2014) do not reference an actual occurrence of this effect. Since the publication of that work, newer studies have further examined the question of possible mortality. Popper et al. (2016) adds further information to the possible levels of impulsive seismic airgun sound to which adult fish can be exposed without immediate mortality. They found that the two fish species in their study, with body masses in the range 200–400 g, exposed to a single-impulse of a maximum received level of either 231 dB re 1 µPa (PK) or 205 dB re 1 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 a standard period should be applied, where this is either defined as a justified fixed period or the duration of the activity, however also include 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 due to the mobile source, 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 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 source (i.e., speed, duty cycle; NMFS 2016, 2018).

Table 6. Criteria for seismic noise exposure for fish and turtles, 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. For turtle injury, a PTS of 232 dB re 1 µPa (PK), and TTS of 226 dB re 1 µPa (PK) from Finneran et al. (2017) has been applied as it represents updated information compared to the information in Popper et al. (2014).

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). 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 (Moein et al. 1995), 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}) (Table 6). 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. The NMFS criterion for behavioural disturbance (SPL of 166 dB re 1 µPa), and a criterion for behavioural disturbance (SPL of 175 dB re 1 µPa) (Moein et al. 1995, McCauley et al. 2000a, McCauley et al. 2000b)_ENREF_62 criterion for behavioural disturbance (SPL of 175 dB re 1 µPa) have been included in this analysis.

3.3. Benthic Invertebrates (Crustaceans and Bivalves)

Research is ongoing into the relationship between sound and its effects on crustaceans, including the relevant metrics for both effect and impact. Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing. Water depth, seabed material and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves.

At the seafloor interface, crustaceans and bivalves are subject to particle motion stimuli from several acoustic or acoustically induced waves. These include the particle motion associated with an impinging sound pressure wave in the water column (the incident, reflected, and transmitted portions), substrate acoustic waves, and interface waves of the Scholte type. However, it is unclear which aspect(s) of these waves is/are most relevant to the animals, either when they normally sense the environment or their physiological responses to loud sounds so there is not enough information to establish similar criteria and thresholds as done for marine mammals and fish. Including recent research, such as Day et al. (2016a), current literature does not clearly define an appropriate metric or identify relevant levels (pressure or particle motion) for an assessment. This includes the consideration of what particle motion levels lead to a behavioural response, or mortality. Therefore, at this stage, we cannot propose authoritative thresholds to inform the impact assessment. However, levels can be determined for pressure metrics presented in literature to assist the assessment.

For crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is considered to be associated with no impact, and therefore applied in the assessment. Additionally for context, the PK-PK sound levels determined for crustaceans in Day et al. (2016a), 209–212 dB re 1 µPa, are also included.

For bivalves, literature does not present a sound level associated with no impact, and as particle motion is the more relevant metric, particle acceleration from the seismic source has been presented for comparing the results in Table 7 and Day et al. (2016a). The maximum particle acceleration assessed for scallops was 37.57 ms^{-2}.

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 3090 in^3 seismic source 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.

The array was modelled over AASM's full frequency range, up to 25 kHz. Appendix B details this model.

4.2. Sound Propagation Models

Three sound propagation models were used to predict the acoustic field around the seismic source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 10 Hz to 25 kHz).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 0.5 Hz to 1024 Hz).
- Wavenumber integration model (VSTACK, 10 Hz to 2048 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 was used to calculate SEL of a 360° area around each source location. VSTACK was used to calculate close range PK, PK-PK, and SEL along transects at the seafloor from the broadside direction of the seismic source. VSTACK was also used to compute estimates of particle acceleration and velocity at all modelling sites.

4.3. Parameter Overview

The specifications of the seismic source and the environmental parameters used in the propagation models are described in detail in Appendix D. Three 3090 in^3 seismic source arrays consisting of two strings each were modelled in a flip-flop-flap configuration. The three arrays considered were towed at a depth of 6 m, and the lateral distance between the arrays was 25 m. A single sound speed profile for May was considered in the modelling; this was identified as the seasonal period that would provide the greatest propagation (Appendix D.3.2). Sediment in the area was modelled as a succession from soft to hard sediments (silty carbonate sand to calcarenites) (Table D-1).

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 cetacean and fish SEL criteria used in this report (Sections 3.1 and 3.2) 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 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.

4.5. Geometry and Modelled Regions

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances at least 100 km from the source, 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 3000 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, from 5 to 1024 Hz in 0.5 Hz steps. 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 1500 m and a variable receiver range increment that increased away from the source was used. The increment increased from 5 to 50 m. Received levels were computed for receivers at 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.

Table 7 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 array. 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 600 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the array and correspond with the volumes and relative locations of the airguns to each other.

Table 7. Far-field source level specifications for the 3090 in^3 array, 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** μPa^{2}m^{2}s)	
		10–2000 Hz	2000–25000 Hz
Broadside	249.4	225.1	184.5
Endfire	245.7	223.2	187.8
Vertical	255.0	228.2	195.0
Vertical (surface affected source level)	255.0	230.6	198.0

5.2. Per-pulse Sound Fields

5.2.1. Tabulated results

Per-pulse results for the 3090 in³ seismic source towed at 6 m are presented for SPL, SEL, PK, and PK-PK, including seafloor PK and PK-PK. Tables 8–11 list the estimated ranges for the various applicable maximum-over-depth per-pulse effects criteria and isopleths of interest. Tables 12 and 13 list the estimated ranges for seafloor per-pulse effects criteria and isopleths of interest.

5.2.1.1. Entire water column

Table 8. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 3090 in^3 array to modelled maximum-over-depth unweighted per-pulse SEL isopleths from the four modelled single impulse sites.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 1 (66 m)		Site 2 (125 m)		Site 3 (161 m)		Site 4 (107 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
180	0.16	0.14	0.16	0.14	0.16	0.13	0.16	0.14
170	0.72	0.59	0.74	0.67	0.78	0.69	0.70	0.63
160†	3.10	2.35	2.44	1.99	2.24	1.76	2.42	2.00
150	9.27	7.82	7.90	6.43	7.95	6.42	7.45	6.26
140	25.2	19.2	18.2	14.9	19.1	16.0	17.1	14.0
130	50.5	40.7	36.1	30.9	37.8	32.1	33.7	27.8
120	86.3	71.2	73.4	60.0	67.2	59.1	61.1	51.3

† Low power zone assessment criteria DEWHA (2008).

Table 9. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 3090 in^3 array to modelled maximum-over-depth SPL isopleths from the four modelled single impulse sites.

SPL (L_p; dB re 1 **µPa**)	Site 1 (66 m)		Site 2 (125 m)		Site 3 (161 m)		Site 4 (107 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
190	0.14	0.12	0.13	0.12	0.12	0.12	0.13	0.12
180	0.58	0.50	0.70	0.62	0.54	0.48	0.66	0.60
175#	1.20	0.99	1.01	0.85	1.00	0.84	1.14	0.85
170	2.48	2.09	2.04	1.66	1.80	1.49	2.02	1.72
166†	5.10	3.60	3.32	2.85	3.28	2.68	3.64	2.87
160‡	8.36	6.76	6.47	5.58	6.58	5.65	7.18	5.50
150	20.5	16.3	15.7	13.1	16.5	13.8	14.7	12.2
140	43.6	34.9	30.9	26.2	32.9	27.7	28.5	23.9
130	78.5	64.6	64.5	52.0	60.8	51.0	53.5	44.9

Threshold for turtle behavioural response to impulsive noise (Moein et al. 1995).
† Threshold for turtle behavioural response to impulsive noise (NSF 2011).
‡ Marine mammal behavioural threshold for impulsive sound sources (NMFS 2014).

Table 10. Maximum (R_{max}) horizontal distances (km) from the 3090 in3 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 the modelling sites (Table 4).

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (km)			
		Site 1 (66 m)	Site 2 (125 m)	Site 3 (161 m)	Site 4 (107 m)
Low-frequency cetaceans (PTS)	219	0.03	0.03	0.03	0.03
Low-frequency cetaceans (TTS)	213	0.06	0.06	0.06	0.06
Mid-frequency cetaceans (PTS)	230	<0.02	<0.02	<0.02	<0.02
Mid-frequency cetaceans (TTS)	224	<0.02	<0.02	<0.02	<0.02
High-frequency cetaceans (PTS)	202	0.21	0.21	0.22	0.23
High-frequency cetaceans (TTS)	196	0.68	0.41	0.6	0.7
Fish: No swim bladder (also applied to sharks)	213	0.06	0.06	0.06	0.06
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.11	0.12	0.13	0.12
Turtles (PTS)	232	<0.02	<0.02	<0.02	<0.02
Turtles (TTS)	226	<0.02	<0.02	<0.02	<0.02

Table 11. Maximum (R_{max}) horizontal distances (in km) from the 3090 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 two of the modelling sites (Table 4).

PK-PK (L_{pk-pk}; dB re 1 µPa)	Distance R_{max} (km)			
	Site 1 (66 m)	Site 2 (125 m)	Site 3 (161 m)	Site 4 (107 m)
178	7.93	5.76	6.38	5.32

5.2.1.2. Seafloor

Table 12. Maximum (R_{max}) horizontal distances (in m) from the 3090 in^3 array to modelled seafloor peak pressure level thresholds (PK) from four single-impulse modelling sites (Table 4).

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)			
		Site 1 (66 m)	Site 2 (125 m)	Site 3 (161 m)	Site 4 (107 m)
Sound levels for sponges and corals†	226	—	—	—	—
Fish: No swim bladder (also applied to sharks)	213	80	52	32	60
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	187	158	145	150

† Heyward et al. (2018)
A dash indicates the level was not reached.

Table 13. Maximum (R_{max}) horizontal distances (in m) from the 3090 in^3 array to modelled seafloor peak-peak pressure level thresholds (PK-PK) from four modelling sites (Table 4). Results included in relation to benthic invertebrates (Section 3.3).

PK-PK (L_{pk-pk}; dB re 1 µPa)	Distance R_{max} (m)			
	Site 1 (66 m)	Site 2 (125 m)	Site 3 (161 m)	Site 4 (107 m)
213	156	150	130	146
212	179	165	156	164
211	204	182	186	188
210	234	209	210	215
209	260	240	229	247
202	468	635	709	591

5.2.2. Sound field maps and graphs

5.2.2.1. Sound level contour maps

Maps of the estimated sound fields, threshold contours, and isopleths of interest for the per-pulse SEL and SPL sound fields have been presented at all modelling sites (Table 4), shown in Figures 2–09.

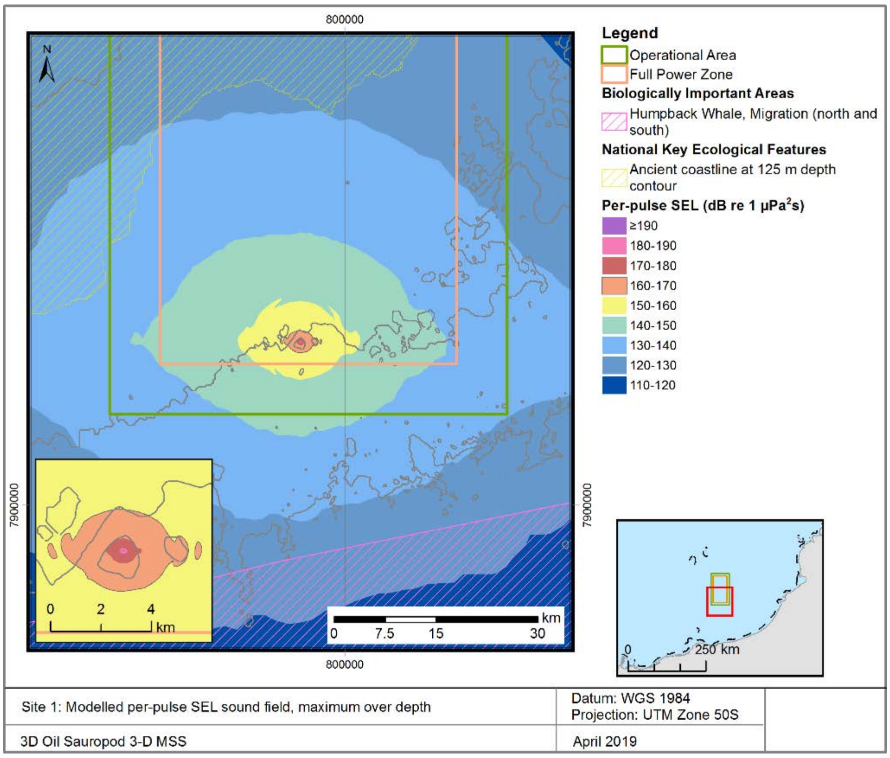


Figure 2. *Site 1, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

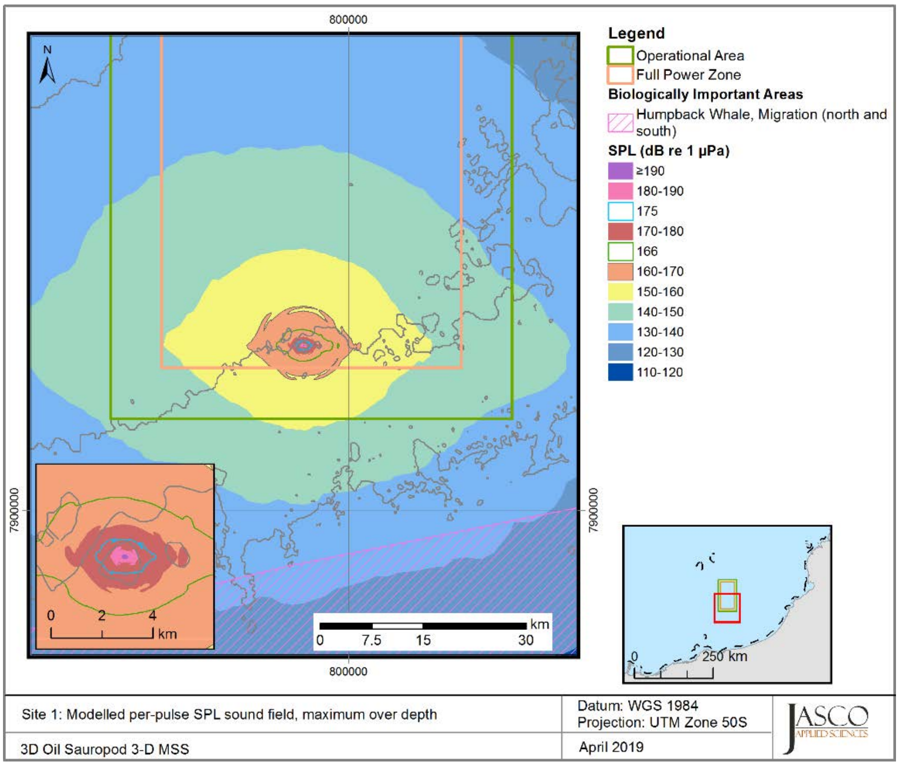


Figure 3. *Site 1, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

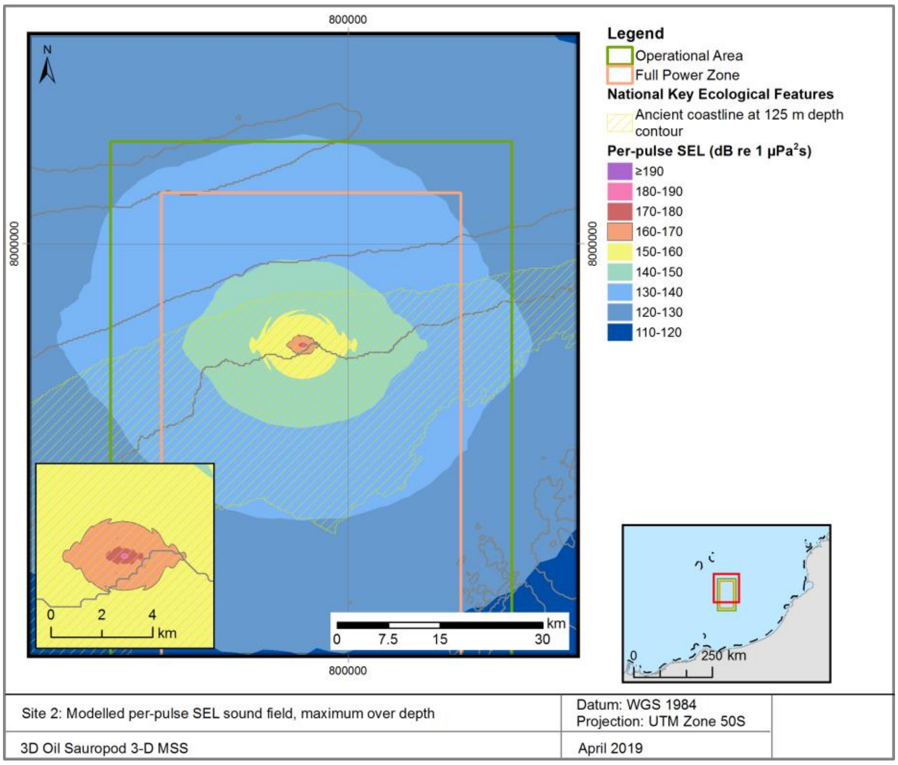


Figure 4. *Site 2, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

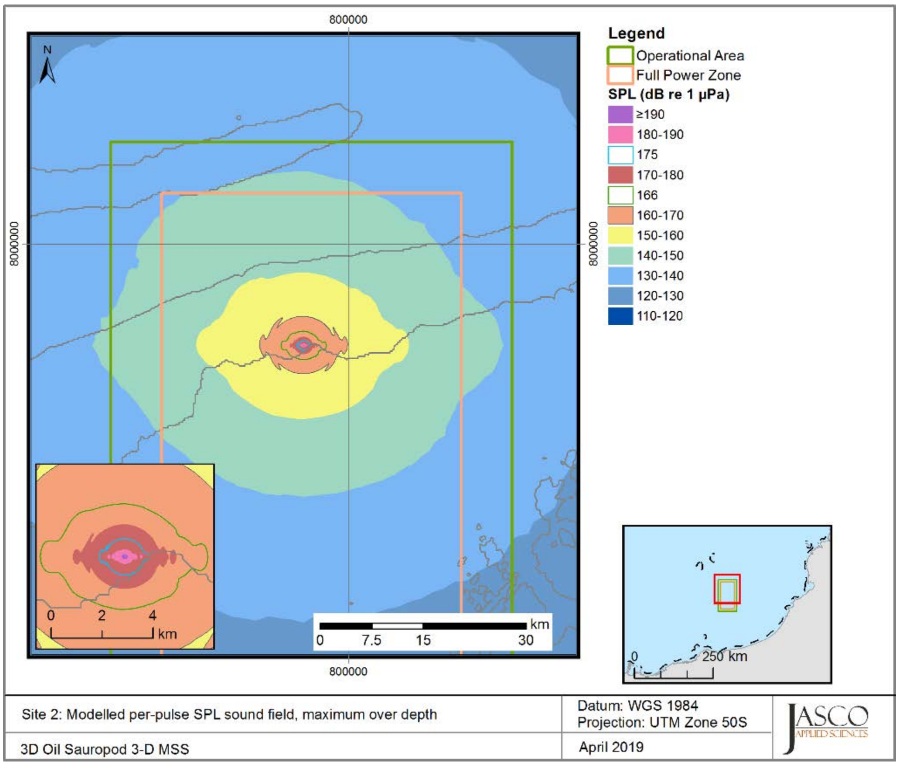


Figure 5. *Site 2, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

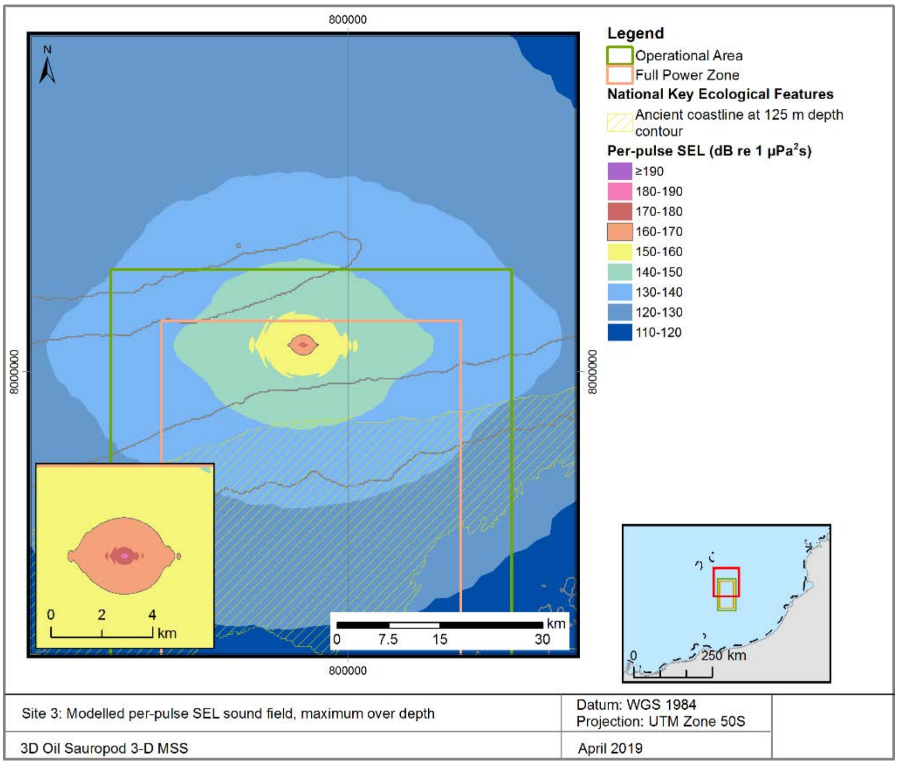


Figure 6. *Site 3, per-pulse SEL*: Sound level contour map showing unweighted maximum-over-depth results.

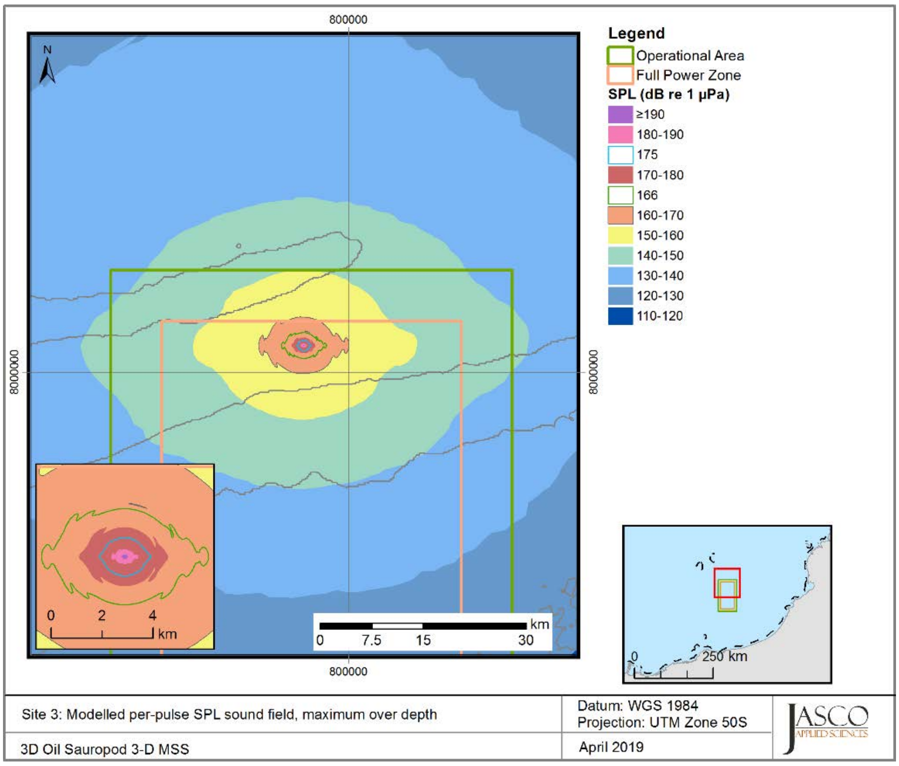


Figure 7. *Site 3, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

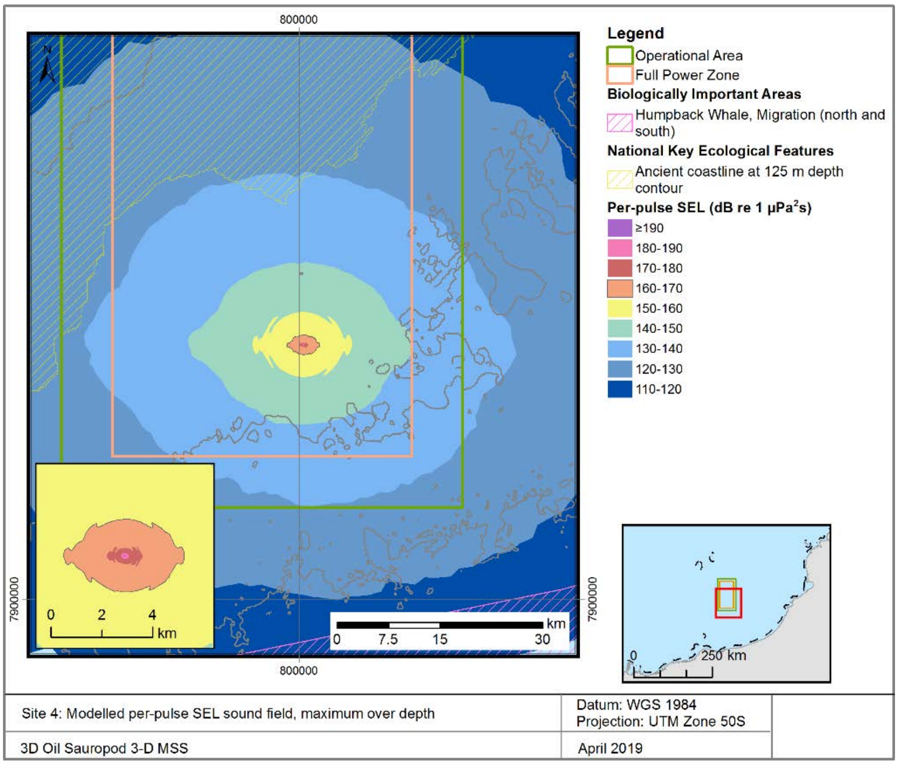


Figure 8. *Site 4, per-pulse SEL*: Sound level contour map showing unweighted maximum-over-depth results.

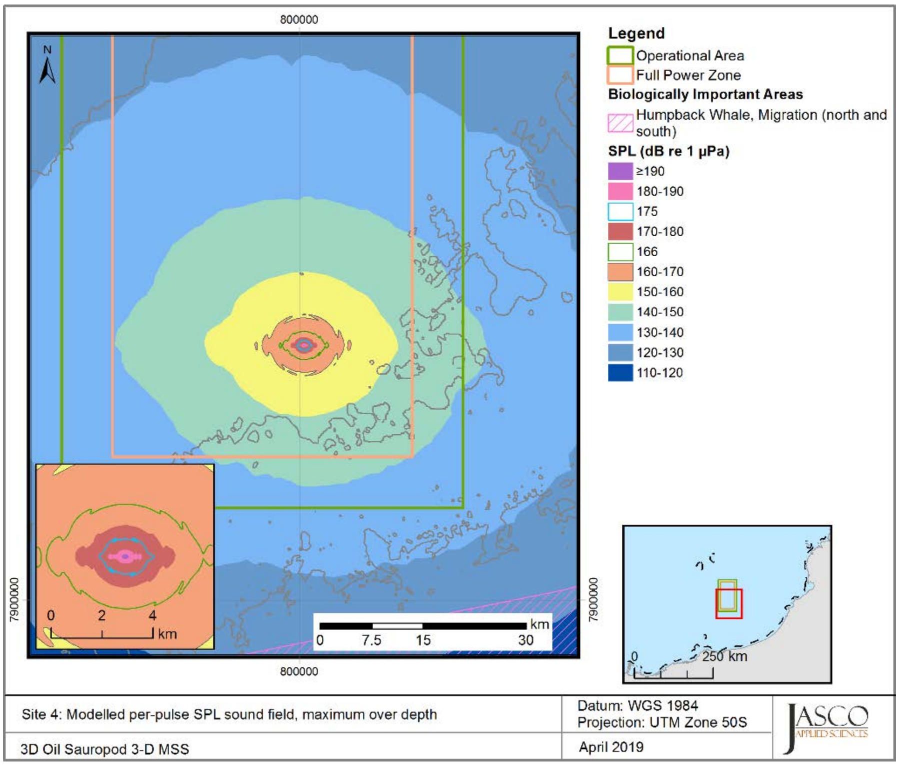


Figure 9. *Site 4, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

5.2.2.2. Vertical slices of modelled sound fields

Vertical slices of the SPL sound fields for the 3090 in^3 airgun array are shown in Figures 10–13.

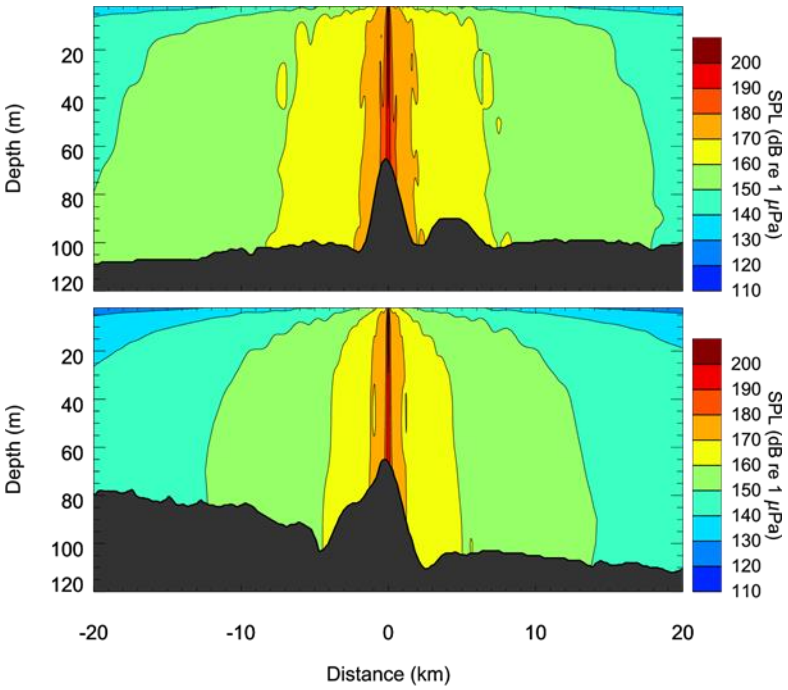


Figure 10. *Site 1, SPL*: Vertical slice of the predicted SPL for the 3090 in^3 array. Levels are shown along the broadside (top) and endfire (bottom) directions.

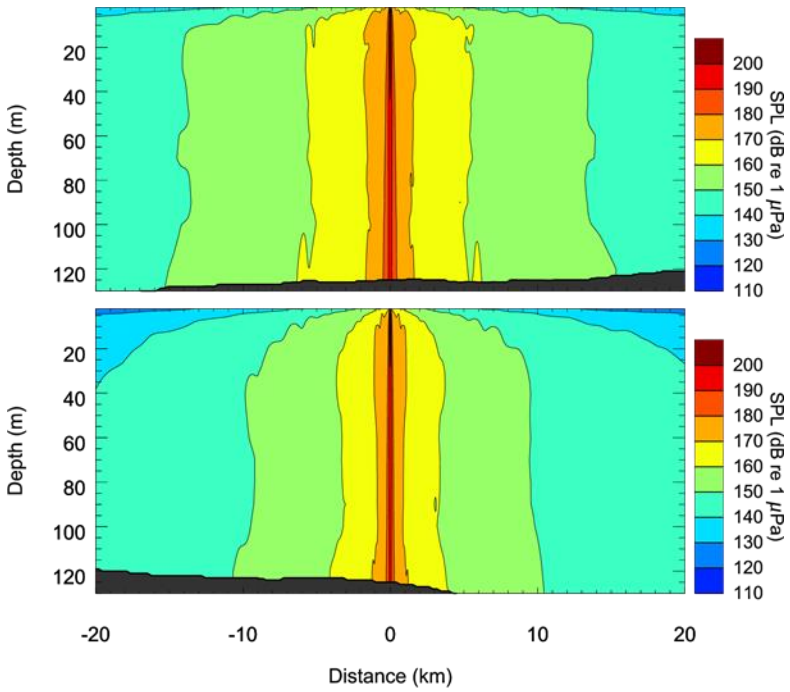


Figure 11. *Site 2, SPL*: Vertical slice of the predicted SPL for the 3090 in^3 array. Levels are shown along the broadside (top) and endfire (bottom) directions.

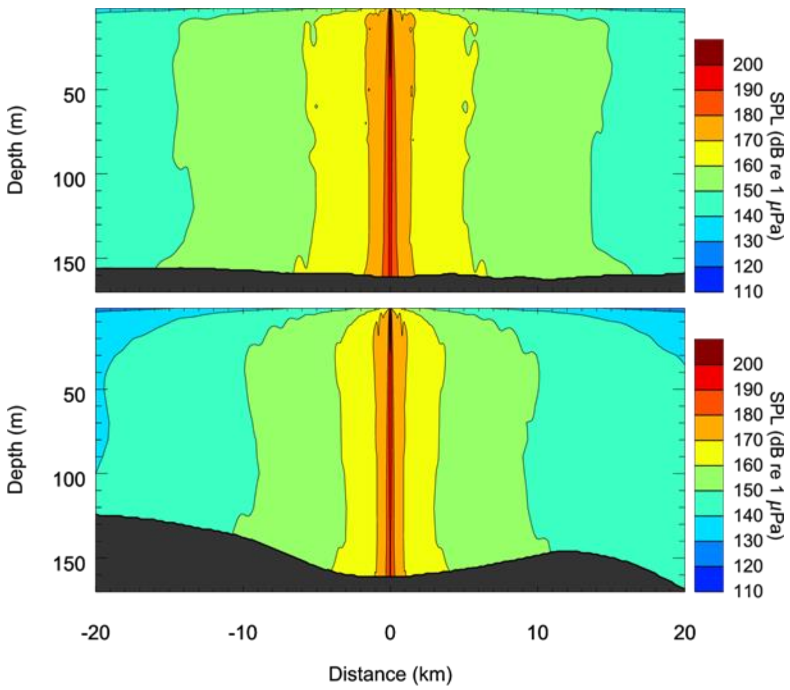


Figure 12. *Site 3, SPL*: Vertical slice of the predicted SPL for the 3090 in^3 array. Levels are shown along the broadside (top) and endfire (bottom) directions.

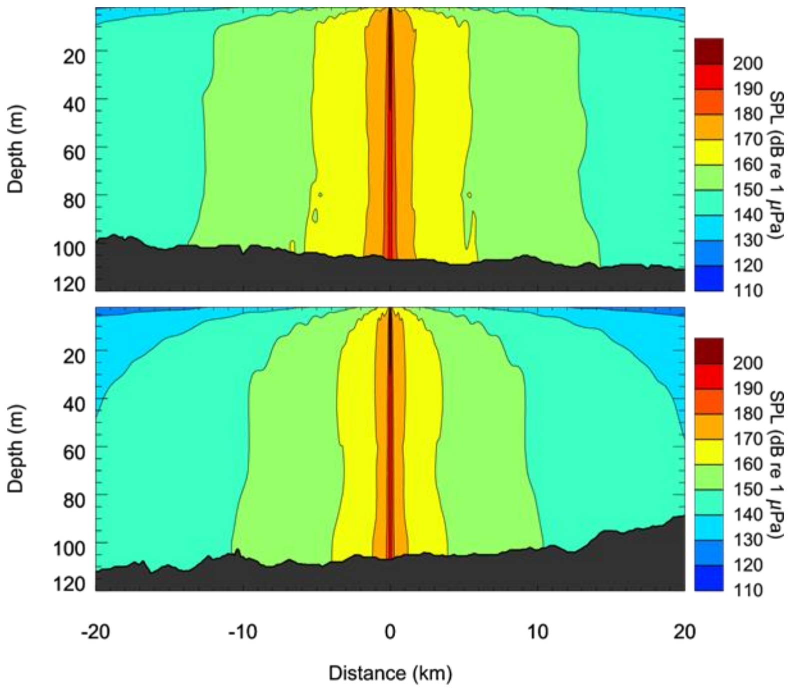


Figure 13. *Site 4, SPL*: Vertical slice of the predicted SPL for the 3090 in^3 array. Levels are shown along the broadside (top) and endfire (bottom) directions.

5.2.3. Particle motion

Particle acceleration and velocity was modelled for seafloor receivers at each site. Modelling was performed in the broadside directions because particle motion was highest along those azimuths. From the modelled 3-D particle motion traces, the peak acceleration and velocity were computed as a function of horizontal range from the centre of the array. The maximum horizontal distance to a peak particle acceleration of 37.57 ms^{-2} (Section 3.3; Day et al. (2016b) is3.3; (Day et al. 2016a)) was 9.1 m, which occurred at the shallowest site, Site 1, Figure 14. The results for Sites 2–4 are shown in Appendix E.1, Figures E-1 to E-3.

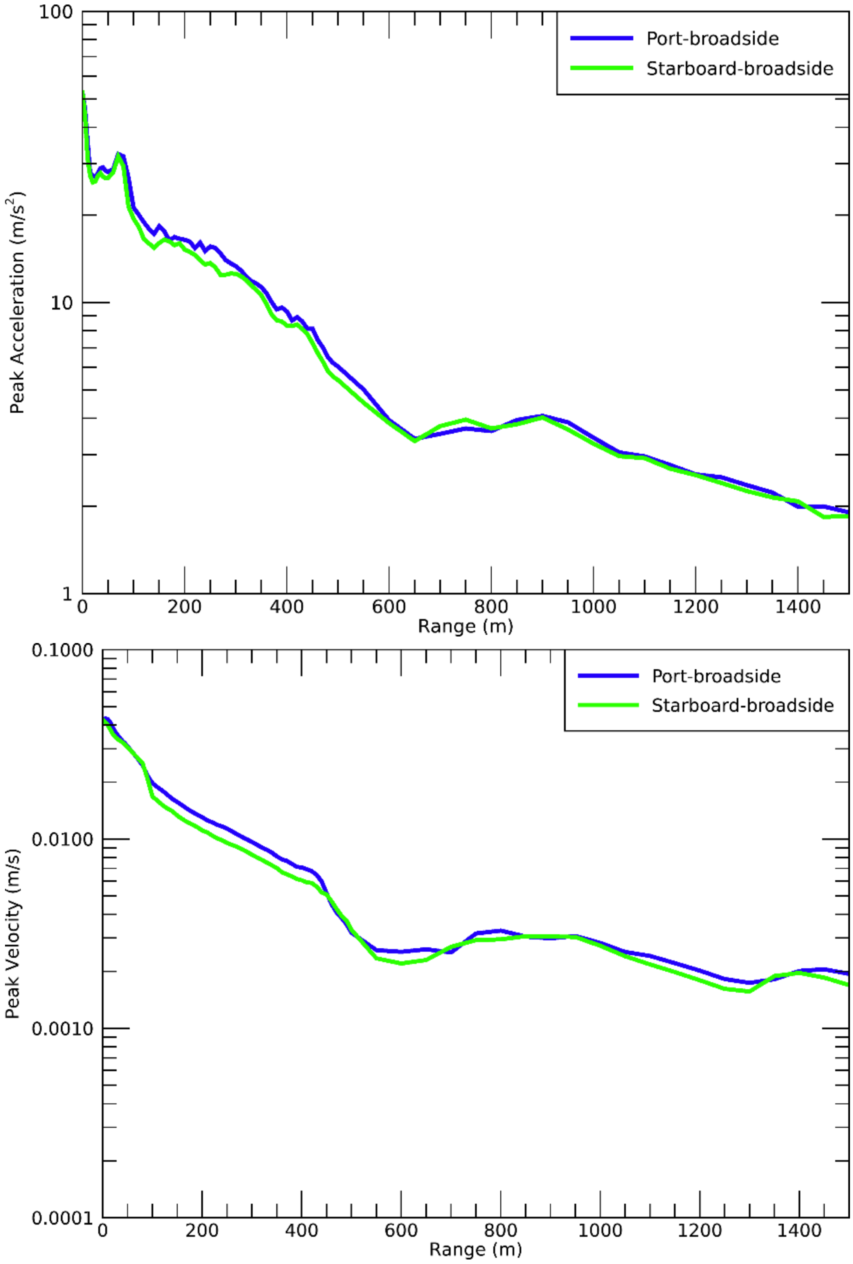


Figure 14. Site 1: Maximum particle acceleration (top) and velocity (bottom) at the seafloor as a function of horizontal range from the centre of a single 3090 in^3 seismic source along the broadband directions.

5.3. Multiple Pulse Sound Fields

The SEL_{24h} results for the proposed survey are presented for one possible operational scenario within the Acquisition Area (Section 2). Tables 14 and 15 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 cetaceans and fish, are presented in Figure 15, while estimates of the sound field at the seafloor and threshold contours relevant to fish are presented in Figure 16.

Table 14. Maximum-over-depth distances to SEL_{24h} based marine mammal PTS and TTS thresholds (NMFS 2018).

Hearing group	PTS		
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (km)	Area (km²)
Low-frequency cetaceans	183	0.63	147.93
Mid-frequency cetaceans	185	—	—
High-frequency cetaceans	155	0.03	8.99
Hearing group	TTS		
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	R_{max} (km)	Area (km²)
Low-frequency cetaceans	168	15.4	2974.8
Mid-frequency cetaceans	170	—	—
High-frequency cetaceans	140	0.23	78.2

A dash indicates the threshold is not reached.

Table 15. Distances to SEL_{24h} based fish criteria.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth		Seafloor	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	<0.03	9.75	—	—
II, Fish eggs and fish larvae	210	<0.03	12.44	—	—
III	207	0.04	13.28	—	—
Fish recoverable injury					
I	216	<0.03	12.00	—	—
II, III	203	0.04	13.28	—	—
Fish TTS					
I, II, III	186	2.81	720.12	2.79	715.75

A dash denotes a value below the minimum resolution of the modelling.
Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

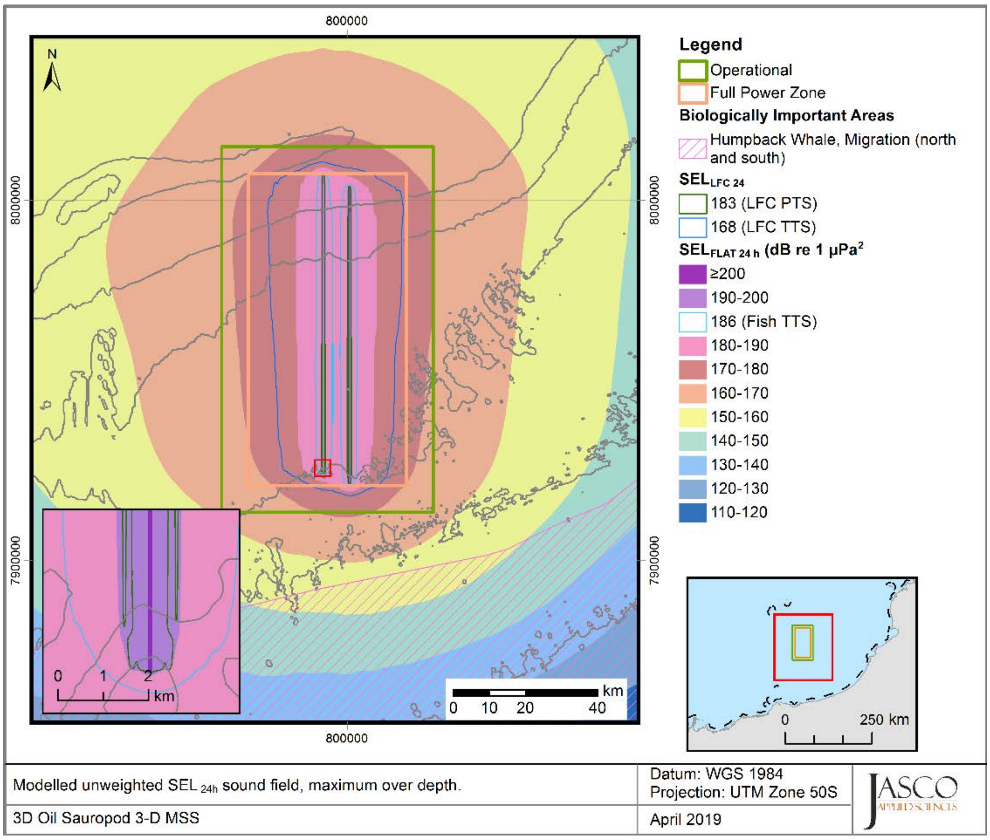


Figure 15. Sound level contour map showing maximum-over-depth SEL_{24h} results.

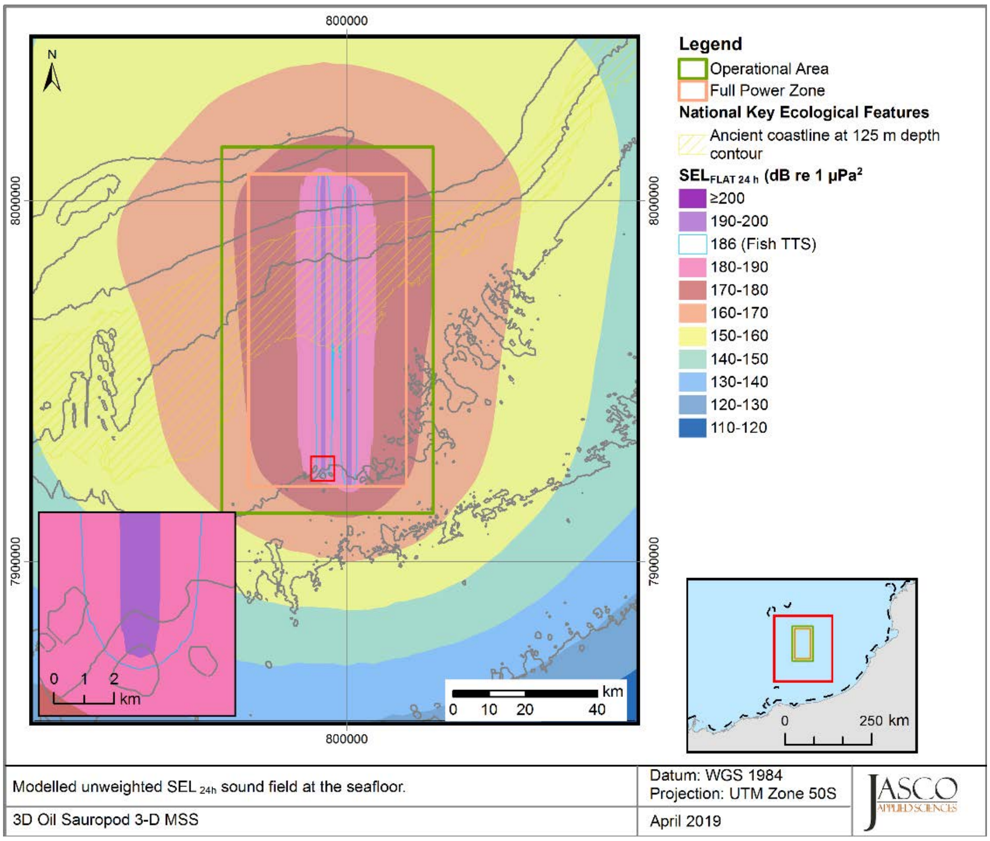


Figure 16. Sound level contour map showing seafloor SEL_{24h} results.

6. Discussion

6.1. Overview and Source Levels

This modelling study predicted underwater sound levels associated with the planned Sauropod 3-D MSS. The underwater sound field was modelled for a 3090 in^3 seismic source (Appendix B) with a water column sound speed profile for May. An analysis of seasonal sound speed profiles (Appendix D.3.2) indicated that this month was the most conducive to sound propagation, and as such it was selected to ensure a conservative estimation of distances to received sound level thresholds over the entire survey period. The 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 158 to about 316 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 3090 in^3 array operating at 6 m depth was 225.1 dB 1 $\mu Pa^2 m^2 s$ in the broadside direction and 223.3 dB 1 $\mu Pa^2 m^2 s$ in the endfire direction. The peak pressure level in the same directions was 249.4 and 245.7 dB re 1 µPa m, respectively, these results are presented in Table 7.

6.2. Per-Pulse Sound Fields

At all sites, the distances to identified isopleths were greater in the broadside direction than in the endfire direction, which is apparent in all footprint maps in Section 5.2.2; this is due to the directionality of the array. The acoustic footprints were not substantially influenced by changes in water depth because changes in bathymetry within the modelling area was marginal and gradual (Figure D-3). The shallowest site, Site 1 (66 m) had the farthest distance to almost all isopleths, with the distances at the other three modelling sites being more similar. The combination of the geology, water depth, local and bathymetry support longer range propagation at this site when compared to the three other sites in deeper water. This difference is noticeable in both the close range seafloor modelling results (Table 12) and the maximum-over-depth results at greater distances (Table 8). The vertical slice plot for Site 1 (Figure 10) shows that this site is located on a localised shallow point surrounded by deeper water, which contributes to the way the sound is reflected both from and within the seafloor at this site. The other vertical slice plots (Section 5.2.2.2) demonstrate the difference between the broadside and endfire directions within the water column but also the similarity of the footprints for each respective direction at Sites 2–4.

The distances to PK based potential injury criteria (Section 3.2 and 3.3) for fish and benthic crustaceans at the seafloor decreased with increasing depth, apart from the distance to the 202 dB re 1 µPa (PK-PK) relevant to crustaceans, which increased with increasing depth. The distances to these criteria did not always consistently change with increasing depth, phenomena related to complex patterns of surface and bottom reflections that affect sound propagation in shallow water; the distances could be greater for depths even slightly shallower or deeper. However, the number of modelling sites considered within the Acquisition Area, representing the variations in bathymetry, provides a good representation of potential variability.

6.3. Particle Motion

Section 3.3 discuss the relevance of particle motion (acceleration and velocity) to benthic invertebrates. Peak particle acceleration and velocity decayed rapidly with horizontal distance from the centre of the array (Figure 14). There was little difference in particle motion between the two modelled broadside directions.

Particle motion traces generated during the modelling showed that vertical particle motion was larger than horizontal particle motion for receivers directly underneath or at short ranges from the array, but at longer ranges the horizontal particle motion dominated. The duration of particle motion also increased with distance as critically reflected multipath propagation becomes important.

Day et al. (2016a) included an empirical regression of particle acceleration versus range for the single 150 in^3 airgun used in their study (minimum range of 6 m) and showed that acceleration between 10 and 100 m range was typically between 26 and 5 ms^{-2}, respectively. Day et al. (2016a) also referenced an unpublished maximum particle acceleration measurement of 6.2 ms^{-2} from a 3130 in^3 airgun array at 477 m range in 36 m of water. In our study, modelled peak acceleration at 10 m range was predicted to be between 35 and 19 ms^{-2} depending on the site; corresponding values at 100 m range are between 21 and 12 ms^{-2}. At approximately 477 m, our study predicts an acceleration of between 8.5 and 5.8 ms^{-2} in both the port and starboard broadside directions. This result aligns reasonably with the measurements reported in Day et al. (2016a).

The maximum distance to peak particle acceleration of 37.57 ms^{-2}, determined for comparing literature (Section 3.3; (Day et al. 2016a), Day et al. (2016b)) is 9.1 m (Figure 14). This distance is less than that predicted for other studies in the region (Quijano et al. 2018); however, the difference is likely due to the different airgun array configuration and tow depth, as well as the geology for the respective studies. The geology for this study, silty carbonate sand to calcarenites (Appendix D.3.3), is less reflective than seabeds that have thin layers of sand over calcarenite substrate.

6.4. Multiple Pulse Sound Fields

The accumulated SEL over 24 hours of seismic operation was modelled considering a realistic acquisition pattern within the Acquisition Area. The model 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 cetaceans and the SEL_{24h} based fish criteria. The results were presented both as maps of the accumulated exposure levels and as tables of ranges to threshold levels and areas exposed above given effects criteria (Section 5.3). The footprint of the accumulated SEL (Figures 15 and 16) showed a slight widening of the contours at the deeper end of the survey lines. The single impulse modelling site, Site 1, was only representative of a small portion of the survey lines; therefore, despite having the largest single impulse footprints, the influence on the 24 h footprints was not noticeable.

The extents of isopleths associated with criteria for cetaceans and fish was relatively uniform along the survey lines, with the maximum distances being reached only a few kilometres to the side of each modelled survey line, as shown in the insert maps in Figures 15 and 16. The distance to the maximum-over-depth SEL_{24h} of 219 dB re 1 µPa²·s for fish (<30 m) was determined by the lateral distance between the airgun arrays (25 m), with the three arrays operated in a flip-flop-flap configuration. The 219 dB re 1 µPa²·s 24-hour contour extended a short distance beyond the outer arrays.

Note that ranges to thresholds were calculated based on maximum over depth levels, these ranges represent a worst-case threshold distance which implies that an animal would remain static throughout the 24 hour period. The actual dose an animal receives will be dependent on the path the animal takes relative to the operating survey; in the case of a fleeing animal, the received sound levels will be typically be much lower than if it remained stationary.

6.5. Summary

The findings of the study pertaining each of the metrics and criteria for various marine species of interest are summarised below with references to the result location.

Cetacean injury and behaviour

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 6.47 and 8.36 km (Site 2, 125 m and Site 1, 66 m), Table 9.
- 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 16 summarises the maximum distances for PTS, along with the relevant metric.

Table 16. Summary of maximum cetacean PTS onset distances for SEL_{24h} modelled scenarios (PK values from Table 10 and SEL_{24h} values from Table 14)

Relevant hearing group	Metric associated with longest distance to PTS onset	R_{max} (km)
Low-frequency cetaceans†	SEL_{24h}	0.63
Mid-frequency cetaceans	PK	<0.02
High-frequency cetaceans	PK	0.23

† The model does not account for shutdowns.

- The 24-h SEL is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding SEL_{24h} radii for low-frequency cetaceans were larger than those for peak pressure criteria, but they represent an unlikely worst-case scenario. More realistically, cetaceans (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with impairment (either PTS or TTS) if it remained in that location for 24 hours.

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 from the centre of the array. Because the arrays are not a point source (approximately 14 × 8 m), the actual ranges from the edge of airgun arrays are small.
- The distances to where the NMFS criterion (NSF 2011) for behavioural effects in turtles of turtles of 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) (Moein et al. 1995, McCauley et al. 2000a, McCauley et al. 2000b) could be exceeded are summarised in Table 17.

Table 17. Distances to turtle behavioural response criteria (from Table 9).

SPL (L_p; dB re 1 **µPa**)	Distance (km)	
	Min	Max
175†	1.00	1.20
166‡	3.28	5.10

† Threshold for turtle behavioural response to impulsive noise (Moein et al. 1995, 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} (water column only) 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 18 summarises the distances to injury criteria for fish, fish eggs, and fish larvae along with the relevant metric.

Table 18. 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 10 and 12, SEL_{24h} values from Table 15).

Relevant hearing group	Injury criteria	Water column		Seafloor	
		Metric associated with longest distance to injury criteria	R_{max} (km)	Metric associated with longest distance to injury criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.06	PK	0.08
	TTS	SEL_{24h}	2.81	SEL_{24h}	2.79
Fish: Swim bladder not involved in hearing Swim bladder involved in hearing	Injury	PK	0.13	PK	0.19
	TTS	SEL_{24h}	2.81	SEL_{24h}	2.79
Fish eggs, and larvae	Injury	PK	0.13	PK	0.19

Crustaceans and Bivalves, Sponges and Coral, and Plankton

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; it was reached at ranges between 468 and 709 m depending on the modelled site (Table 13).
- Bivalves: the distance where a particle acceleration of 37.57 ms^{-2} at the seafloor could occur was determined for comparing to results presented in Day et al. (2016a). The maximum distance to this particle acceleration level was 9.1 m, Section 5.2.3.
- Sponges and coral: The PK sound level at the seafloor directly underneath the seismic source was estimated at all modelling sites considered for seafloor fish receptors, and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); it was found that the level was not reached at any of the four considered sites (Table 12).
- Plankton: The distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at two modelling sites through full-waveform modelling using FWRAM; the results ranged from 5.32 km to 7.93 km (Table 11).

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 2017a).

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.

particle velocity
The physical speed of a particle in a material moving back and forth in the direction of the pressure wave. Unit: meters per second (m/s). Symbol: v.

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 ($Pa^2·s$) (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 $\mu Pa^2·s$. 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: $\mu Pa^2·s/Hz$.

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 $\mu Pa^2·s·m^2$ (exposure level).

spectral density level
The decibel level ($10·\log_{10}$) 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 $\mu Pa^2·s/Hz$, 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. 2017a. *ISO 18405:2017. Underwater acoustics – Terminology*. Geneva. https://www.iso.org/standard/62406.html.

[ISO] International Organization for Standardization. 2017b. *ISO/DIS 18405.2:2017. 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.

[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.

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.

Buckingham, M.J. 2005. Compressional and shear wave properties of marine sediments: Comparisons between theory and data. *Journal of the Acoustical Society of America* 117: 137-152. https://doi.org/10.1121/1.1810231.

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.

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.

Finneran, J.J. and C.E. Schlundt. 2010. Frequency-dependent and longitudinal changes in noise-induced hearing loss in a bottlenose dolphin (*Tursiops truncatus*). *Journal of the Acoustical Society of America* 128(2): 567-570. https://doi.org/10.1121/1.3458814.

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.

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.

Lucke, K., U. Siebert, P. Lepper, A., and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. *Journal of the Acoustical Society of America* 125(6): 4060-4070. https://doi.org/10.1121/1.3117443.

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.

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.

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.

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.

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 US Army Engineer Division and US Naval Submarine Base. Technical Report CERC-95. 90 p.

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.

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.

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.

Quijano, J., R. Racca, and C. McPherson. 2018. *Keraudren 3-D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures*. Document Number 01678, Version 1.0. Technical report by JASCO Applied Sciences for Quadrant Energy Limited. .

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.

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.

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.

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.

Wood, J.D., B.L. Southall, and D.J. Tollit. 2012. *PG&E offshore 3-D Seismic Survey Project Environmental Impact Report–Marine Mammal Technical Draft Report*. Report by SMRU Ltd. 121 p. https://www.coastal.ca.gov/energy/seismic/mm-technical-report-EIR.pdf.

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 impulsive noise 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 noise and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level (PK; L_{pk}; $L_{p,pk}$; dB re 1 μPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max\left(\left|p(t)\right|\right)}{p_0}\right] \quad \text{(A-1)}$$

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 a noise event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure level (PK-PK; $L_{pk\text{-}pk}$; $L_{p,pk\text{-}pk}$; dB re 1 μPa) is the difference between the maximum and minimum instantaneous sound pressure levels in a stated frequency band attained by an impulsive sound, $p(t)$:

$$L_{p,pk-pk} = 10\log_{10}\left\{\frac{\left[\max\left(p(t)\right)-\min\left(p(t)\right)\right]^2}{p_0^2}\right\} \quad \text{(A-2)}$$

The sound pressure level (SPL; L_p; dB re 1 μPa) is the rms pressure level in a stated frequency band over a specified time window (T, s) containing the acoustic event of interest. It is important to note that SPL always refers to a rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \quad \text{(A-3)}$$

The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalization, the passage of a vessel, or over a fixed duration. Because the window length, T, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL. A fixed window length of 0.125 s (critical duration defined by Tougaard et al. (2015)) is used in this study for impulsive sounds.

The sound exposure level (SEL; L_E; $L_{E,p}$; dB re 1 μPa^2·s) is a measure related to the acoustic energy contained in one or more acoustic events (N). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \quad \text{(A-4)}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. It therefore can be construed as a dose-type measurement, so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. 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:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right). \tag{A-5}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.3). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should else be specified.

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. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.3). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 μPa^2·s. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results obtained from MF cetacean studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 μPa^2·s.

As of 2017, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018; only the PK criteria defined in NMFS (2018) are applied in this report.

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:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-6)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016, NMFS 2018). Table A-1 lists the frequency-weighting parameters for each hearing group; Figure A-1 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by NMFS (2018).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	K (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
Mid-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
High-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

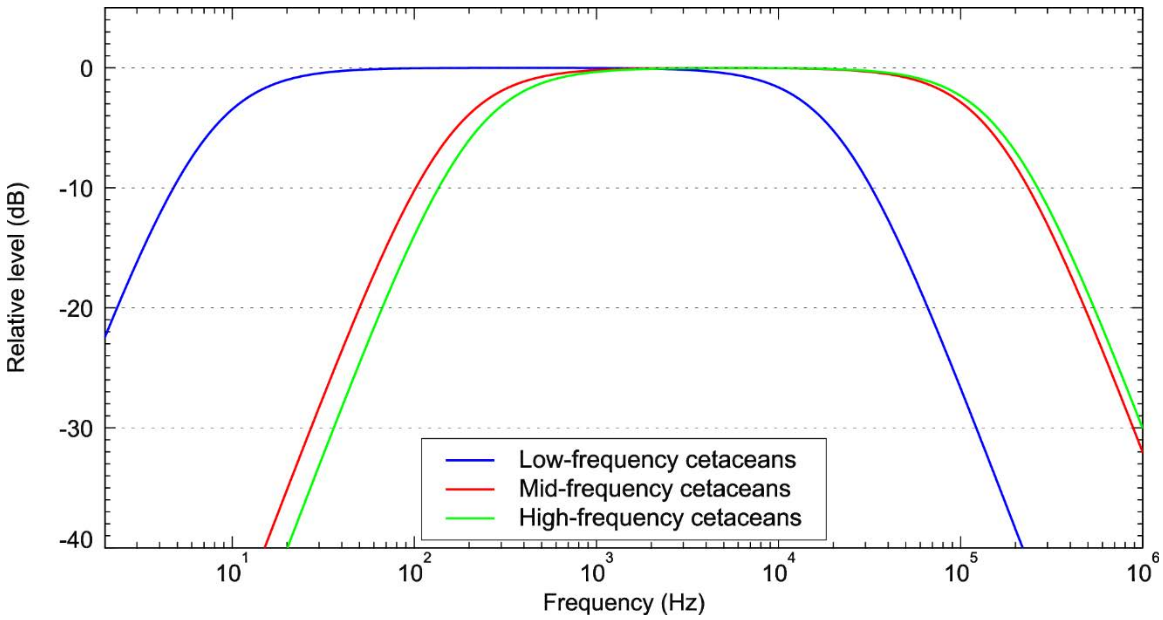


Figure A-1. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by NMFS (2018).

Appendix B. Acoustic Source Model

B.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and 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 3090 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); directivity in the sound field is most noticeable at mid-frequencies as described in the model detail in Appendix B.1.

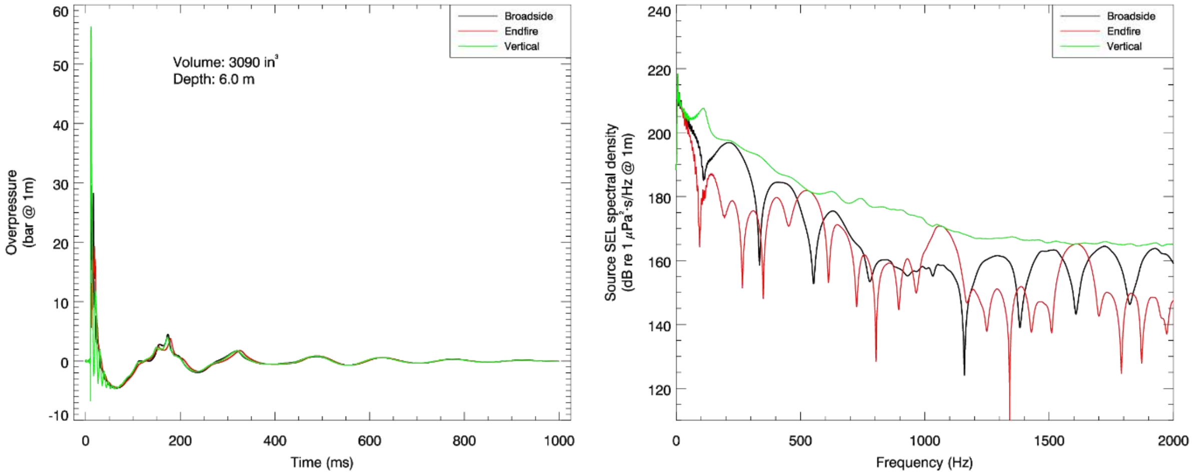


Figure B-1. Predicted source level details for the 3090 in^3 array at a 6 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

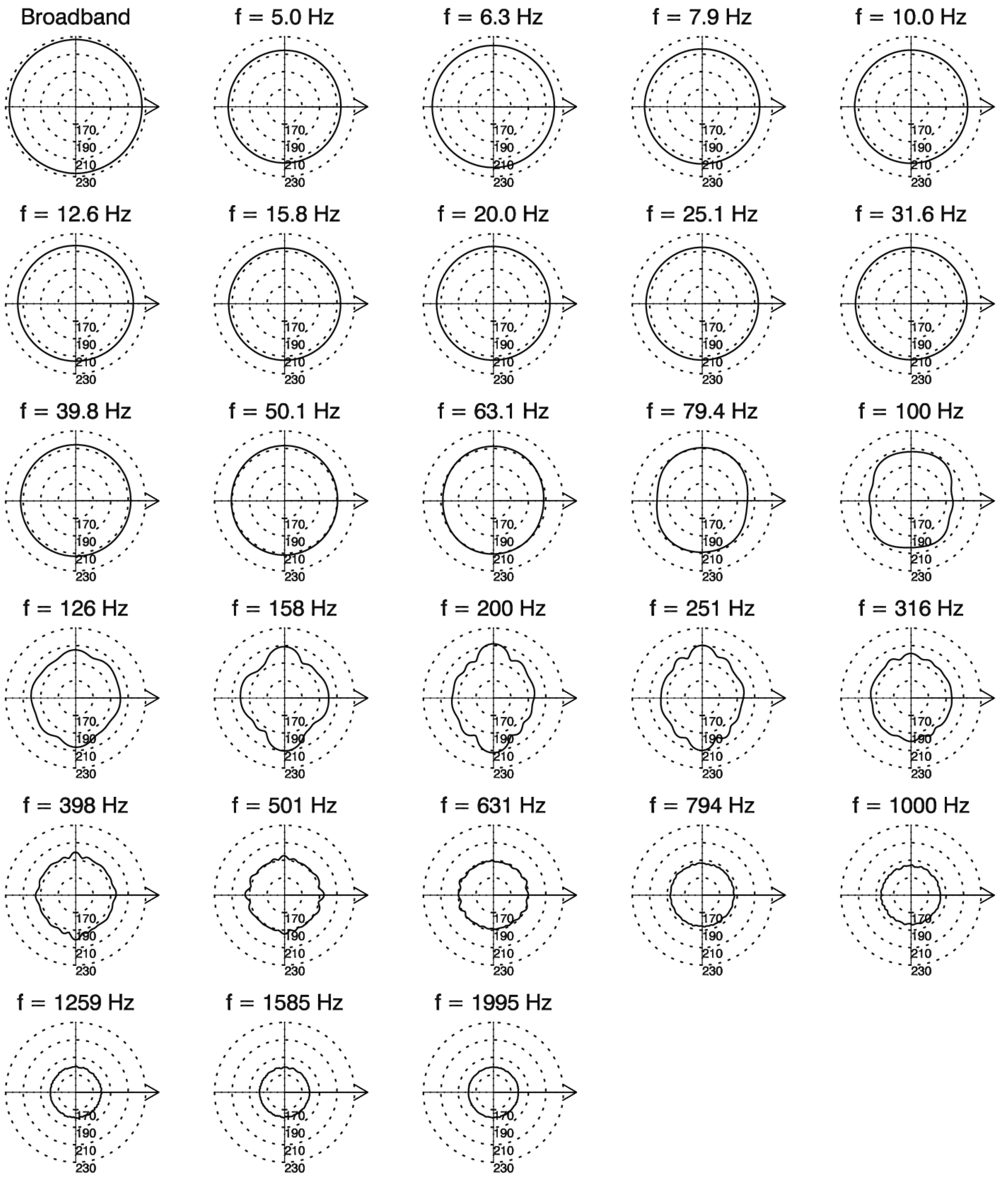


Figure B-2. Directionality of the predicted horizontal source levels for the 3090 in^3 seismic source array, 10 Hz to 2 kHz. Source levels (in dB re 1 $\mu Pa^2 \cdot s\ m^2$) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the 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 10 Hz to 1.25 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies > 1.25 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure C-1).

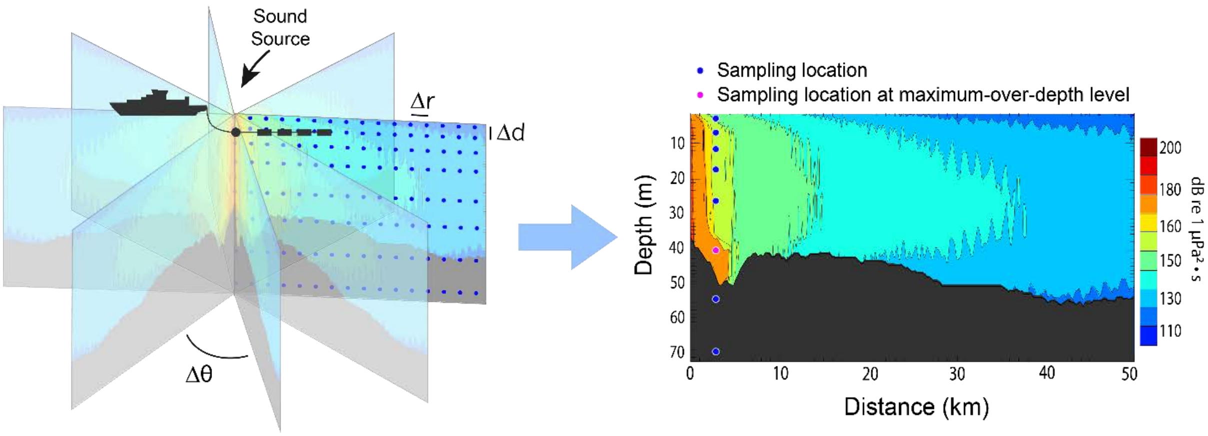


Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-pulse SEL are then computed by summing the received 1/3-octave-band levels.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SEL are presented as colour contours around the source.

An inherent variability in measured sound levels is caused by temporal variability in the environment and the variability in the signature of repeated acoustic impulses (sample sound source verification results is presented in Figure C-2). While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure C-2) upward so that the trend line encompasses 90% of all the data (dashed line, Figure C-2).

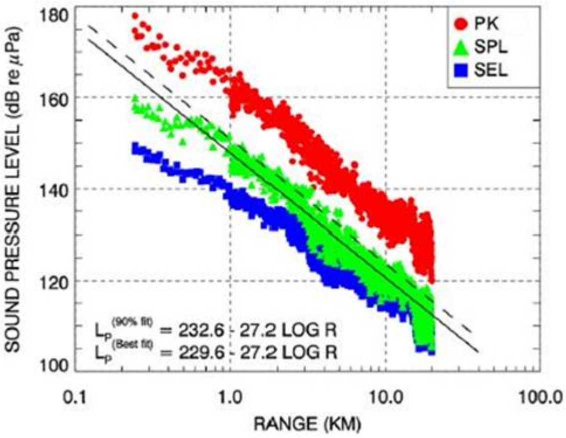


Figure C-2. PK and SPL and per-pulse SEL versus range from a 20 in^3 seismic source. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

C.2. Full Waveform Range-dependent Acoustic Model: FWRAM

For impulsive sounds from the seismic source, time-domain representations of the pressure waves generated in the water are required to calculate SPL and PK. Furthermore, the seismic source must be represented as a distributed source to accurately characterise vertical directivity effects in the near-field zone. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seafloor geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modelled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Besides providing direct calculations of the PK and SPL, the synthetic waveforms from FWRAM can also be used to convert the SEL values from MONM to SPL.

C.3. Wavenumber Integration Model

Sound pressure levels near the seismic source were modelled using JASCO's VSTACK wavenumber integration model. VSTACK computes synthetic pressure waveforms versus depth and range for arbitrarily layered, range-independent acoustic environments using the wavenumber integration approach to solve the exact (range-independent) acoustic wave equation. This model is valid over the full angular range of the wave equation and can fully account for the elasto-acoustic properties of the sub-bottom. Wavenumber integration methods are extensively used in the field of underwater acoustics and seismology where they are often referred to as reflectivity methods or discrete wavenumber methods. VSTACK computes sound propagation in arbitrarily stratified water and seabed layers by decomposing the outgoing field into a continuum of outward-propagating plane cylindrical waves. Seabed reflectivity in the model is dependent on the seabed layer properties: compressional and shear wave speeds, attenuation coefficients, and layer densities. The output of the model can be post-processed to yield estimates of the SEL, SPL, and PK.

VSTACK accurately predicts steep-angle propagation in the proximity of the source, but it is computationally slow at predicting sound pressures at large distances due to the need for smaller wavenumber steps with increasing distance. Additionally, VSTACK assumes range-invariant bathymetry with a horizontally stratified medium (i.e., a range-independent environment) which is azimuthally symmetric about the source. VSTACK is thus best suited to modelling the sound field near the source.

Appendix D. Methods and Parameters

This section describes the specifications of the seismic source that was used at all sites and the environmental parameters used in the propagation models.

D.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure D-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure D-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure D-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

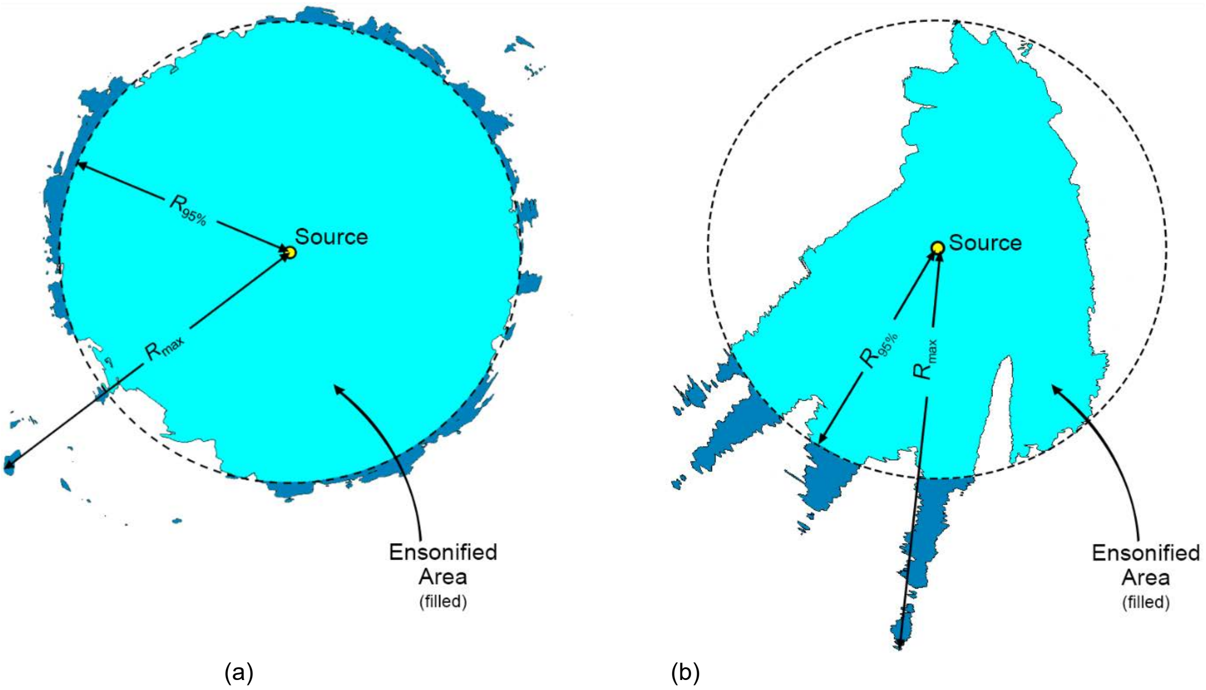


Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

D.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over a pulse's entire duration. The pulse SPL on the other hand, is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms; see Appendix A.1), as implemented in Martin et al. (2017b). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix C.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz. This was performed along all broadside and endfire radials at two 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 0.3 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function for each site. The range- dependent conversion function was averaged between the two sites and applied to predicted per-pulse SEL results from MONM to model SPL values. Figure D-2 shows the conversion offsets for each site; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source. Modelling was conducted using the average conversion function from all four sites.

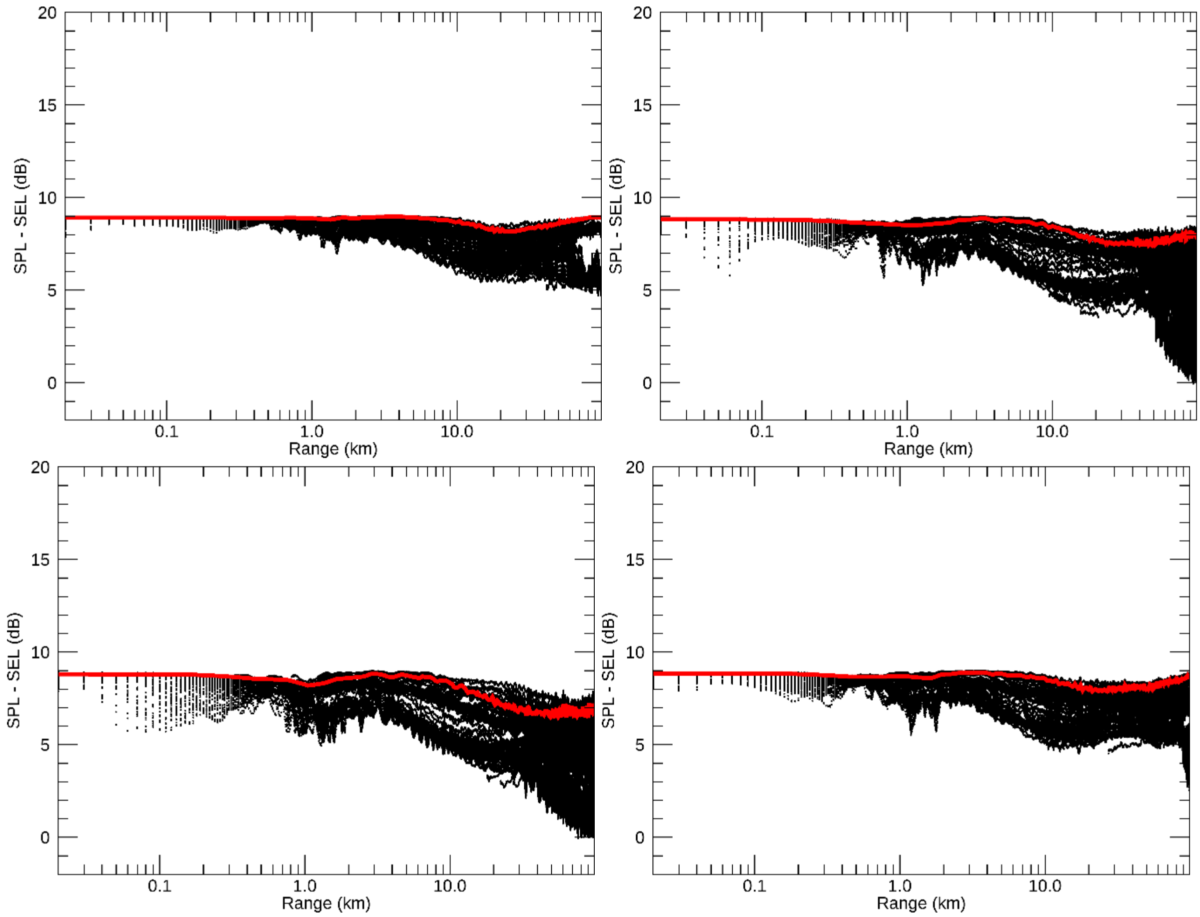


Figure D-2. Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3090 in^3 modelled Site 1 (top left), Site 2 (top right), Site 3 (bottom left), and Site 4 (bottom right). Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

D.3. Environmental Parameters

D.3.1. Bathymetry

Water depths throughout the modelled area were extracted from the Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009) for the region shown in Figure 1. Bathymetry data were extracted and re-gridded onto a Universal Transverse Mercator (UTM) coordinate projection (Zone 50 S) with a regular grid spacing of 100 × 100 m to generate the bathymetry in Figure D-3.

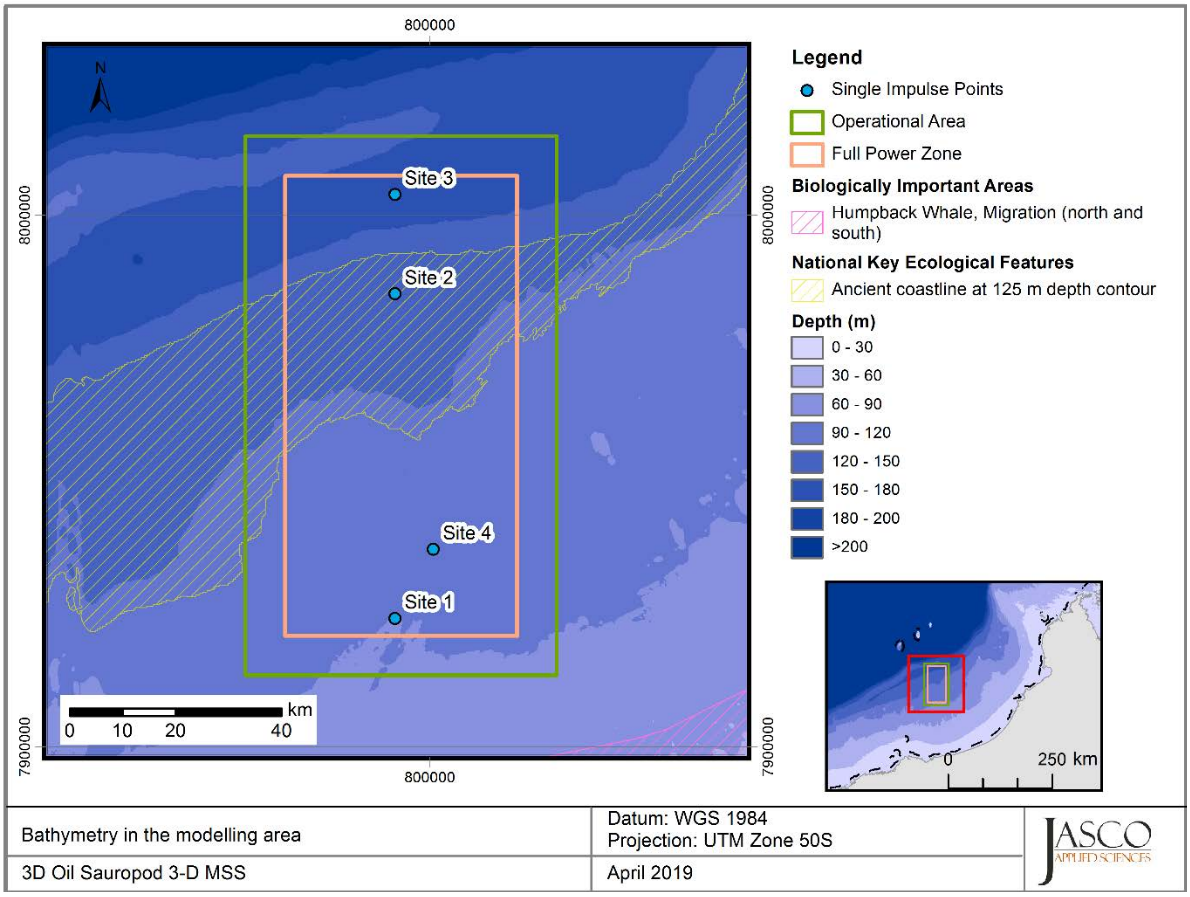


Figure D-3. Bathymetry map of the modelling area.

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 (December to May) were derived from the GDEM profiles within a 200 km box radius encompassing all modelling sites. The May sound speed profile is expected to be most favourable to longer-range sound propagation across the entire year. As such, May was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-4. shows the resulting profile used as input to the sound propagation modelling.

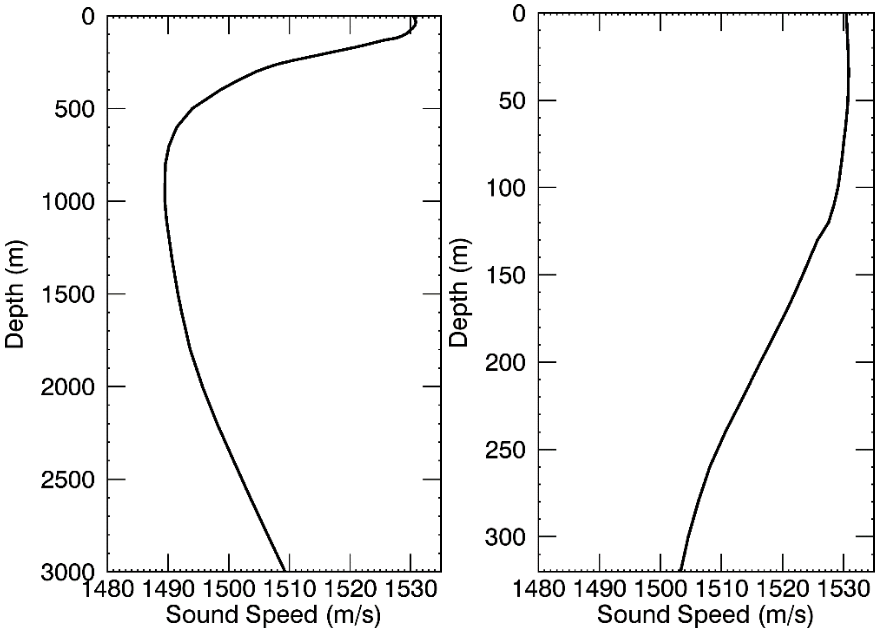


Figure D-4. The final sound speed profile (May) used for the modelling showing the entire water column (left) and the top 300 m within the profile (right). Profiles are calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

D.3.3. Geoacoustics

Geoacoustic parameters were derived from sedimentary grain size measurements from various locations off the coast of Western Australia. Most samples were taken on or near the seafloor, although a smaller number were from depths of up to 6 m. The geoacoustic parameters used for numeric modelling listed in Table D-1 were estimated from the sediment model of Buckingham (2005).

Table D-1. Geoacoustic profile for all sites in this study. Within each depth range, each parameter varies linearly within the stated range. The compressional wave is the primary wave. The shear wave is the secondary wave.

Depth below seafloor (m)	Predicted lithology	Density (g/cm^3)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–26	Silty carbonate sand to interbedded sandy carbonated mud and sand	1.78	1523–1674	0.05-0.67		
26–42	Carbonated sandy silt to muddy, sandy carbonate silt/silty mud	1.80	1685–1716	0.68–0.79		
42–72	Carbonate silty sand with occasional poorly cemented calcarenite layers	1.78	1704–1745	0.77–0.91	180	0.1
72–108	Silty sandy poorly cemented calcarenite	2.32–2.37	2121–2181	0.32–0.33		
108–188	High strength calcarenite zone, locally sandy	2.87–2.96	2781–2909	0.53–0.55		

D.4. Seismic Source

The layout of the seismic sources considered in Appendix B is provided in Figure D-5. Details of the airgun parameters are provided in Table D-2.

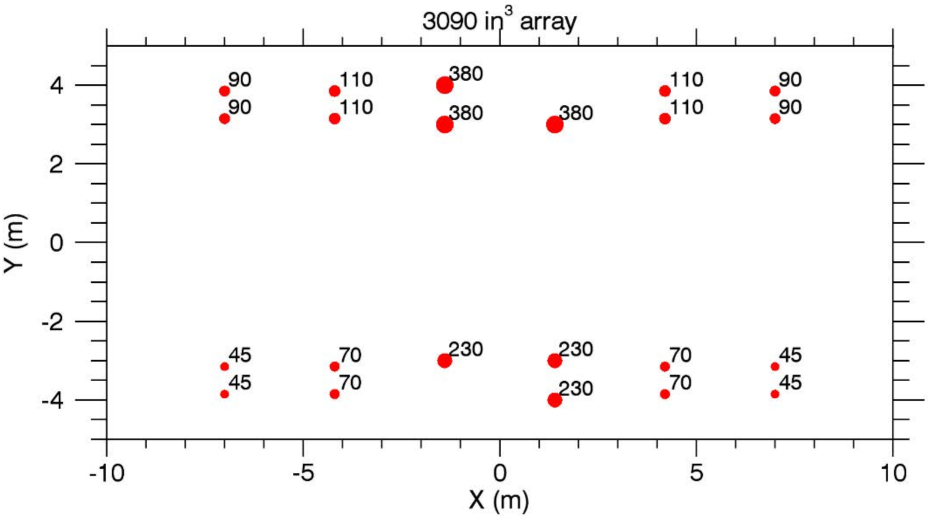


Figure D-5. Layout of the modelled 3090 in^3 seismic source array. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-2.

Table D-2. Layout of the modelled 3090 in^3 seismic source array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure D-5.

Gun	x (m)	y (m)	z (m)	Volume (in^3)	Gun	x (m)	y (m)	z (m)	Volume (in^3)
1	7.00	−3.85	6.00	45	12	7.00	3.15	6.00	90
2	7.00	−3.15	6.00	45	13	7.00	3.85	6.00	90
3	4.20	−3.85	6.00	70	14	4.20	3.15	6.00	110
4	4.20	−3.15	6.00	70	15	4.20	3.85	6.00	110
5	1.40	−4.00	6.00	230	16	1.40	3.00	6.00	380
6	1.40	−3.00	6.00	230	17	−1.40	3.00	6.00	380
7	−1.40	−3.00	6.00	230	18	−1.40	4.00	6.00	380
8	−4.20	−3.85	6.00	70	19	−4.20	3.15	6.00	110
9	−4.20	−3.15	6.00	70	20	−4.20	3.85	6.00	110
10	−7.00	−3.85	6.00	45	21	−7.00	3.15	6.00	90
10	−7.00	−3.15	6.00	45	22	−7.00	3.85	6.00	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. Additional Results

E.1. Particle Motion

Figures E-1 to E-3 show the maximum particle acceleration and velocity for Sites 2–4, as a function of horizontal range from the centre of the array in broadside directions, which generate the higher amplitude results, results for Site 1 are shown in Figure 14.

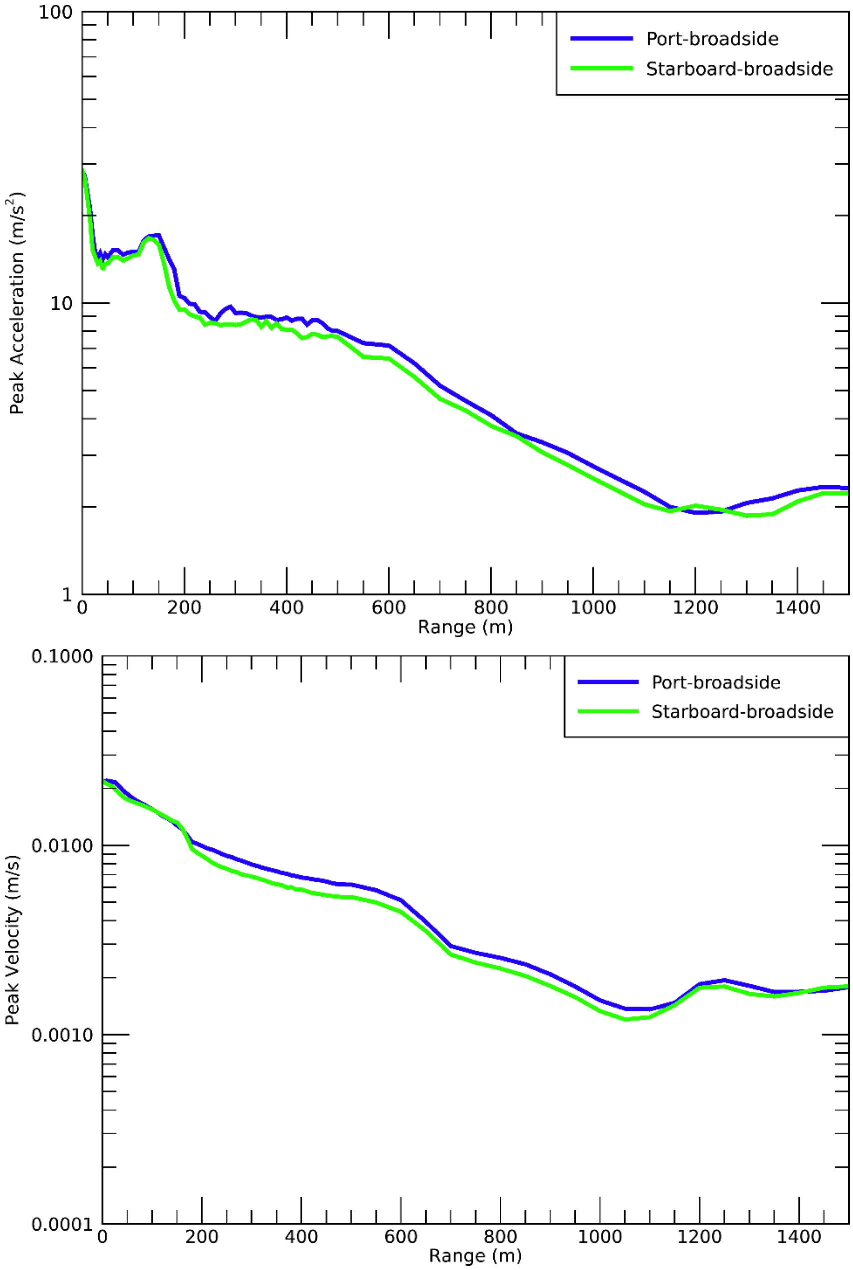


Figure E-1. Site 2: Maximum particle acceleration (top) and velocity (bottom) at the seafloor as a function of horizontal range from the centre of a single 3090 in^3 seismic source along the broadband directions.

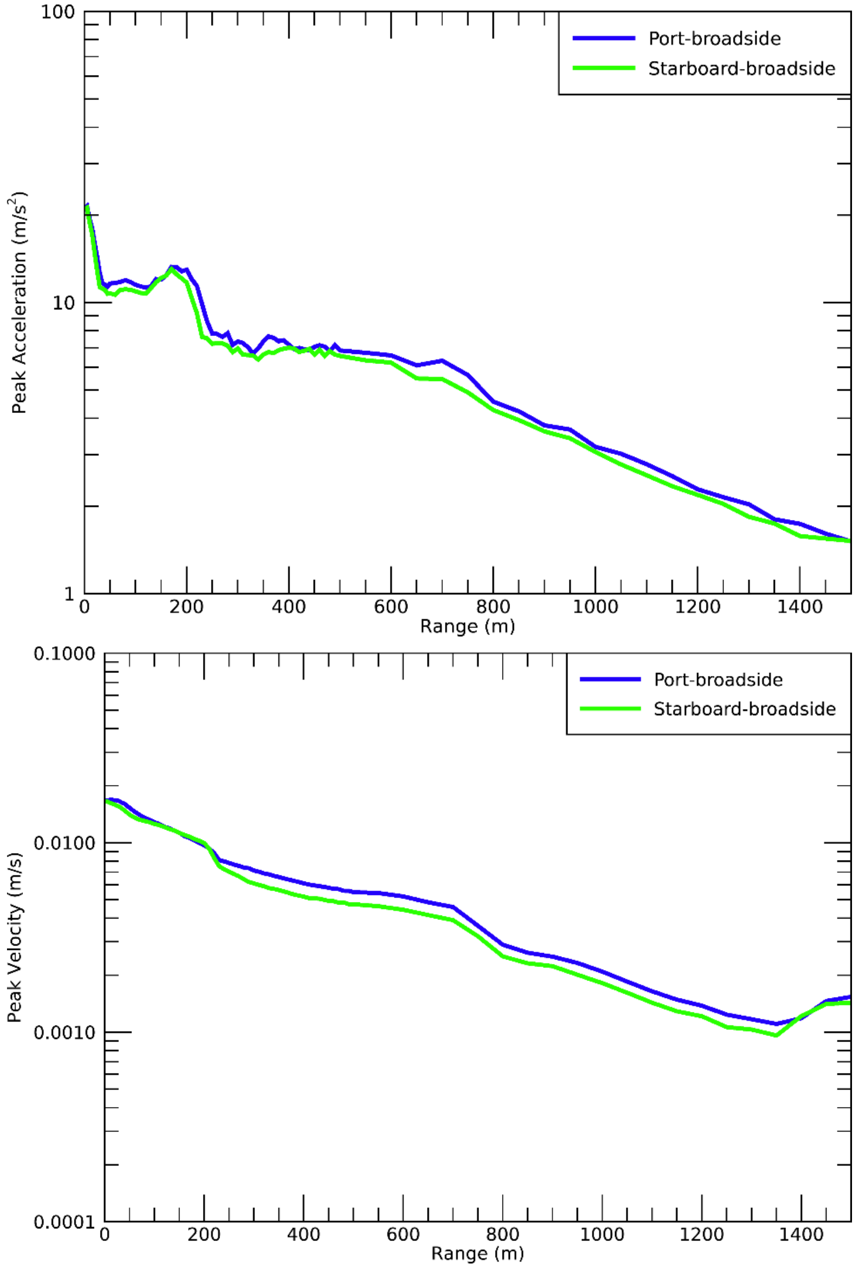


Figure E-2. Site 3: Maximum particle acceleration (top) and velocity (bottom) at the seafloor as a function of horizontal range from the centre of a single 3090 in^3 seismic source along the broadband directions.

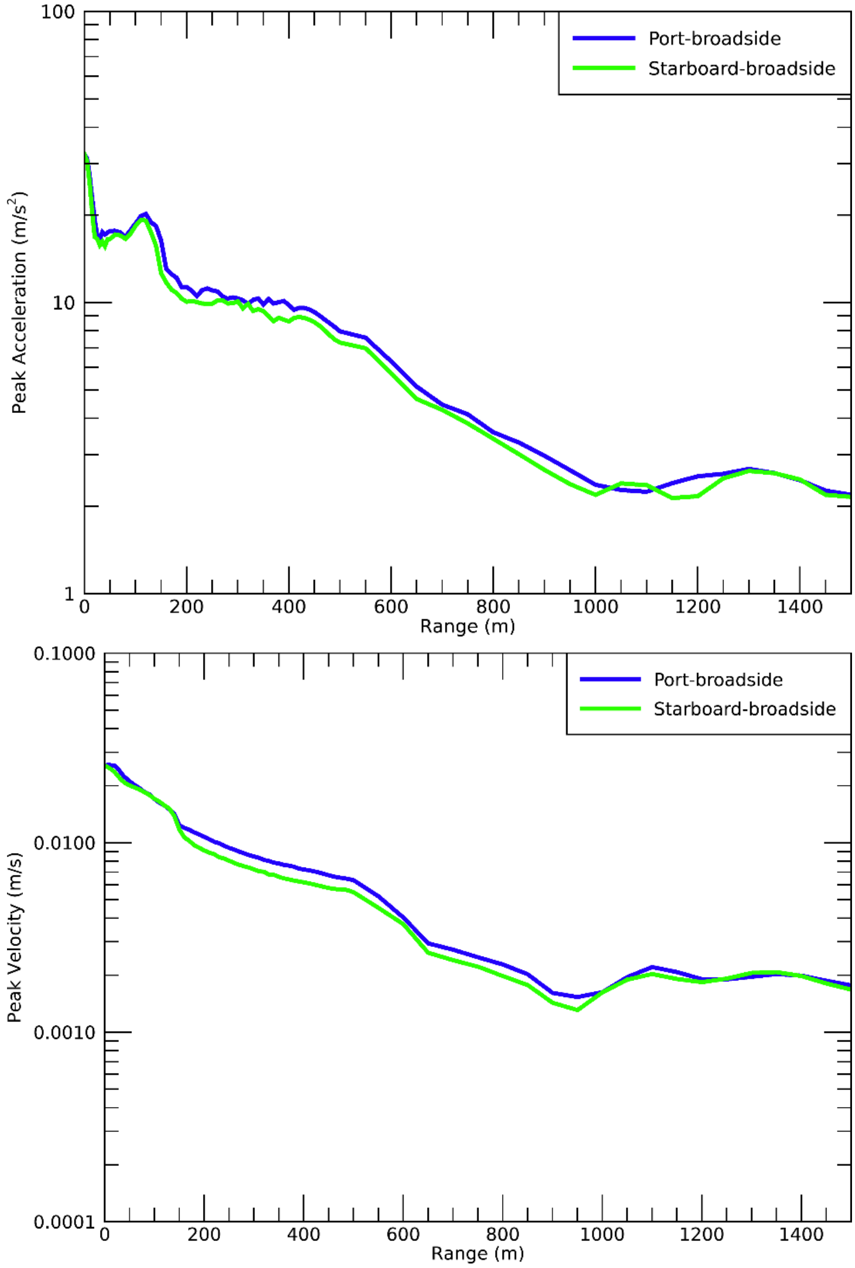


Figure E-3. Site 4: Maximum particle acceleration (top) and velocity (bottom) at the seafloor as a function of horizontal range from the centre of a single 3090 in^3 seismic source along the broadband directions.

Appendix E: Seismic Array Comparison

Unit 1, 14 Hook Street
Capalaba, Queensland, 4157

Tel: +61 7 3823 2620
www.jasco.com

Technical Memo

DATE: 10 August 2021

FROM: Craig McPherson and Jorge E. Quijano (JASCO Applied Sciences (Australia) Pty Ltd)

TO: RPS Australia

Subject: CGG Sauropod Survey, Comparison between the original 3090 in^3 array and the proposed 2820 in^3 array.

JASCO Applied Sciences (JASCO) previously conducted acoustic modelling for the 3D Oil Sauropod Marine Seismic Survey (MSS), and considered using a 3090 in^3 source array with a 6 m tow depth (Quijano and McPherson 2019). CGG, who will be conducting the survey, has identified an alternative seismic source option, a 2820 in^3 array also with a 6 m tow depth (Appendix A). The alternative array, along with a revised acquisition pattern require consideration and explanation to assist the approval process for the survey.

To assist CGG in verifying that the newly identified source will not exceed the sound levels and effects assessed in the 3D Oil Sauropod MSS Environment Plan (EP), JASCO performed the following tasks:

- Source modelling of the 2820 in^3 array
- Comparison of the 3090 in^3 array with the 2820 in^3 array
- Maximum-over-depth Sound Field Comparison for one modelling site (Site 2)
- Qualitative assessment of the survey plans between the old and new survey, to discuss the expected differences in sound field extents for accumulated Sound Exposure Levels (SEL) over 24 h of acquisition.

In the original scope of work, single-impulse sound fields were predicted at four defined locations within the CGG Sauropod survey areas (see Figure 1 and Table 1).

The metrics used to represent underwater acoustic fields and the effect criteria considered, and the details the methodology for predicting the source levels and modelling the sound propagation are provided in Quijano and McPherson (2019). The specifications of both seismic sources are provided in Appendix A. Section 2 presents the results, which are then discussed and summarised in Section 3.

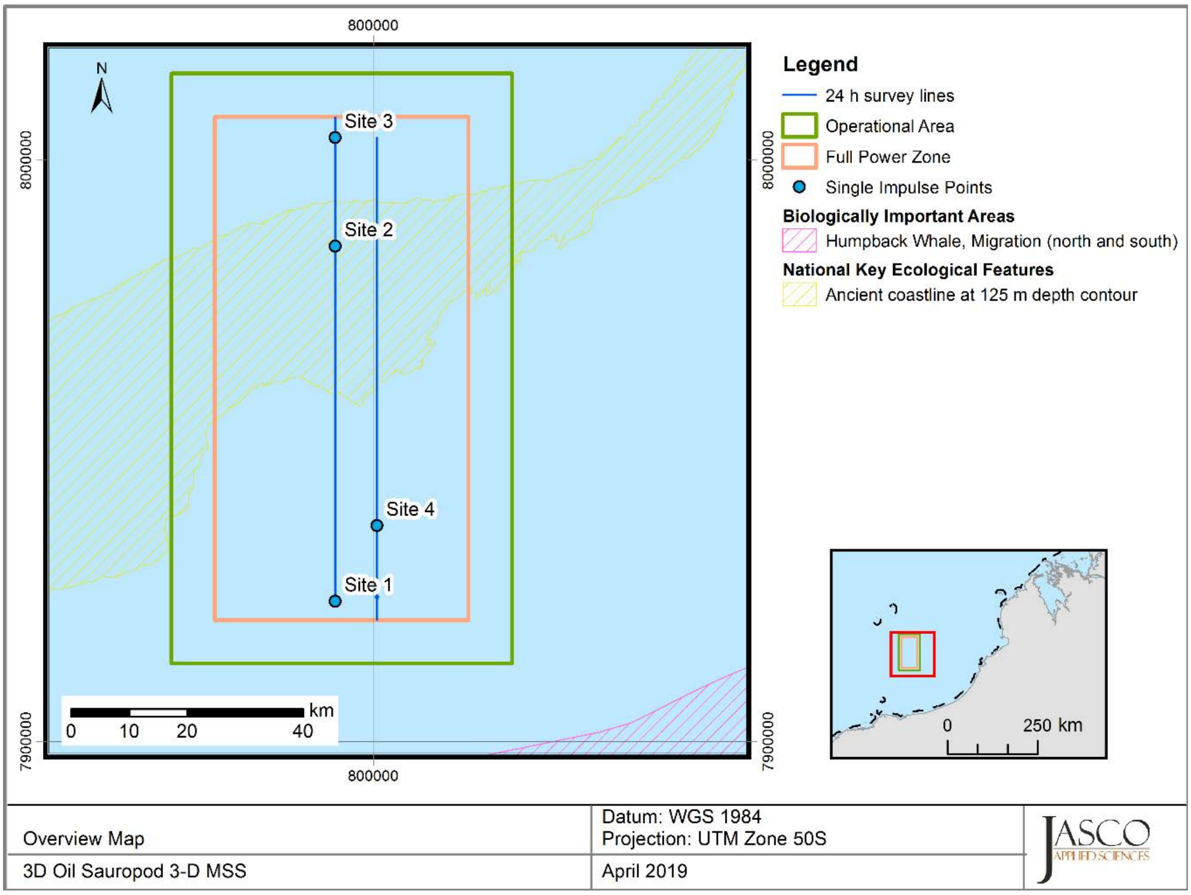


Figure 1. Overview of the modelling sites, acquisition lines, and features for the 3D Oil Sauropod 3-D MSS modelling (Quijano and McPherson 2019).

Table 1. Location details for the 3D Oil Sauropod 3-D MSS modelling sites (Quijano and McPherson 2019).

Site	Latitude (S)	Longitude (E)	UTM (WGS1984) Zone 50S		Water depth (m)	Representative tow direction (°)
			X (m)	*Y* (m)		
1	18° 45' 14.3694"	119° 46' 58.6168"	793425	7924100	66	0 & 180
2	18° 12' 08.6755"	119° 46' 26.6060"	793425	7985200	125	
3	18° 02' 00.9264"	119° 46' 17.0335"	793425	8003900	161	
4	18° 38' 07.1558"	119° 50' 57.1375"	800625	7937133	107	

1. Methods

The specifications of the seismic source and the input parameters for the propagation models are summarised here. A detailed description can be found in Quijano and McPherson (2019).

1.1. Acoustic Source Model

The pressure signature of the individual airguns and the composite decidecade-band point-source equivalent directional levels (i.e., source levels) of the two seismic sources (3090 in^3 and a 2820 in^3) were modelled with JASCO's Airgun Array Source Model (AASM).

AASM considers:

- Array layout.
- Volume, tow depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

Both seismic source arrays considered were modelled over AASM's full frequency range, up to 25 kHz.

1.2. Sound Propagation Modelling

To compare the two sources in a representative environment. SEL, SPL and zero-to-peak sound pressure level (PK) metrics for each source were predicted with JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM). FWRAM was used to model synthetic seismic pulses out to 100 km at the considered single impulse modelling sites, along four radials (fore and aft endfire, and port and starboard broadside). The acoustic fields were modelled with the same input configuration as discussed in Quijano and McPherson (2019).

2. Results

2.1. Acoustic Source Levels and Directivity

Table 2 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 for the two different seismic sources considered during the seismic source analysis. The broadside, endfire, and vertical overpressure signature and corresponding power spectrum levels for the additional sources considered, the 2820 and 3090 in^3 sources with a 6 m tow depth, are provided in Appendix A.

Table 2. Far-field source level specifications for the 3090 and 2820 in^3 sources with 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 µPa²m²s)
			10–25000 Hz
3090[A]	Broadside	249.4	225.1
2820		248.8	224.5
3090[A]	Endfire	245.7	223.3
2820		244.8	223.0
3090[A]	Vertical	255.0	228.2
2820		254.9	227.9

[A] Far-field source level from Quijano and McPherson (2019).

2.2. Per-Pulse Sound Fields

FWRAM (Section 1.2) was used to model synthetic seismic pulses at the 4 sites using the 3090 and 2820 in^3 arrays. FWRAM calculated SEL, SPL and zero-to-peak sound pressure level (PK) metrics for each source, which allowed the two sources to be compared in a representative environment. Modelling was performed over all broadside and endfire radials. Figures 2–5 show the maximum-over-depth for all radials for SEL and PK metrics as a function of range. The SEL curves can be used to compare the energy emission of the arrays into the environment and the PK curves can be used to assess source pulse characteristics in the environment.

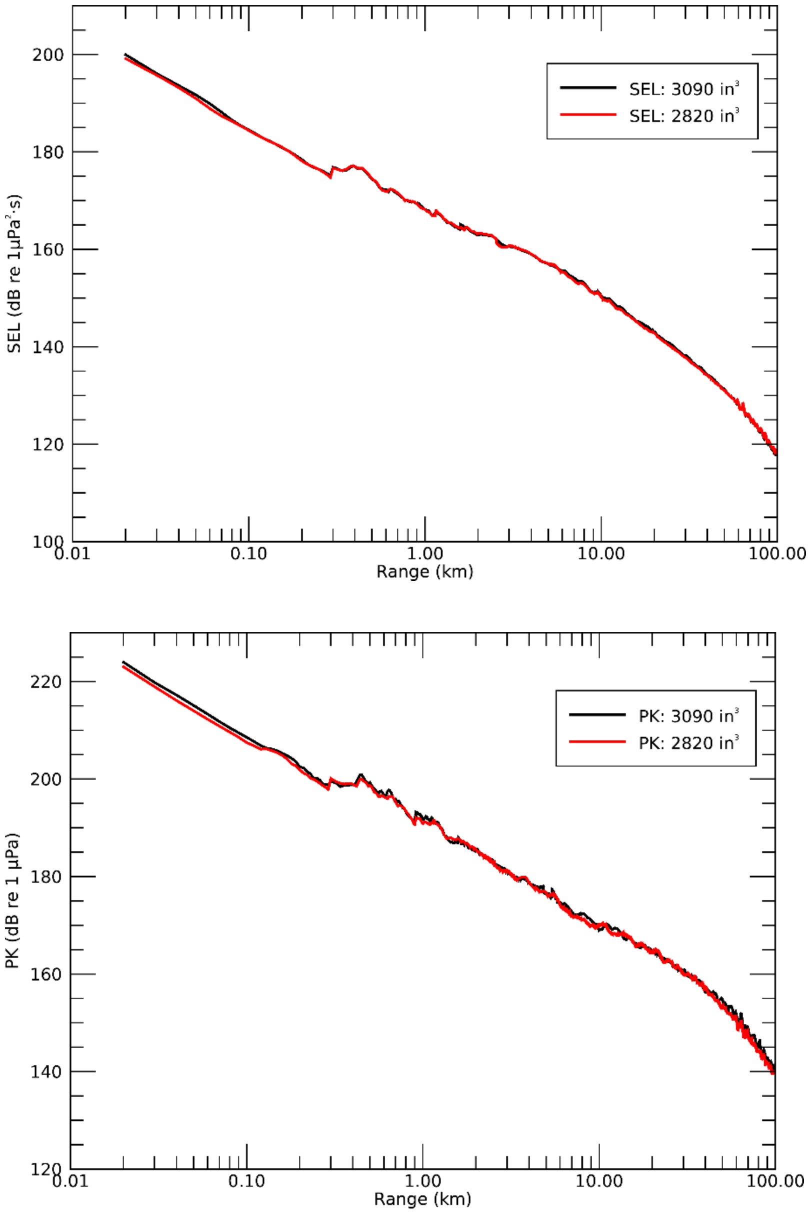
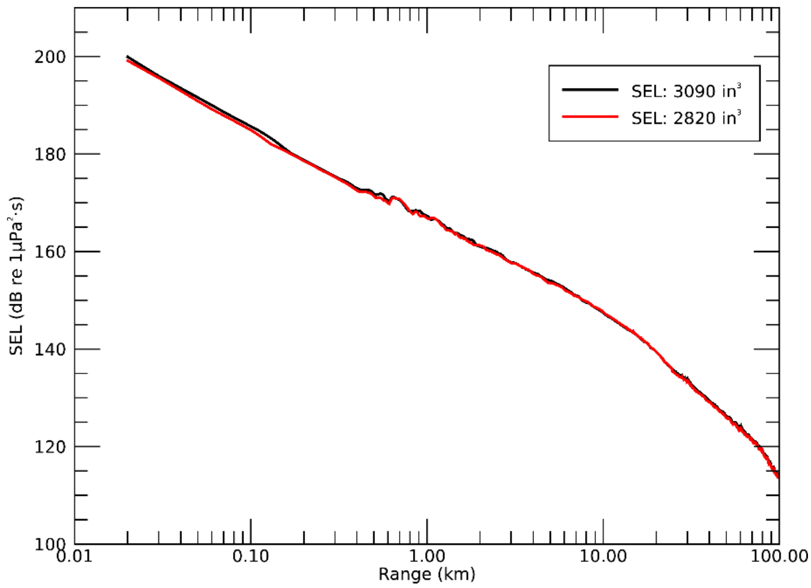


Figure 2. Site 1: Maximum-over-depth SEL (top) and PK (bottom) predicted for the 3090 and 2820 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.



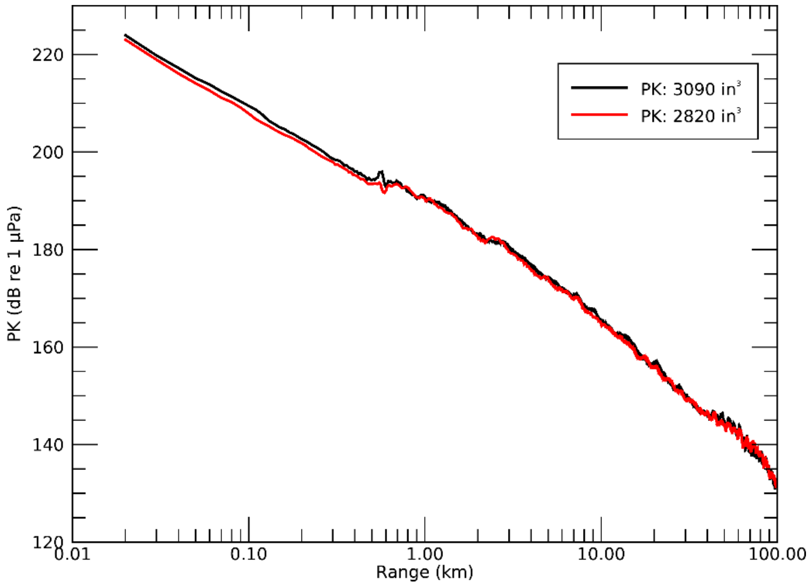


Figure 3. Site 2: Maximum-over-depth SEL (top) and PK (bottom) predicted for the 3090 and 2820 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.

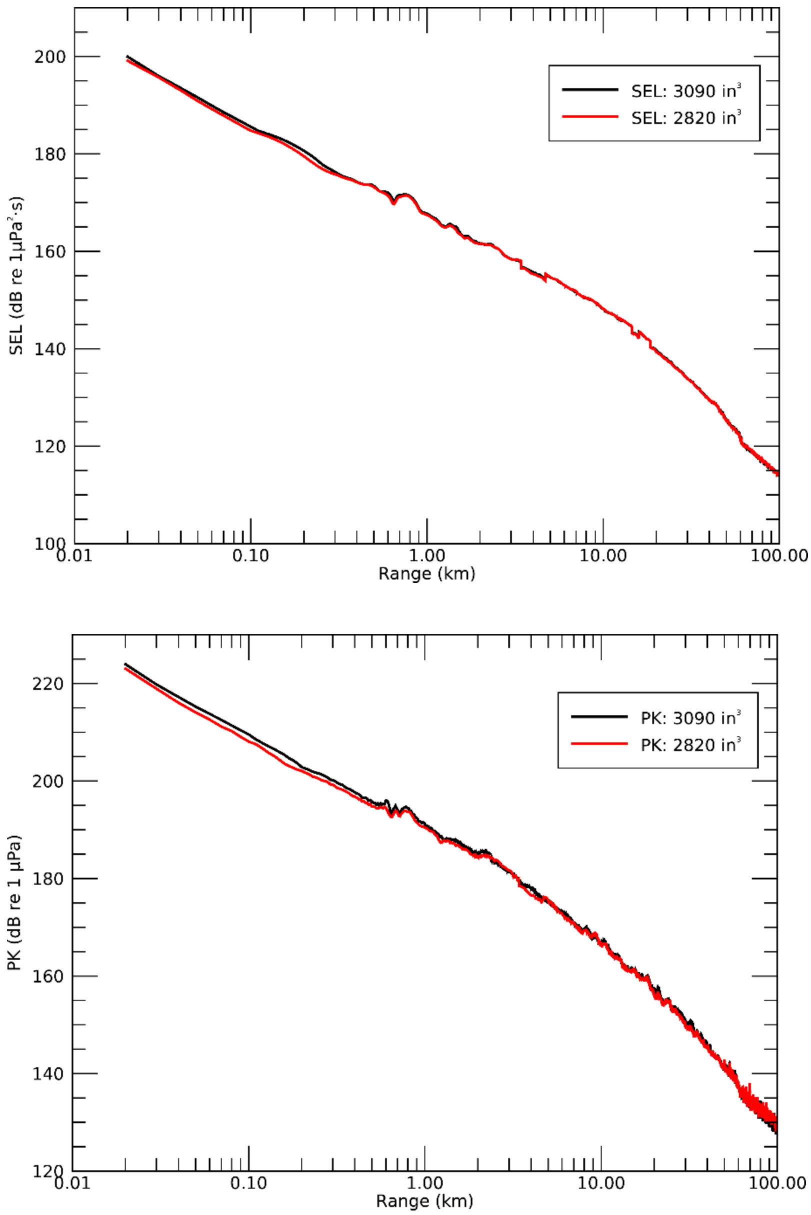


Figure 4. Site 3: Maximum-over-depth SEL (top) and PK (bottom) predicted for the 3090 and 2820 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.

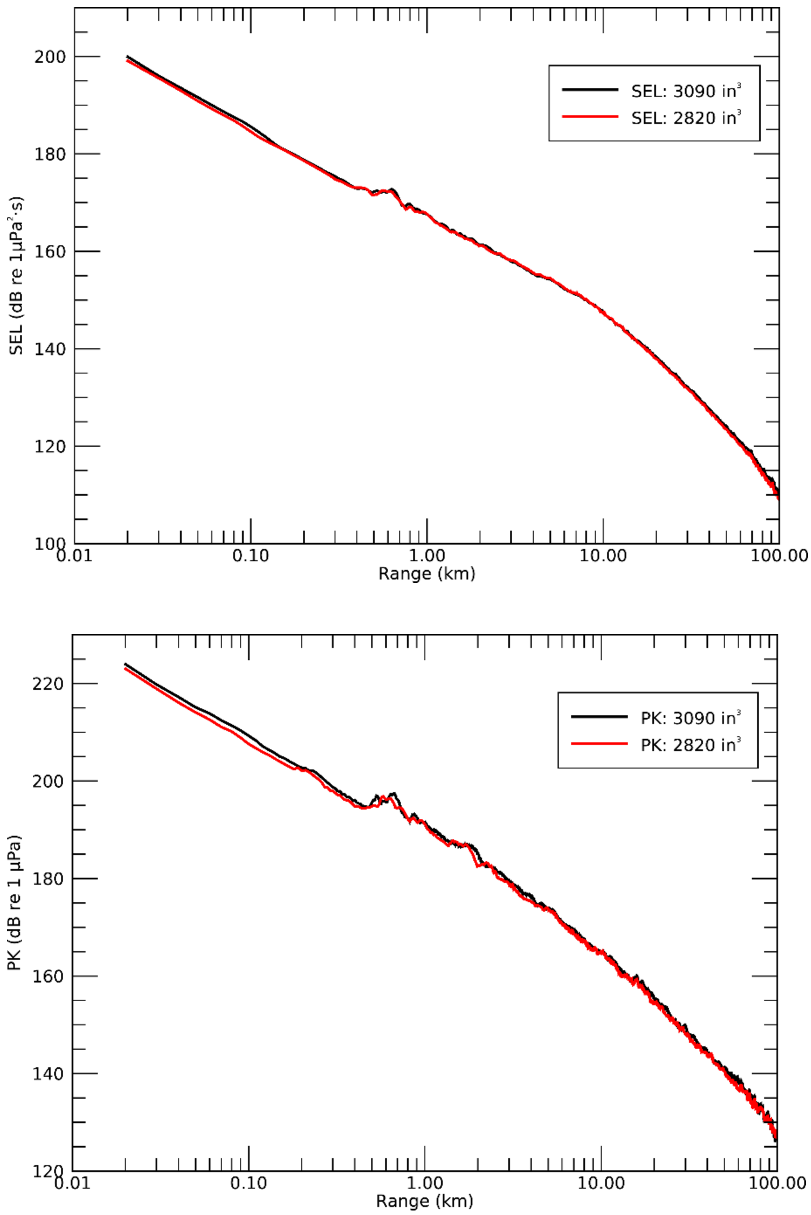


Figure 5. Site 4: Maximum-over-depth SEL (top) and PK (bottom) predicted for the 3090 and 2820 in³ sources from FWRAM. Levels are the maximum over all the broadside and endfire directions.

3. Discussion and Conclusion

3.1. Acoustic Source Levels and Per-Pulse Sound Levels

A comparison between far-field source level specifications for the 3090 and the 2820 in^3 sources with a 6 m tow depth using values in Table 2 is provided in Table 3. In all cases, the 2820 in^3 array exhibits smaller peak and SEL than the 3090 in^3 array, although the differences never exceed 0.9 dB for the peak metric, and 0.6 dB for the SEL metric.

Table 3. Peak and per-pulse SEL difference between the 3090 and the 2820 in^3 sources with a 6 m tow depth using values in Table 2..

Total volume (in^3)	Direction	Difference in peak source pressure level ($L_{S,pk}$; dB re 1 µPa m)	Difference in per-pulse source SEL ($L_{S,E}$; dB 1 µPa^{2}m^{2}s)
			10-25000 Hz
3090 vs 2820	Broadside	-0.6	-0.6
	Endfire	-0.9	-0.3
	Vertical	-0.1	-0.3

3.2. Per-Pulse Sound Fields

The per-pulse source levels in Table 2 are free-field levels which do not incorporate environmental effect like sea-surface or seabed reflections and interference. The maximum-over-depths curves in Section 2.2 provide a better comparison of the sources when environmental effects are considered. These figures show that either the 3320 in^3 and 2820 in^3 arrays will result in similar distances to thresholds, and that the sound fields are practically indistinguishable from each other.

3.3. Qualitative Assessment of SEL 24h Sound Fields

The parameters relevant to the acoustic modelling for both the original 3D Oil survey and the current alternative CGG version of the survey are provided and contrasted in Table 4. The modelling scenario for the original 3D Oil survey accounted for 13280 impulses within the modelled scenario. The new CGG configuration will result in a reduction of the original 3D Oil survey ensonified area, due to the following factors:

- The 2820 in^3 array yields sound fields (PK, SEL, and SPL) that are marginally smaller compared to those from the 3090 in^3, as shown in this memo. If the survey parameters (vessel speed, distance between consecutive survey lines, shooting interval) remain the same, the 2820 in^3 array will result in almost the same distances to thresholds.
- Additional reductions in ensonified area/distances to SEL 24h thresholds are expected. This can be illustrated with an example: in Figure 1, consider the SEL 24h sound field at Site 4, which is the summation of the fields from line 1 (the line Site 4 is located on) and from line 2. If the separation between lines increases, and line 2 shifts to the west, the SEL 24h sound field extents as measured at Site 4 will be reduced due to the additional propagation loss from a longer distance.

- If the survey vessel speed remains the same, the increased distance between surveys will also result in less time for acquisition (active source operations) within a 24h period as the turns are longer, thereby reducing the accumulated sound field even further.

The assessment above is applicable as long as the array parameters remain unaltered. If the vessel speed increases, the line separation decreases or the tow depth increases, additional modelling would be required to assess the impact on sound levels, frequency content, and directivity.

Table 4. Sauropod survey parameters influencing acoustic modelling.

Survey Parameter	CGG Survey	3D Oil Survey
Length of sail lines	83 km	83 km
Time to traverse a sail line	~10 hours	~10 hours
Orientation of sail lines	North–south	North–south
Distance between sail lines	675 m – 716 m	450 m
Turn radius	5200 m	3500 m
Seismic vessel sail line speed	4.5 knots	Modelled at 4.4 knots
Seismic source discharge interval	Approximately every 12.5 m (approximately every 5.4 seconds) along survey lines	
Seismic Source		
Type	Airgun / three arrays, which will be discharged alternately	
Size	2820 in^3	3090 in^3
Pressure	2,000 psi	
Sound source tow depth	Modelled at 6 m	Modelled at 6 m
Streamers		
Number	12	12
Streamer length	7050 m	7000 m
Distance from seismic vessel bow to tail buoy	7800 m	7525 m
Distance between streamers	112.5 m	75 m

References

Quijano, J.E. and C.R. McPherson. 2019. *3-D Oil Sauropod 3-D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures*. Document Number 01781, Version 1.0. Technical report by JASCO Applied Sciences for Environmental Resources Management (ERM). Appendix E *In* 3D OIL Sauropod 3D Marine Seismic Survey (WA-527-P): Environment Plan. https://docs.nopsema.gov.au/A683046

Unit 1, 14 Hook Street
Capalaba, Queensland, 4157

Tel: +61 7 3823 2620
www.jasco.com

Appendix A. Seismic Sources

The layouts of the 3090 in³ and 2820 in³ seismic sources considered in this study are detailed as follows:

- 3090 in³ seismic source: layout is shown in Figure A-1, and details of the airgun parameters are provided in Table A-1.
- 2820 in³ seismic source: layout is shown in Figure A-2, and details of the airgun parameters are provided in Table A-2.

A.1. 3090 in³ Source Details

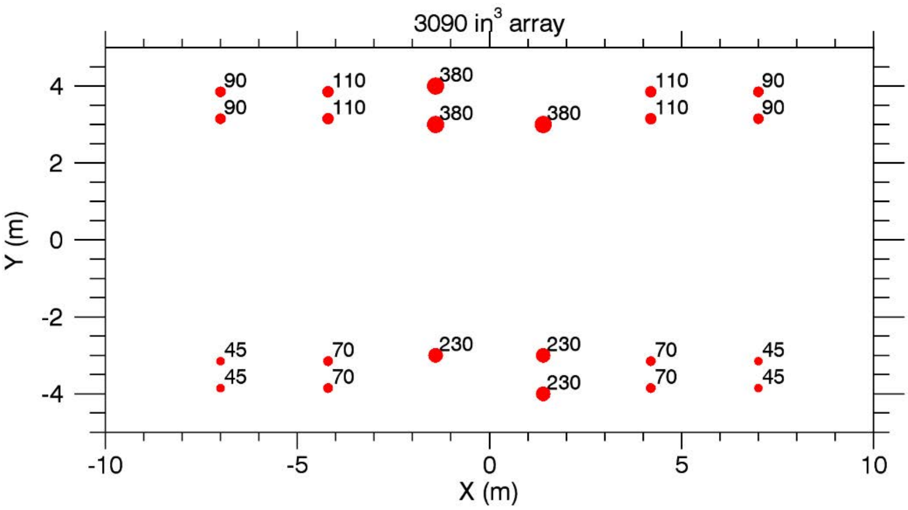


Figure A-1. Layout of the modelled 3090 in³ array. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table A-1.

Table A-1. Layout of the modelled 3090 in³ seismic source array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure A-1.

Gun	x (m)	y (m)	z (m)	Volume (in³)	Gun	x (m)	y (m)	z (m)	Volume (in³)
1	7.00	−3.85	6.00	45	12	7.00	3.15	6.00	90
2	7.00	−3.15	6.00	45	13	7.00	3.85	6.00	90
3	4.20	−3.85	6.00	70	14	4.20	3.15	6.00	110
4	4.20	−3.15	6.00	70	15	4.20	3.85	6.00	110
5	1.40	−4.00	6.00	230	16	1.40	3.00	6.00	380
6	1.40	−3.00	6.00	230	17	−1.40	3.00	6.00	380
7	−1.40	−3.00	6.00	230	18	−1.40	4.00	6.00	380
8	−4.20	−3.85	6.00	70	19	−4.20	3.15	6.00	110
9	−4.20	−3.15	6.00	70	20	−4.20	3.85	6.00	110
10	−7.00	−3.85	6.00	45	21	−7.00	3.15	6.00	90
10	−7.00	−3.15	6.00	45	22	−7.00	3.85	6.00	90

A.2. 2820 in³ Source Details

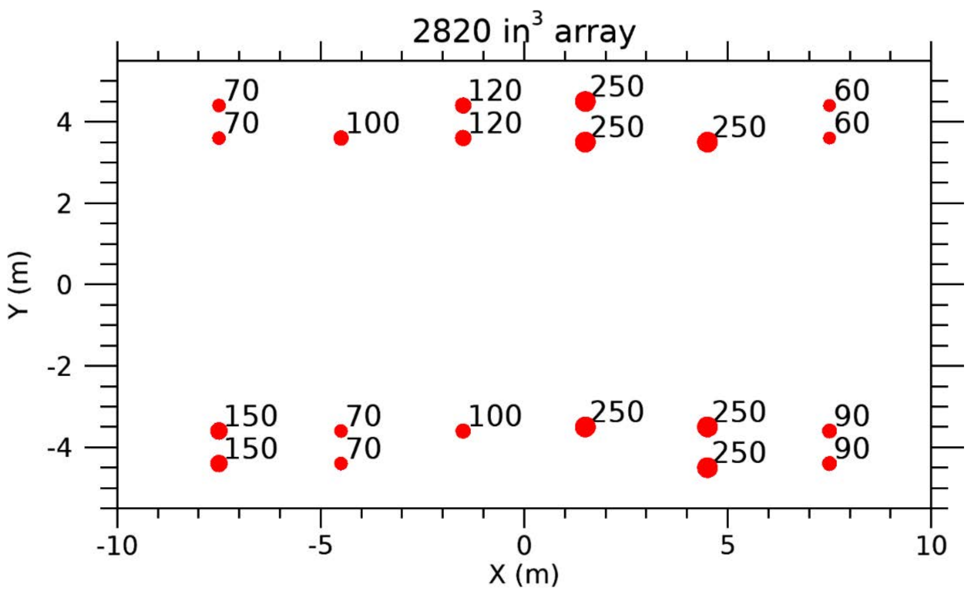


Figure A-2. Layout of the modelled 2820 in³ array. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table A-2.

Table A-2. Layout of the modelled 2820 in^3 array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure A-2.

Gun	x (m)	y (m)	z (m)	Volume (in^3)	Gun	x (m)	y (m)	z (m)	Volume (in^3)
1	0	-4.4	6	90	13	0	3.6	6	60
2	0	-3.6	6	90	15	0	4.4	6	60
3	3	-4.5	6	250	16	3	3.5	6	250
4	3	-3.5	6	250	17	6	3.5	6	250
6	6	-3.5	6	250	18	6	4.5	6	250
8	9	-3.6	6	100	19	9	3.6	6	120
9	12	-4.4	6	70	20	9	4.4	6	120
10	12	-3.6	6	70	21	12	3.6	6	100
11	15	-4.4	6	150	22	15	3.6	6	70
12	15	-3.6	6	150	23	15	4.4	6	70

A.3. Array Source Levels and Directivity

Figure A-3 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 3090 in^3 array. Horizontal decidecade-band source levels are shown as a function of band centre frequency and azimuth (Figure A-5). Figure A-4 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 2820 in^3 array. Horizontal decidecade-band source levels are shown as a function of band centre frequency and azimuth (Figure A-6).

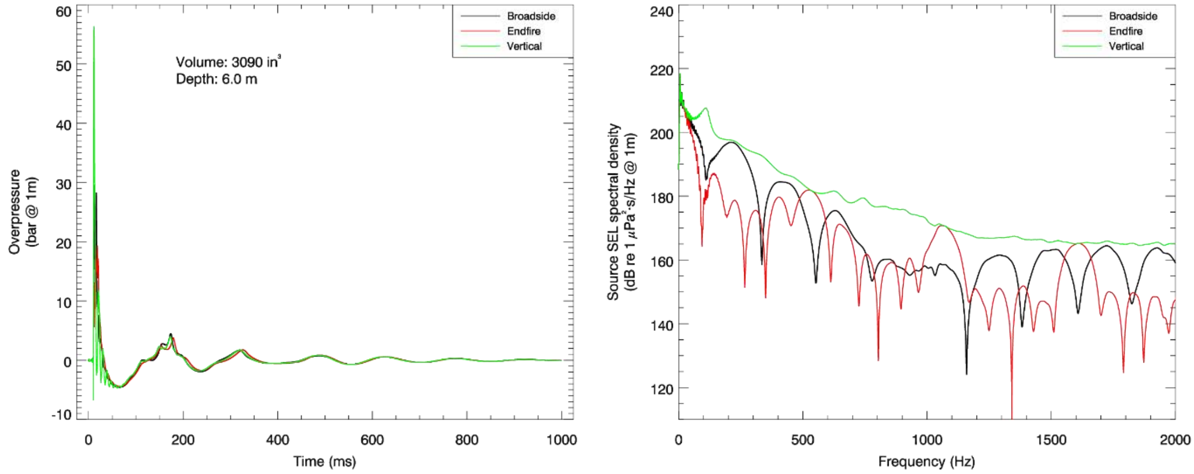


Figure A-3. Predicted source level details for the 3090 in^3 array at 6 m towed depth.(Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions (no surface ghost).

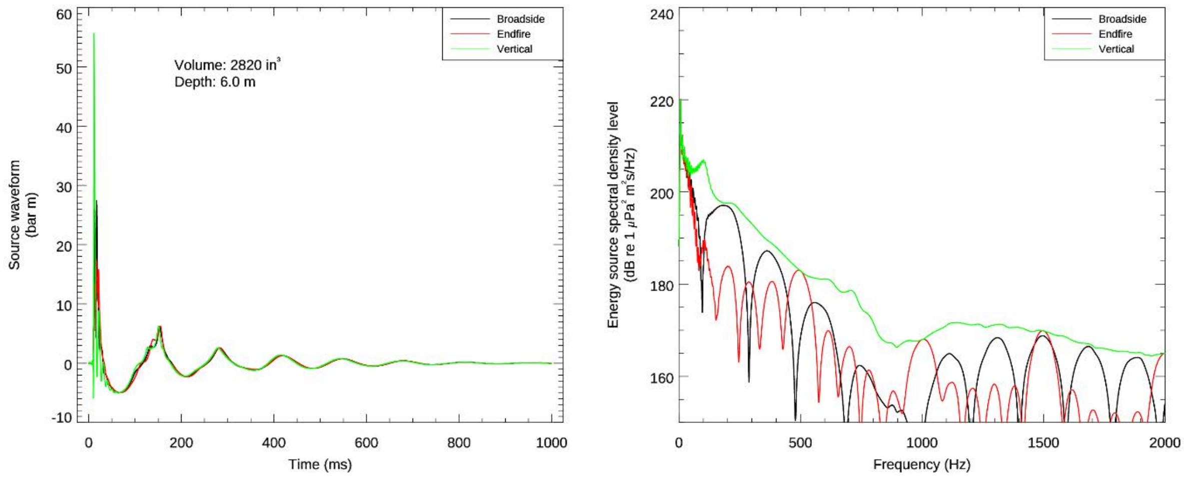


Figure A-4. Predicted source level details for the 2820 in^3 array at 6 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions (no surface ghost).

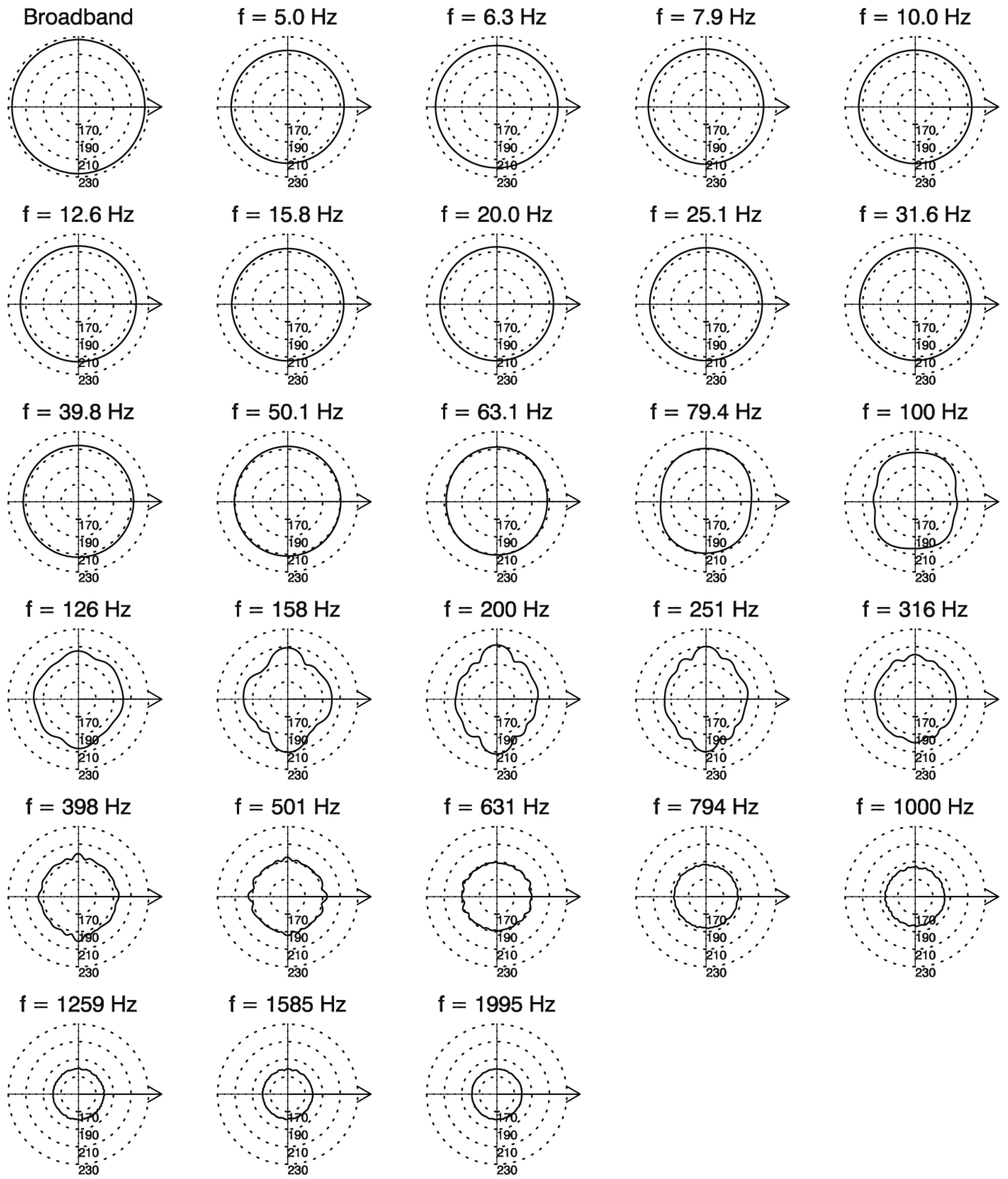


Figure A-5. Directionality of the predicted horizontal source levels for the 3090 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 μPa^2·s m^2) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Tow depth is 6 m (see Figure A-1).

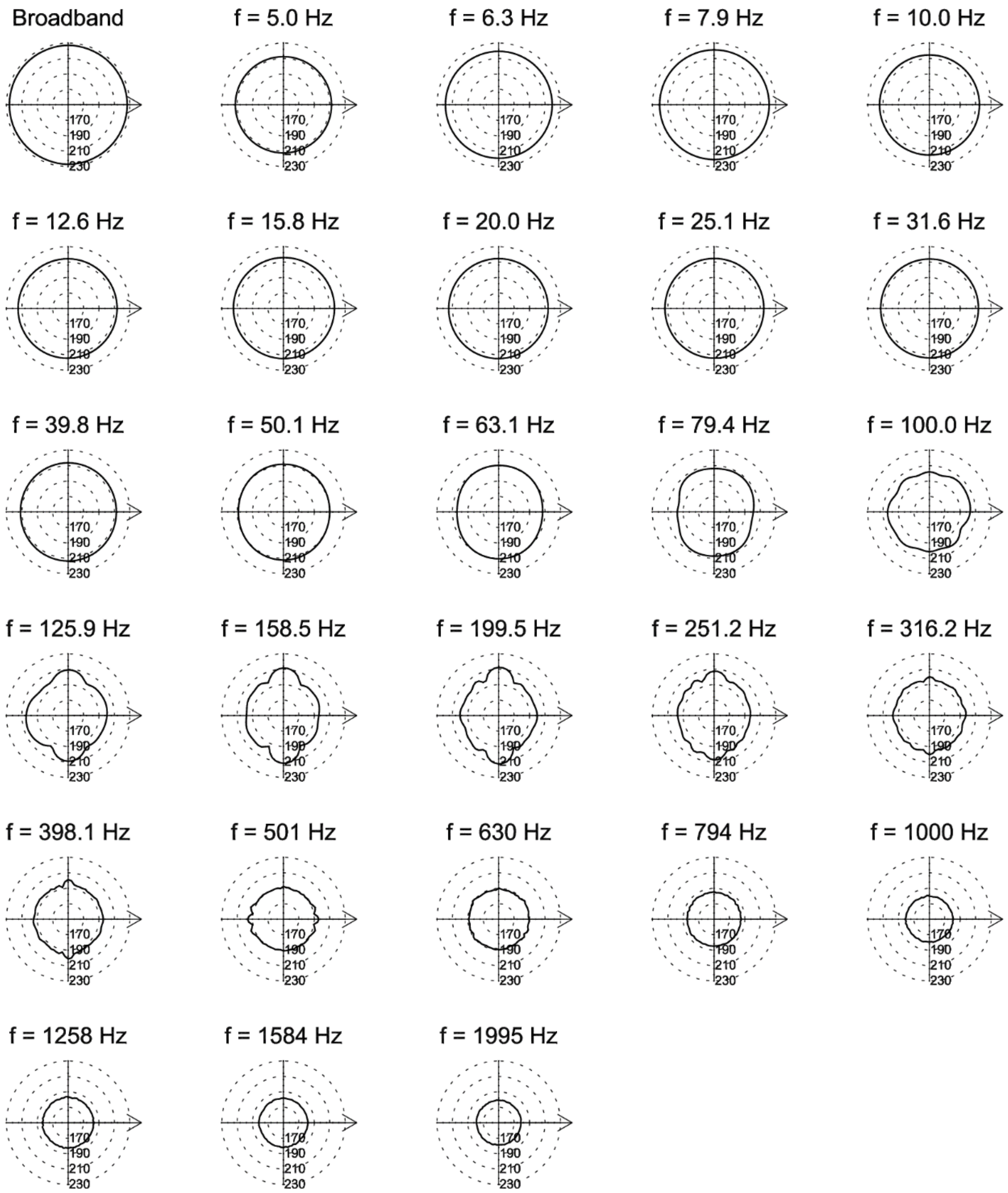


Figure A-6. Directionality of the predicted horizontal source levels for the 2820 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 $\mu Pa^2 \cdot s\ m^2$) are shown as a function of azimuth for the centre frequencies of the decidecade bands modelled; frequencies are shown above the plots. The perpendicular direction to the frame is to the right. Tow depth is 6 m (see Figure A-2).

Appendix F: Hydrocarbon Spill Modelling

Report

29 MAY 2019

3D Oil WA-527-P

Oil Spill Modelling

Document status

Version	Purpose of document	Authored by	Reviewed by	Review date
Rev0	Draft issued for client review	Jeremie Bernard	Nathan Benfer	29 April 2019
Rev1	Final report	Jeremie Bernard	Fernando Alvarez	29 May 2019

Approval for issue

Name	Signature	Date
Nathan Benfer		29 May 2019

Prepared by: **RPS AUSTRALIA WEST PTY LTD**
Suite E1, Level 4
140 Bundall Road
Bundall, QLD 4217
Australia

T: +61 7 5574 1112
E: Jeremie.bernard@rpsgroup.com.au

Prepared for: **ERM AUSTRALIA**
Level 2
5 Mill Street
Perth WA 6000 Australia

T: +61 8 64671654
E: christopher.thomson@erm.com
W: www.erm.com

Author: Jeremie Bernard
Reviewed: Nathan Benfer
Approved: Nathan Benfer
No.: MAQ0793J
Version: Rev1
Date: 29 May 2019

Contents

Tables

Figures

RPS

Terms and Abbreviations

°	Degrees
‘	Minutes
“	Seconds
Actionable oil	Oil which is thick enough for effective use of mitigation strategies, such as mechanical clean up (e.g. skimmers), booms, dispersed, or burned
AMP	Australian marine parks
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute gravity (A measure of how heavy or light a petroleum liquid in comparison to water)
ASTM	American Society for Testing and Materials
Bonn Agreement Oil Appearance Code	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union
°C	Degree Celsius (unit of temperature)
cP	Centipoise (unit of viscosity)
CFSR	Climate Forecast System Reanalysis
cm	Centimetre (unit of length)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions
Dissolved aromatic hydrocarbons	Dissolved hydrocarbons within the water column with alternating double and single bonds between carbon atoms forming rings, containing at least one six-membered benzene ring
g/m^2	Grams per square meter (unit of surface or area density)
EIA	Environmental impact assessment
Entrained oil	Droplets or globules of oil that are physically mixed (but not dissolved) into the water column. Physical entrainment can occur either during pressurised release from a subsurface location, or through the action of breaking waves (>12 knots)
EP	Environmental plan
EEZ	Exclusive Economic Zone
Evaporation	The process whereby components of the oil mixture are transferred from the sea-surface to the atmosphere
GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model is a data-assimilative, three-dimensional ocean model
HYDROMAP	Advanced ocean/coastal tidal model used to predict tidal water levels, current speed and current direction
IOA	Index of Agreement gives a non-dimensional measure of model accuracy or performance
IBRA	Interim Biogeographic Regionalisation for Australia
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
Isopycnal layers	Water column layers with corresponding water densities

ITOPF	The International Tanker Owners Pollution Federation
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
KEF	Key ecological feature
Knot	unit of wind speed (1 knot = 0.514 m/s)
LC_{50}	Median lethal dose. The dose required for mortality of 50% of a tested population after a specified test duration
LGA	Local Government Area
m	Meters (unit of length)
m^2	Meters squared (unit of area)
m^3	Meters cubed (unit of volume)
m/s	Meters per Second (unit of speed)
MAE	Mean Absolute Error is the average of the absolute values of the difference between model predicted and observed data (e.g. surface elevations)
MB	Marine boundary
MNP	Marine National Park
MS	Marine Sanctuary
NASA	National Aeronautics and Space Administration
NCEP	National Centres for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
nm	nautical mile (unit of distance; 1 nm = 1.852 km)
NP	National Parks
Ocean current	Large scale and continuous movement of seawater generated by forces such as breaking waves, wind, the Coriolis effect, and temperature and salinity gradients. It is the main flow of ocean waters
OECD	Organisation for Economic Co-operation and Development
P&A	Plug and abandon
PFW	Produced formation water
PNEC	Predicted no-effect concentration
ppb	Parts per billion (concentration)
ppb.hrs	ppb multiplied for hours (concentration x time)
PSU	Practical salinity units
Ramsar site	A wetland site designated of international importance under the Ramsar Convention
RAMSAR Convention	The Convention on Wetlands, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
Sea surface exposure	Floating oil on the sea surface equal to or above reporting threshold (e.g. 0.5 g/m^2)
Shoreline contact	Stranded oil on the shoreline equal to or above reporting threshold (e.g. 10 g/m^2)
SIMAP	Spill Impact Mapping Analysis Program
US EPA	United States Environmental Protection Agency
Visible oil	Floating oil on the sea surface equal to or above reporting threshold (e.g. 0.5 g/m^2)

EXECUTIVE SUMMARY

Background

3D Oil is seeking approval to undertake a work program consisting of the acquisition and processing of 3-dimensional seismic survey data in permit area WA-527-P, in the offshore Roebuck Basin. In order to obtain environmental approvals for the planned marine seismic survey operations, ERM Australia (ERM) commissioned RPS, on behalf of 3D Oil to undertake a comprehensive oil spill modelling study.

The study considered the following hypothetical, yet plausible scenario:

- A 280 m^3 release of marine diesel oil resulting from a vessel collision incident at the closest point of the operational area to the Rowley Shoals.

SIMAP's stochastic model was used to quantify the probability of exposure to the sea surface and in the water column as well as the probability of shoreline contact from hypothetical spill scenarios. The SIMAP system, the methods and analysis presented herein use modelling algorithms which have been anonymously peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the ASTM Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Methodology

The modelling study was carried out in several stages. Firstly, a five-year current dataset (2008–2012) that includes the combined influence of three-dimensional ocean and tidal currents was developed. Secondly, the currents, spatial winds and then detailed hydrocarbon properties were used as inputs in the oil spill model to simulate the drift, spread, weathering, entrainment and fate of the spilled hydrocarbons.

As spills can occur during any set of wind and current conditions, a total of 100 spill trajectories for the scenario described above and per season (e.g. summer, transitional and winter) were initiated at random times within a 5-year period (2008–2012) to enable a robust statistical analysis.

Each simulation was configurated with the same spill information (i.e. spill volume, duration and oil type) except for the start time and date which in turn, ensures that the predicted transport and weathering of an oil slick is subject to a wide range of current and wind conditions.

Oil Properties

For this oil spill modelling study, a marine diesel oil (MDO) was used to represent the containment loss from a vessel collision scenario. This oil has a density of 829.1 kg/m^3 (API of 37.6), a pour point (-14^oC) and a viscosity of 4cP which indicate that this oil will spread quickly when released on the sea surface and will form a thin to low thickness film, increasing the rate of evaporation. The oil is categorised as a group II oil (light-persistent) based on categorisation and classification derived from AMSA (2015a) guidelines.

Key Findings

Scenario: Containment loss from a vessel collision

- No shoreline contact above the low (10 g/m^2) threshold was predicted for the scenario;
- Modelling results demonstrated that surface oil at low (1 g/m^2), moderate (10 g/m^2) and high (25 g/m^2) exposure levels could potentially travel greater distances during the transitional period, compared to the summer and winter periods. The maximum distance travelled by surface oil for the low, moderate and high threshold was 66 km, 14 km and 7km, respectively.
- While the low exposure surface oil was predicted to travel in any directions from the release site, surface oil above the moderate and high exposure levels remained along the northwest to southeast axis across all seasons.

- The evaporative nature of MDO and environmental conditions in the area resulted in short-lived surface hydrocarbon exposure, with surface exposure reduced to less than 10 g/m^2 after approximately 12-24 hours.
- The modelling results demonstrated a low likelihood (1-2%) of low surface oil exposure to the Argo-Rowley Terrace Australian Marine Park.
- The maximum time-averaged exposure to dissolved hydrocarbon over 48 hours remained less than 1 ppb for the winter and transitional seasons while reaching 4 ppb for the summer and winter seasons for various receptors. These concentrations are below the defined low threshold for dissolved hydrocarbons.
- The maximum instantaneous exposure to dissolved hydrocarbons ranged from 6 ppb to 73 ppb for the transitional and summer seasons, respectively. None of the receptors was exposed at the moderate (50 ppb) or high (400 ppb) thresholds or above for instantaneous exposure with the exception of the IMCRA – North West Shelf. This receptor had a 1 % probability of exposure to instantaneous dissolved hydrocarbon during the summer season.
- The maximum time-averaged exposure over 48 hours to entrained hydrocarbons ranged from 4 ppb to 499 ppb for the transitional and winter seasons respectively.
- The maximum instantaneous exposure to entrained hydrocarbon was 6,287 ppb for the Northwest Shelf IMCRA during the summer.

1 INTRODUCTION

3D Oil is seeking approval to undertake a work program consisting of the acquisition and processing of 3-dimensional seismic survey data in permit area WA-527-P, in the offshore Roebuck Basin (Figure 1). In order to obtain environmental approvals for the planned marine seismic survey operations, ERM Australia (ERM) commissioned RPS, on behalf of 3D Oil to undertake a comprehensive oil spill modelling study.

The study considered the following hypothetical, yet plausible scenario:

- A 280 m^3 release of marine diesel oil resulting from a vessel collision incident at the closest point of the operational area to the Rowley Shoals.

Table 1 Location of the release site.

Release site	Latitude	Longitude	Water Depth (m)
Release site	-17°56"17.0'	119°30"14.8'	160

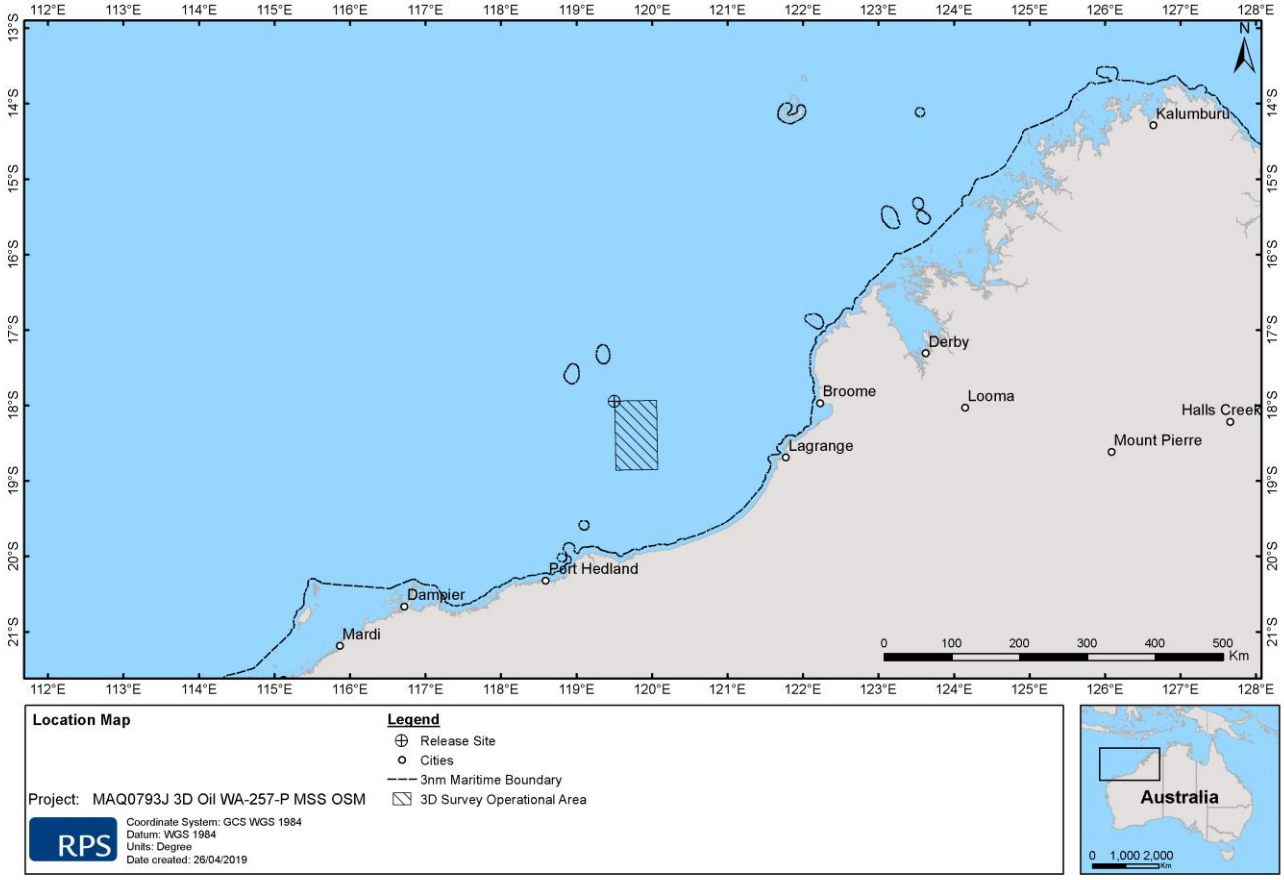


Figure 1 Locality map

2 SCOPE OF WORK

The scope of work will include the following components:

- Generate tidal current patterns of the region using the ocean/coastal model, HYDROMAP;
- Use HYCOM (Hybrid Coordinate Ocean Model) ocean currents combined with HYDROMAP tidal currents over a 5-year period (2008 to 2012) to account for large scale flows offshore and tidal flows nearshore;
- Use 5 years of high-resolution wind, aggregated current data and site-specific oil characteristics as input into the 3-dimensional oil spill model to represent the movement, spreading, entrainment, weathering of the oil over time;
- Use SIMAP's stochastic model (also known as a probability model) to calculate exposure to surrounding waters (sea surface and water column) and shorelines. This will involve running 100 randomly selected single trajectory simulations for each season, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but varying start times. This will ensure that each spill trajectory is subjected to unique wind and current conditions.

3 REGIONAL CURRENTS

The permit area is located within the offshore Roebuck Basin, on the central North West Shelf, a shallow (generally <100 m) waterbody bordered by the Indian Ocean and Timor Sea. The North West Shelf is characterised by complex geomorphological features such as shoals, valleys and terraces and is dominated by high-amplitude tides and seasonally-dependant wind driven currents (DEWHA, 2007).

Although the Indonesian Throughflow and Holloway current generate south-westerly flows all year-round, warm and less saline waters originating from the tropics can generate internal gyres that typically migrate through the area and result in large variation in the speed and direction of local currents. The Holloway current generally intensifies during April to July due to increased wind forcing.

A comprehensive description of the circulation patterns of the Northwest Shelf and Bonaparte Gulf is provided in a review by Condie and Andrewartha (2008) and a schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 2.

While, tidal currents are generally weaker in the deeper waters, its influence is greatest along the near shore and around islands. Therefore, to accurately account for the movement of an oil spill, which can move between the offshore and near shore region, ocean and tidal currents were combined as part of the study.

Figure 3 and Figure 4 present summer and winter current trends within the Roebuck Basin and the southern section of the North West Shelf.

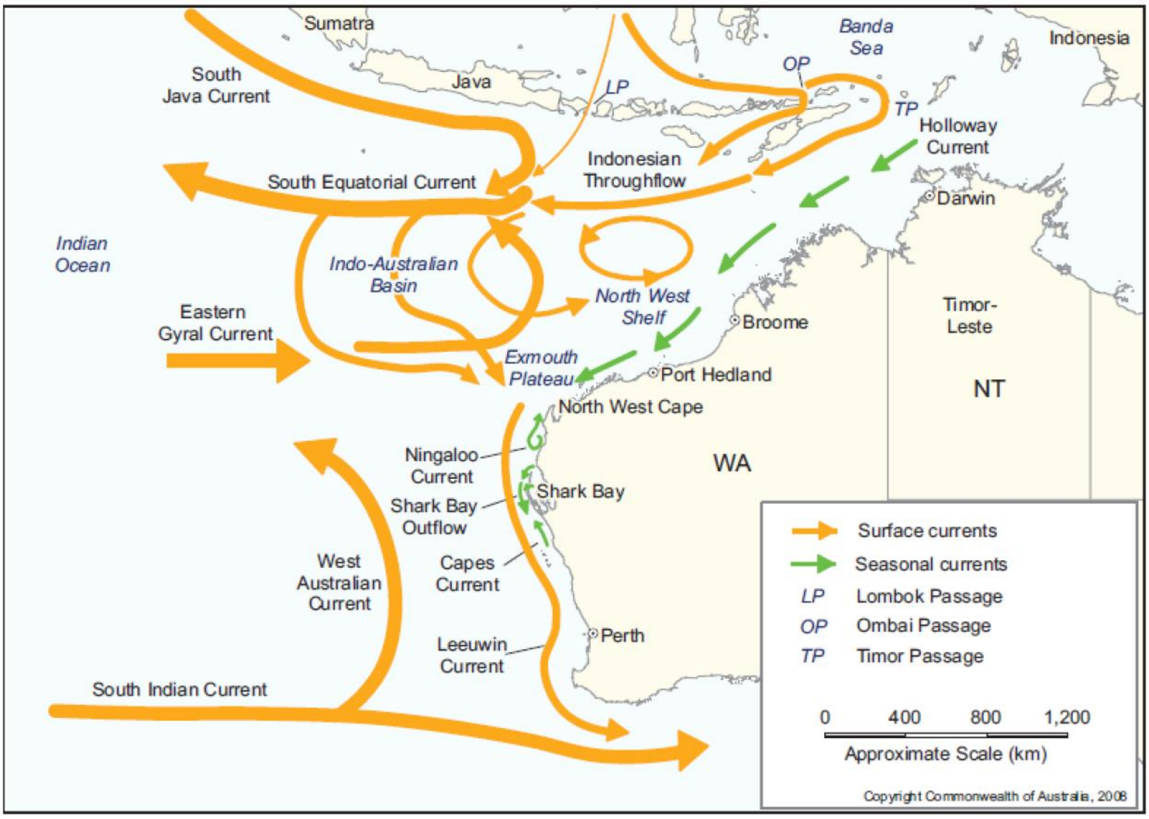


Figure 2 Schematic of ocean currents along the Northwest Australian continental shelf. Image adapted from DEWHA (2008).

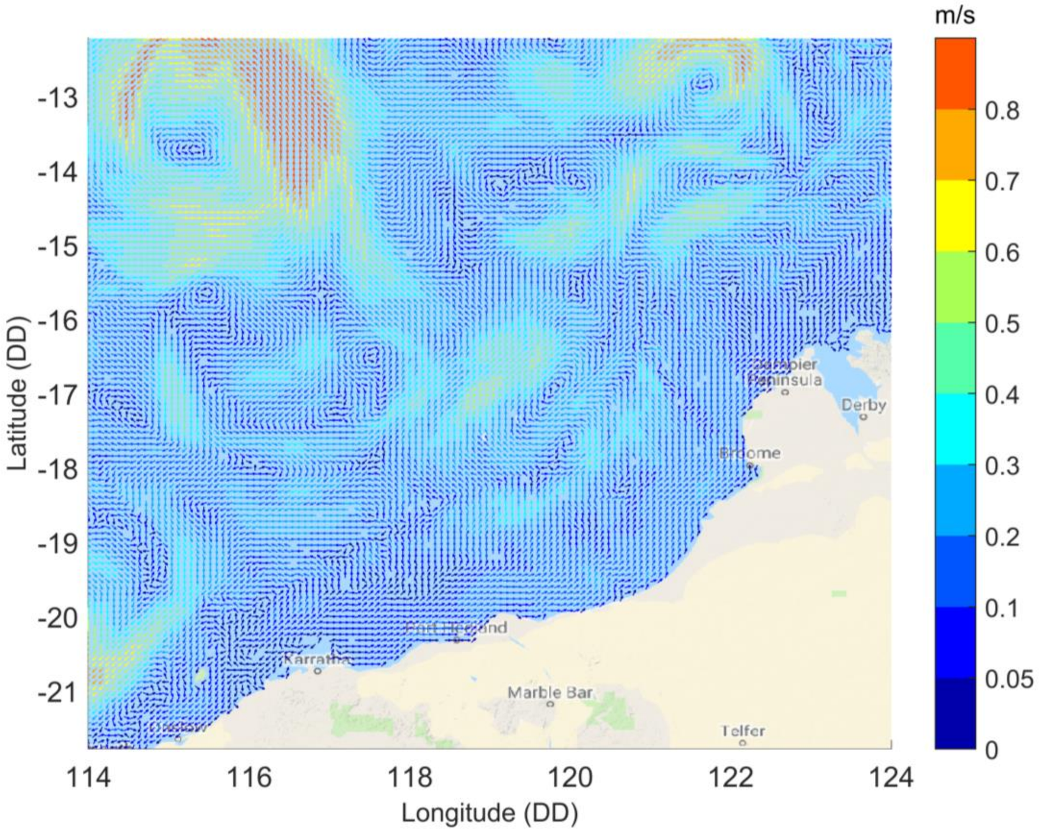


Figure 3 **Typical ocean current circulation pattern during the summer months.**

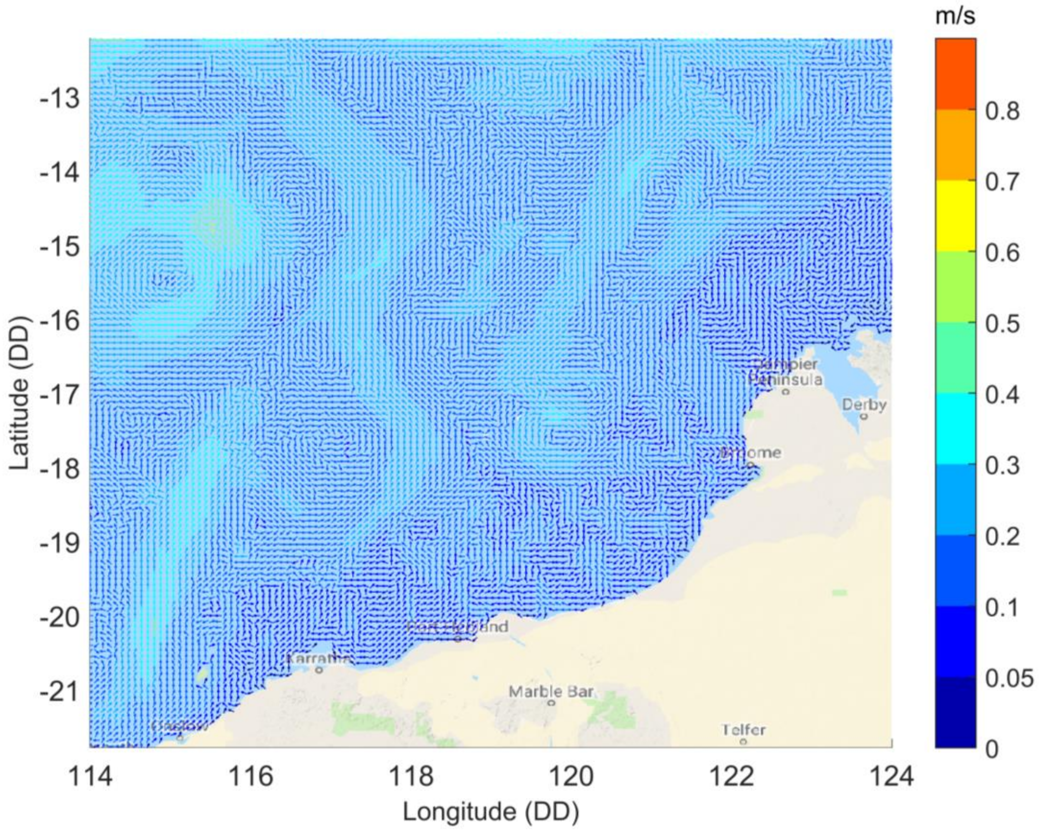


Figure 4 **Typical ocean current circulation pattern during the winter months.**

3.1 Tidal Currents

Tidal current data was generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over the past 32 years (Isaji & Spaulding, 1984; Isaji, et al., 2001; Zigic, et al., 2003). HYDROMAP tidal current data has been used as input to forecast (in the future) and hindcast (in the past) pollutant spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by AMSA (Australian Maritime Safety Authority).

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

3.1.1 Grid Setup

RPS has a seamless global tidal model calibrated to modelled and measured (when available) tidal data around the world. The tidal domains are sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grids were allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over regions with more complex bathymetry. Figure 5 shows the tidal model grid covering the study domain.

A range of datasets were sourced and merged to describe the shape of the seabed within the grid domain. These included spot depths and contours which were digitised from nautical charts released by the hydrographic offices as well as Geoscience Australia database and depths extracted from the Shuttle Radar Topography Mission (SRTM30_PLUS) Plus dataset (see Becker et al., 2009).

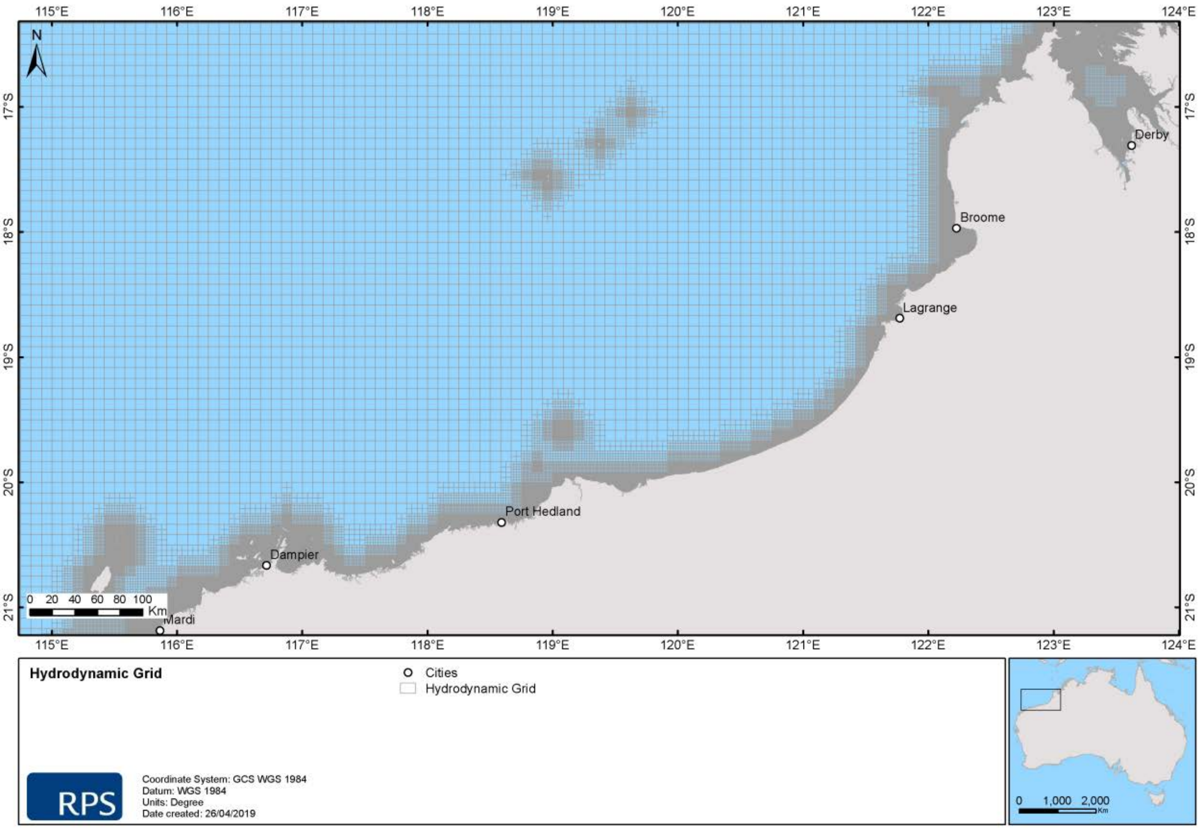


Figure 5 Map showing the regions of sub-gridding for the study area.

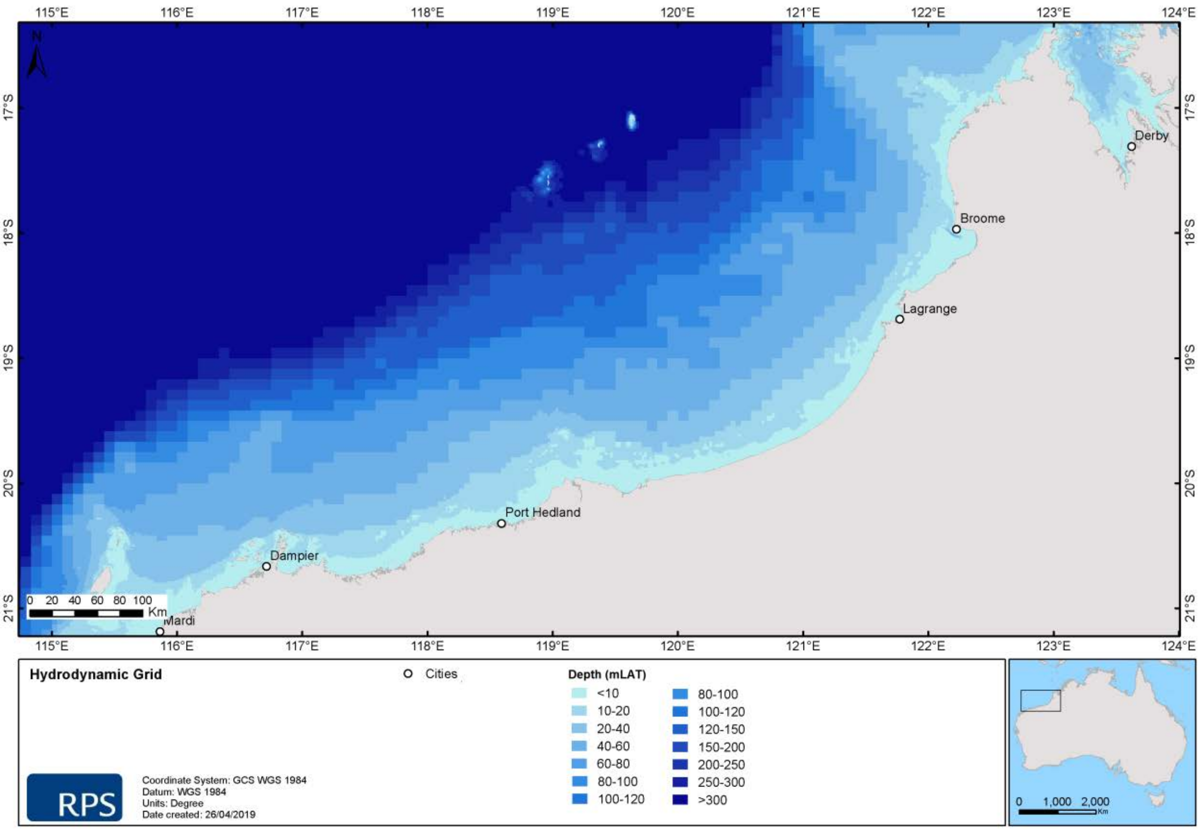


Figure 6 Bathymetry defined throughout the tidal model domain.

RPS

3.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The TOPEX/Poseidon satellite data has a global resolution of 0.25 degrees and is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites equipped with two highly accurate altimeters and capable of taking sea level measurements with an accuracy of ± 5 cm measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total, these satellites carried out 62,000 orbits of the planet.

The TOPEX/Poseidon tidal data has been widely used amongst the oceanographic community, being included in more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the TOPEX/Poseidon tidal data is considered suitably accurate for this study.

3.1.3 Surface Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at eight locations (see Figure 7).

To provide a statistical measure of the model performance, the Index of Agreement (IOA - Willmott (1981)) and the Mean Absolute Error (MAE - Willmott (1982) and Willmott and Matsuura (2005)) were used.

The MAE (Eq.1) is simply the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error (Willmott and Matsuura, 2005) and more readily understood. The MAE is determined by:

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i| \qquad \text{Eq.1}$$

Where: N = Number of observations

P_i = Model predicted surface elevation

O_i = Observed surface elevation

The Index of Agreement (IOA; Eq. 2) in contrast, gives a non-dimensional measure of model accuracy or performance. A perfect agreement between the model predicted and observed surface elevations exists if the index gives an agreement value of 1, and complete disagreement between model and observed surface elevations will produce an index measure of 0 (Wilmott, 1981). Willmott et al (1985) also suggests that values larger than 0.5 may represent good model performance. The IOA is determined by:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2} \qquad \text{Eq.2}$$

Where: X_{model} = Model predicted surface elevation

X_{obs} = Observed surface elevation

Clearly, a greater IOA and lower MAE represent a better model performance.

Figure 8 and Figure 9 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graph, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles.

Table 2 Statistical comparison between the observed and predicted surface elevations.

Tide Station	IOA	MAE (m)
Broome	0.90	1.11
Lagrange Bay	0.96	0.71
Lynher Bank	0.98	0.31
Port Hedland	0.98	0.33
Port Walcott	0.99	0.20
Red Bluff	0.98	0.46

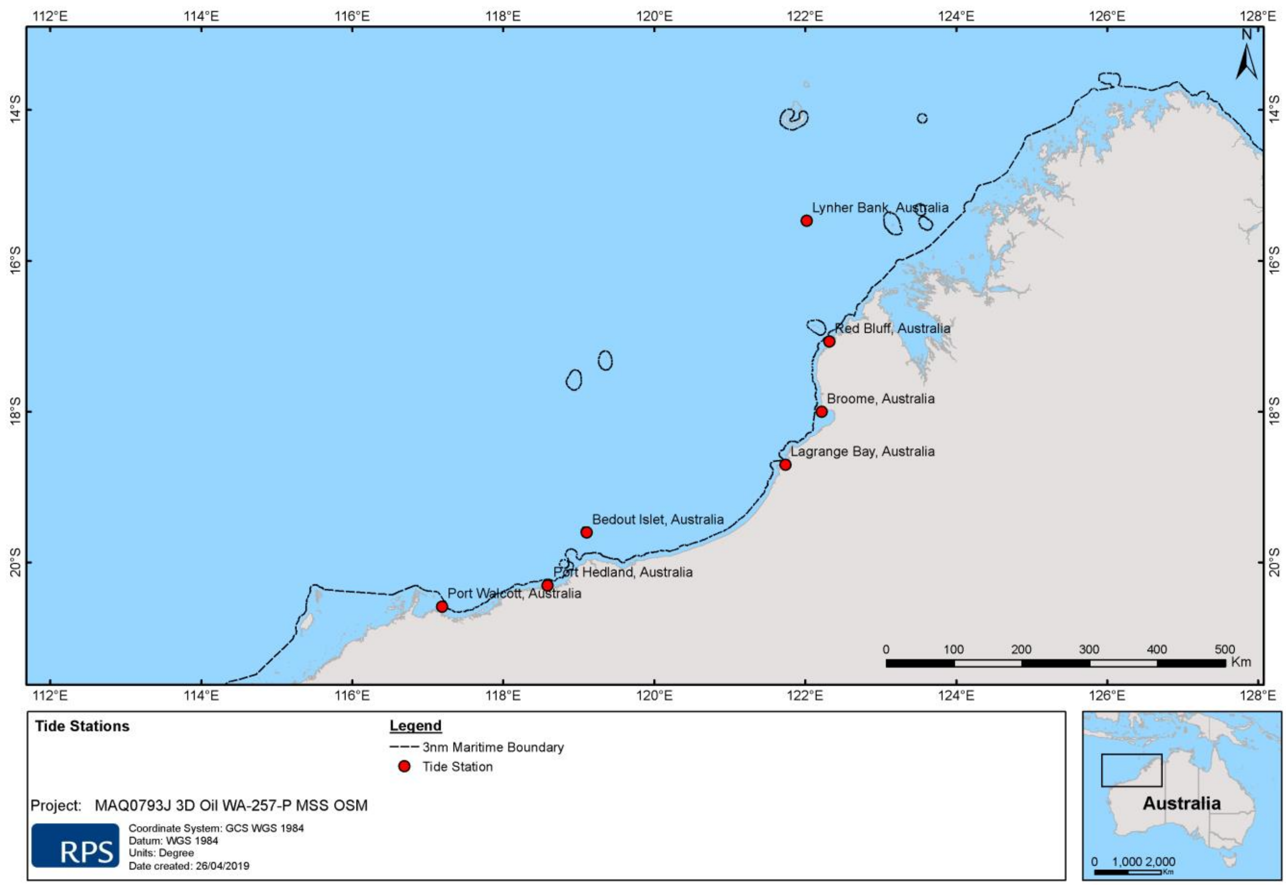


Figure 7 Tide stations used to calibrate surface elevation within the model.

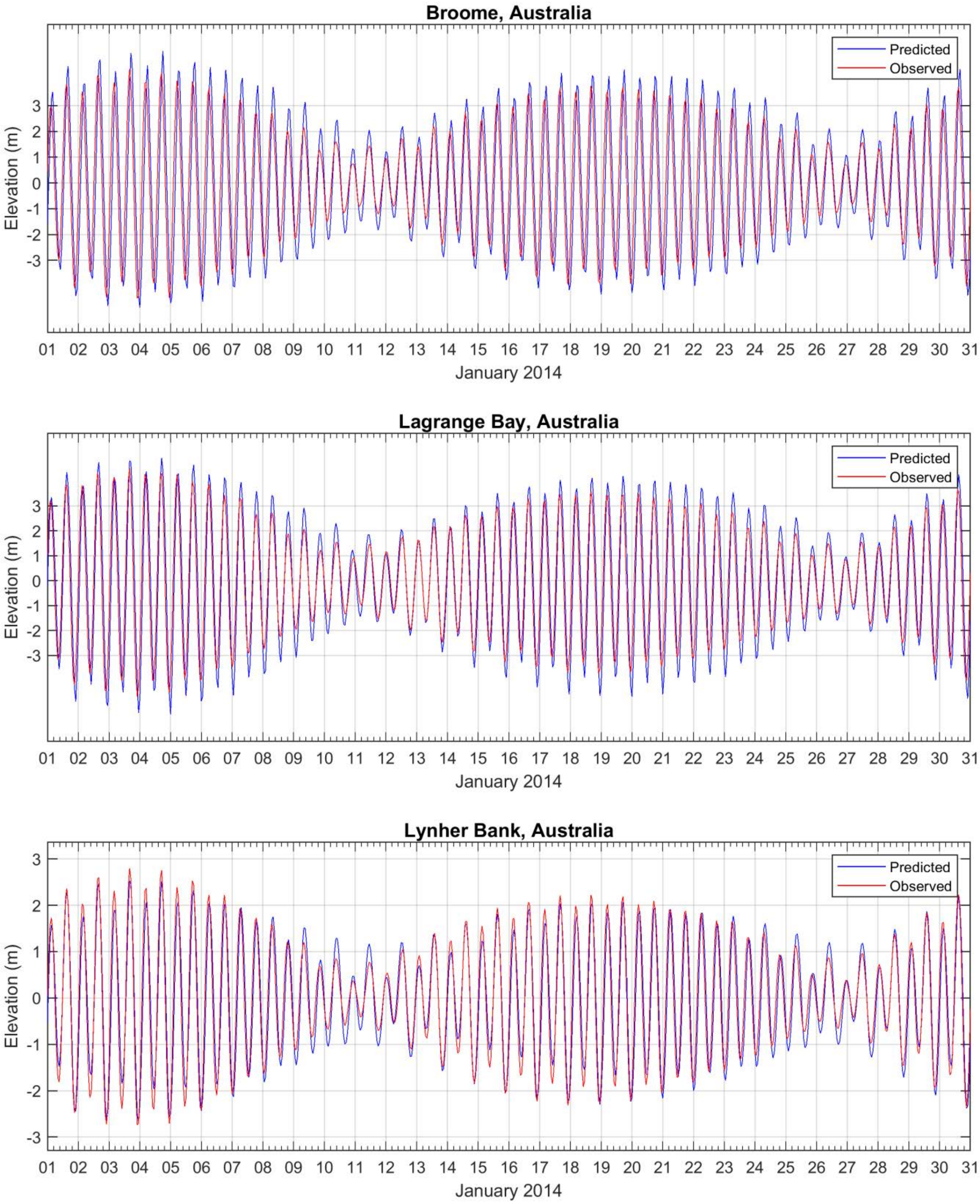


Figure 8 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

RPS

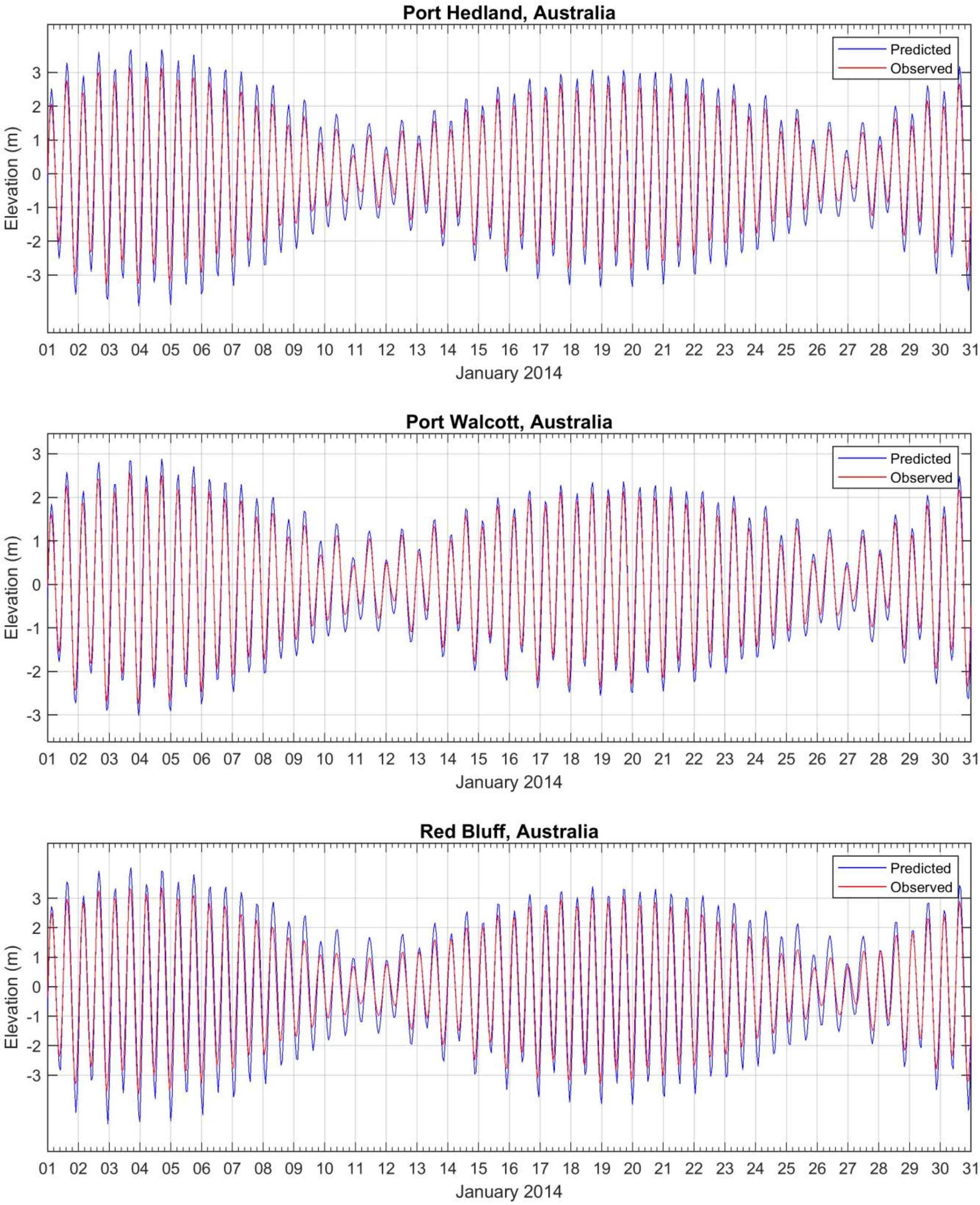


Figure 9 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation.

3.2 Ocean Currents

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea surface height, sea surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009). The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km (1/12th of a degree) over the region, at a frequency of once per day. HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the HYCOM reanalysis hindcast currents were obtained for the years 2008 to 2012 (inclusive).

3.3 Surface Currents at the release site

Table 3 displays the predicted average and maximum surface current speed near the release site. Figure 10 illustrates the monthly current rose distributions (2008-2012 inclusive) derived from combining HYCOM ocean current data and HYDROMAP tidal data.

Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen bins of 22.5° each are used to describe the current direction. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are predominantly used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

The combined current data (ocean plus tides) demonstrated that the release site is situated in a dynamic environment, with waters flowing along a predominant northwest to southeast axis all year-round. Monthly average surface current speed ranged between 0.30 m/s (December) and 0.38 m/s (March, May and September) while maximum surface current speed peaked at 1.26 m/s in February.

Table 3 Predicted monthly average and maximum surface current speeds adjacent to the release location. Data derived by combining the HYCOM ocean data and HYDROMAP high resolution tidal data from 2008-2012 (inclusive).

Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction (towards)
January	0.34	0.95	NNW – SE
February	0.36	1.26	NNW – SE
March	0.38	1.24	NW – SSE
April	0.37	0.95	NW – SSE
May	0.38	1.15	WNW – SSE
June	0.32	0.80	WNW – SSE
July	0.35	0.93	NW – SW
August	0.36	1.03	NW – SE
September	0.38	1.04	NW – SE
October	0.35	1.06	NW – SE
November	0.32	0.84	NNW – SE
December	0.30	0.87	NW – SE
Minimum	**0.30**	**0.80**	
Maximum	**0.38**	**1.26**	

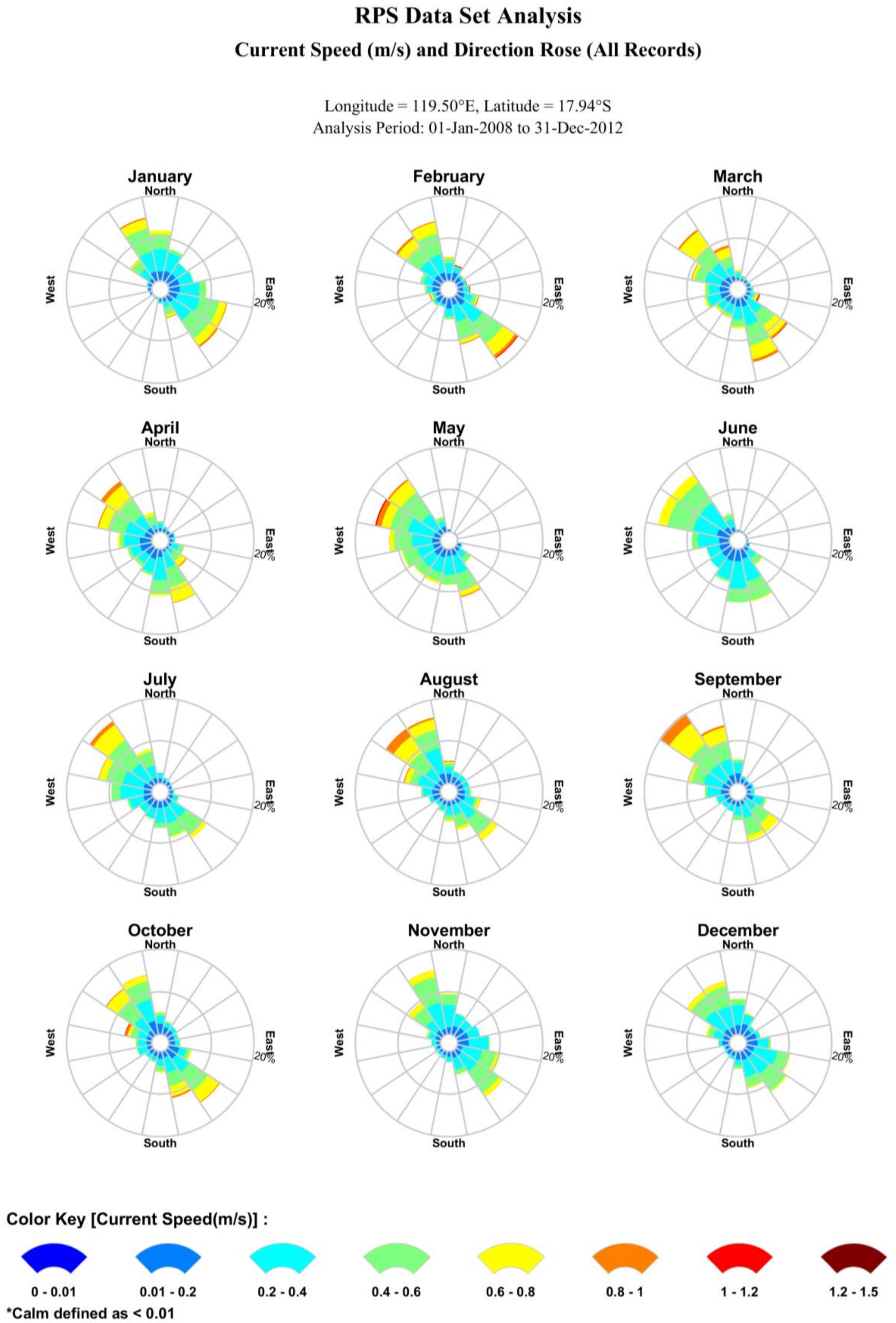


Figure 10 Monthly surface current rose plots near the release location (derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2008 – 2012 inclusive).

4 WIND DATA

High resolution wind data was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010) from 2008 to 2012 (inclusive).The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations and is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. Figure 11 shows the spatial resolution of the wind field used as input into the oil spill model. Table 4 shows the monthly average and maximum winds derived from the CFSR node located adjacent to the release site. Figure 12 to Figure 14 show the monthly, seasonal and annual wind rose distributions, respectively.

Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen bins of 22.5° each are used to describe the wind direction. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 3 knot intervals, excluding the calm and near calm conditions are used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

Table 4 illustrates predicted average and maximum wind velocities as well as general direction for each month. The data indicated that winds are generally stronger during the summer months as a result of easterly trade winds, reaching a maximum of 58 knots in March. Monthly average wind velocities oscillated between 8 knots (April) and 13 knots (July).

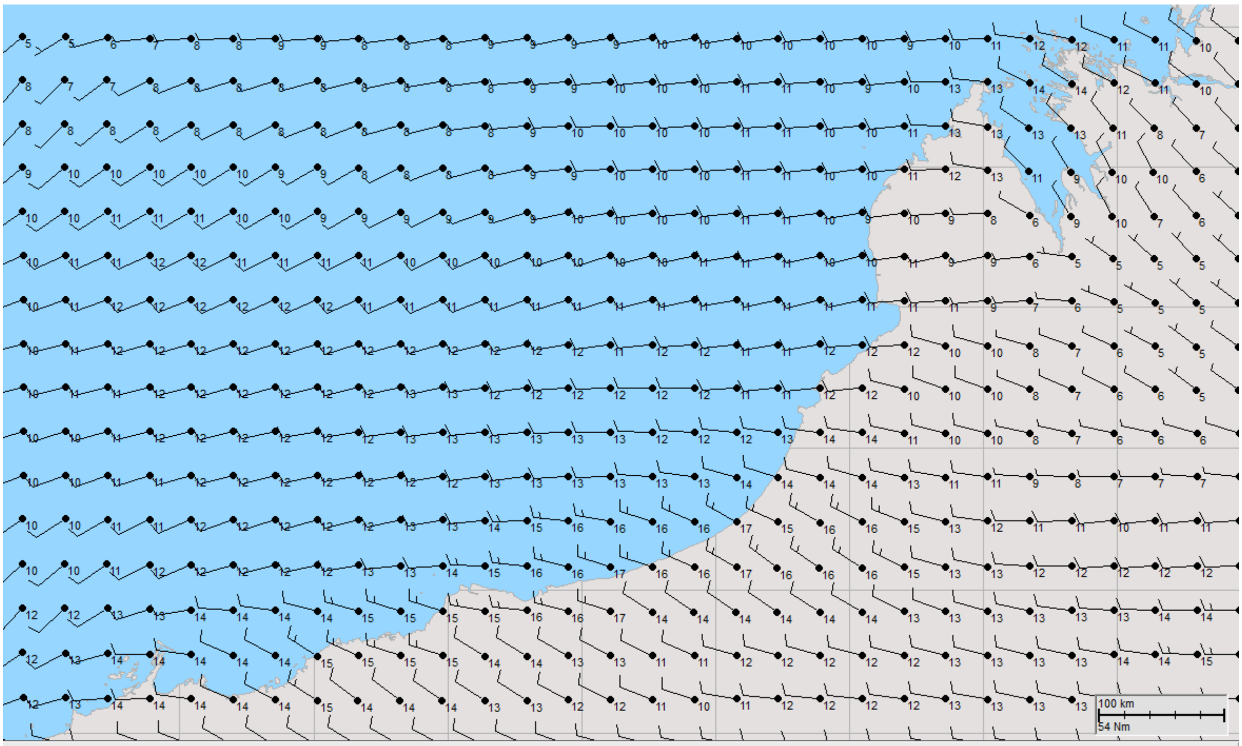


Figure 11 Sample of the CFSR modelled wind data

RPS

Table 4 Predicted monthly average and maximum winds for the wind node adjacent to the release location. Data derived from CFSR hindcast model from 2008-2012 (inclusive).

Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
January	11	35	W
February	11	47	W
March	9	58	Variable
April	8	27	Variable
May	13	32	ESE
June	13	30	ESE
July	13	29	ESE
August	11	29	ESE
September	11	31	Variable
October	10	25	WSW
November	10	27	WSW
December	11	36	W
Minimum	**8**	**25**	
Maximum	**13**	**58**	

RPS

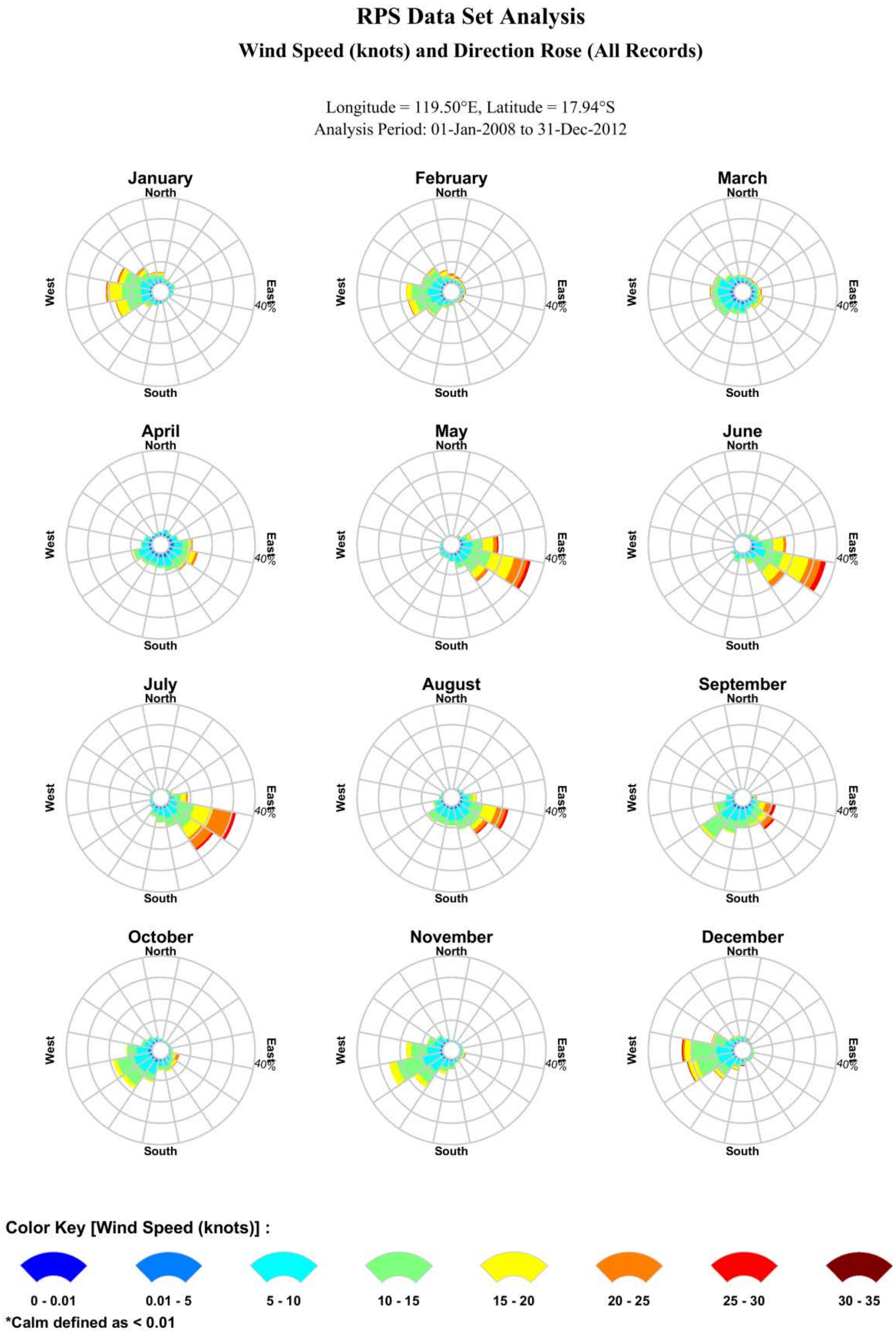


Figure 12 Monthly wind rose distributions derived from the CFSR model from 2008–2012 (inclusive), for the nearest wind node to the release site.

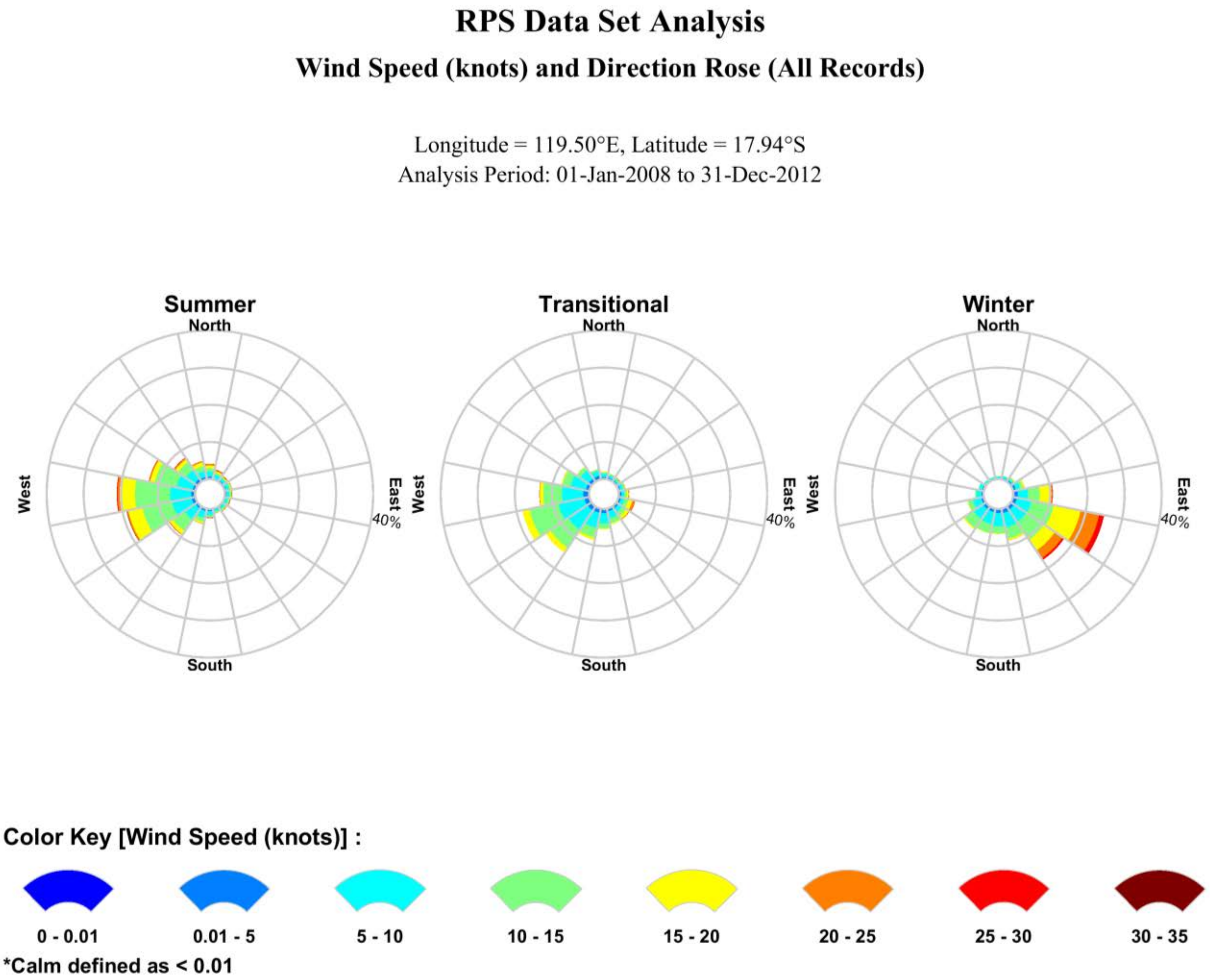


Figure 13 Seasonal wind rose distributions derived from the CFSR model from 2008–2012 (inclusive), for the nearest wind node to the release site.

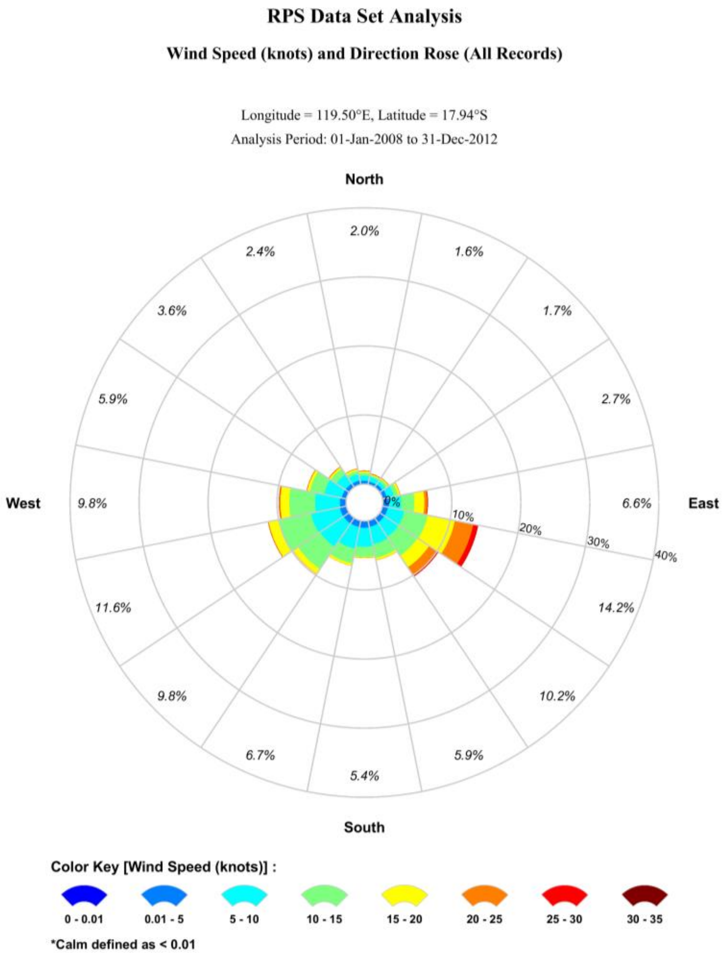


Figure 14 Annual wind rose distributions derived from the CFSR model from 2008–2012 (inclusive), for the nearest wind node to the release site.

RPS

5 WATER TEMPERATURE AND SALINITY

The monthly sea temperature and salinity profiles of the water column adjacent to the release site was obtained from the World Ocean Atlas 2013 (WOA13) produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) (see Levitus et al., 2013).

To account for depth-varying sea temperature and salinity the modelling used monthly average sea temperature and salinity profiles at 5 m intervals through the water column (refer to Figure 15).

Table 5 details the monthly average sea surface temperatures and salinity (0-5 m depth layer). Monthly average sea surface temperatures were shown to range from 25.2°C (September) and 30.2°C (March). Salinity remained consistent throughout the year ranging from 34.3 to 35.0 psu.

Table 5 Monthly average sea surface temperature and salinity in the 0–5 m depth layer near the release site

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	30.0	29.9	30.2	29.5	27.7	28.1	25.4	25.3	25.2	26.7	28.1	28.8
Salinity (psu)	34.8	34.6	34.6	34.8	34.5	34.8	34.3	34.7	34.6	34.7	35.0	34.9

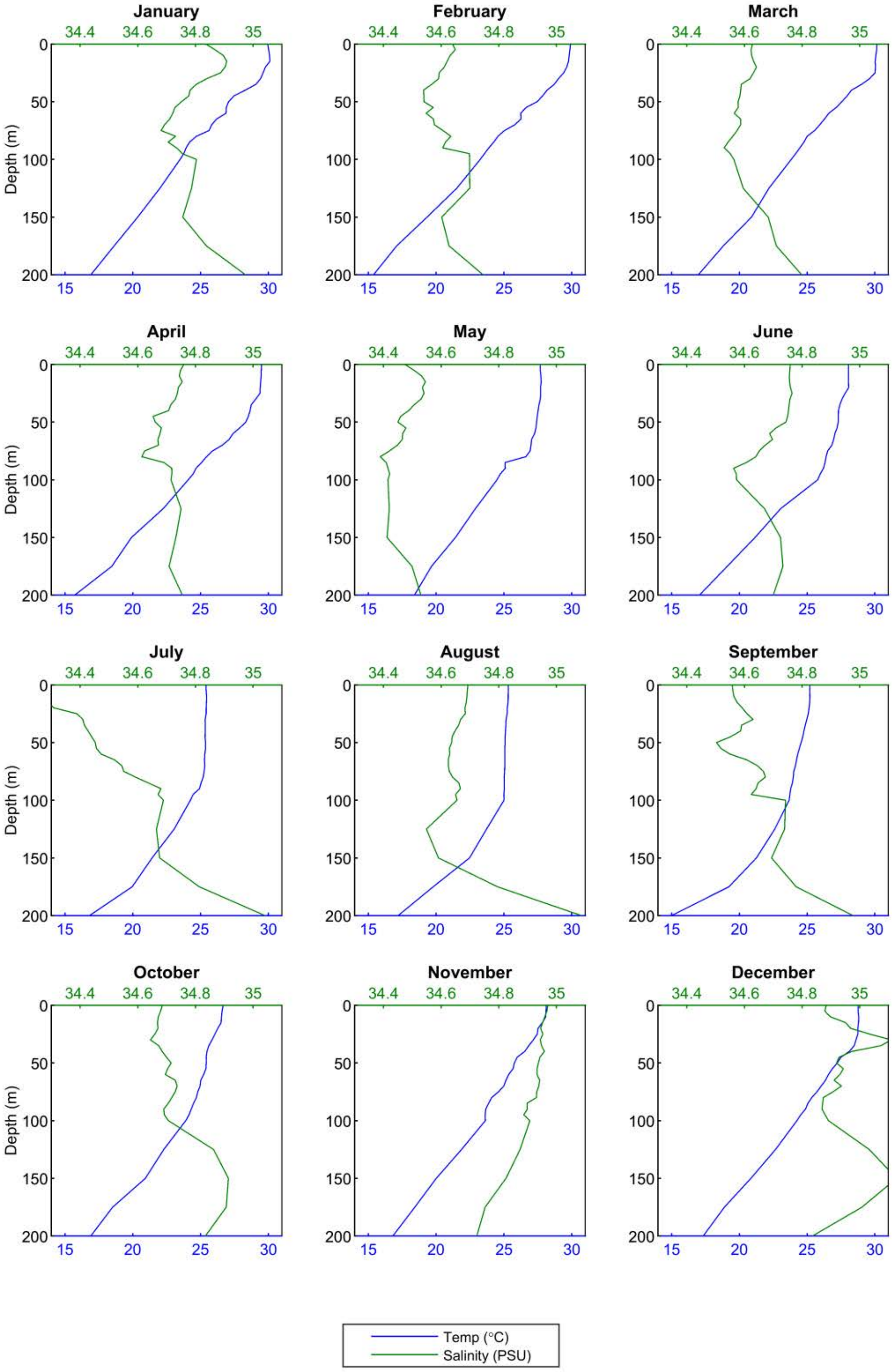


Figure 15 Monthly water temperature and salinity profiles near the release site.

RPS

6 OIL SPILL MODEL – SIMAP

The oil spill modelling was performed using SIMAP. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for both the surface and subsurface releases (Spaulding et al., 1994; French et al., 1999; French-McCay, 2003; French-McCay, 2004; French-McCay et al., 2004; Spaulding, et al., 2015).

The SIMAP model calculates two components: (i) the transport, spreading, entrainment, evaporation and decay of surface oil slicks and, (ii) the entrained and dissolved hydrocarbons released from the slicks into the water column. Input specifications for oil-types include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

The SIMAP trajectory model separately calculates the movement of the material that: (i) is on the water surface (as surface slicks), (ii) in the water column (as either entrained whole oil droplets or dissolved hydrocarbon), (iii) has stranded on shorelines, or (iv) that has precipitated out of the water column onto the seabed. The model calculates the transport of surface slicks from the combined forces exerted by surface currents and wind acting on the oil. Transport of entrained oil (oil that is below the water surface) is calculated using the currents only.

6.1 Stochastic Modelling

SIMAP's stochastic model was used to quantify the probability of exposure to the sea surface and in-water and probability of shoreline contact from hypothetical spill scenarios.

As spills can occur during any set of wind and current conditions, a total of 100 spill per season (e.g. summer, transitional and winter) were initiated at random times within a 5-year period (2008–2012) to enable a robust statistical analysis.

Each simulation was configurated with the same spill information (i.e. spill volume, duration and oil type) except for start the time and date. This approach ensures that the predicted transport and weathering of an oil slick is subject to a wide range of current and wind conditions.

During each spill trajectory, the model records the grid cells exposed to hydrocarbons, as well as the time elapsed. Once all the spill trajectories have been run, the model then combines the results from the individual simulations to determine the following:

- Maximum exposure (or load) observed on the sea surface;
- Minimum time before sea surface exposure;
- Probability of contact to any shorelines;
- Probability of contact to individual sections of shorelines;
- Maximum volume of oil that may contact shorelines from a single simulation;
- Maximum load that an individual shoreline may experience;
- Maximum exposure from entrained hydrocarbons observed in the water column; and
- Maximum exposure from dissolved aromatic hydrocarbons observed in the water column.

The stochastic model output does not represent the extent of any one spill trajectory (which would be significantly smaller) but rather provides a summary of all trajectories run for the scenario.

6.2 Sea surface, Shoreline and In-Water Exposure Thresholds

The sea surface, shoreline and in-water exposure thresholds used to assess the oil spill modelling results and generate statistical tables and spatial maps were communicated by the client and are summarised in Table 6.

Table 6 Exposure threshold values requested by ERM

Exposure level	Sea Surface Exposure (g/m^2)	Shoreline Contact (g/m^2)	Dissolved Hydrocarbon Concentration (ppb)#	Entrained Hydrocarbon Concentrations (ppb)#
Low	1	10	6	10
Moderate	10	100	50	100
High	25	1,000	400	1,000

#These threshold values refer to a) instantaneous concentrations (i.e. exposure over a 1-hour timestep) and b) time-averaged exposure over a 48-hour window. Both sets of results are provided in the Result Section(s).

6.3 Oil Properties

6.3.1 Marine Diesel Oil

Marine Diesel Oil (MDO) is a light-persistent fuel oil used in the maritime industry. It has a density of 829.1 kg/m^3 (API of 37.6) and a low pour point (-14°C). The low viscosity (4cP) indicates that this oil will spread quickly when released and will form a thin to low thickness film on the sea surface, increasing the rate of evaporation. The oil is categorised as a group II oil (light-persistent) based on categorisation and classification derived from AMSA (2015a) guidelines. The classification is based on the specific gravity of hydrocarbons in combination with relevant boiling point ranges.

Table 7 details the physical properties of MDO, while Table 8 presents the boiling point ranges of the MDO used in this study.

Figure 16 shows weathering graphs for a 280 m^3 release of MDO over 6 hours (tracked for 30 days) during three static wind conditions.

The prevailing weather conditions will influence the weathering and fate of the MDO. Under lower wind-speeds (5 knots), the MDO will remain on the surface longer, spread quicker, and in turn increase the evaporative process. Conversely, sustained stronger winds (>15 knots) will generate breaking waves at the surface, causing a higher amount of MDO to be entrained into the water column and reducing the amount available to evaporate.

Table 7 Physical properties of Marine Diesel Oil

Characteristic	Marine Diesel Oil (MDO)
Density (kg/m^3)	829.1
API	37.6
Dynamic viscosity (cP)	4
Pour Point (°C)	-14
Wax content (%)	1
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light - Persistent

Table 8 Boiling point ranges of Marine Diesel Oil

Characteristic	Not Persistent			Persistent
	Volatile	Semi-volatile	Low volatility	Residual
Boiling point (ºC)	< 180	180 - 265	265 - 380	>380
Marine Diesel Oil	*6.0*	*34.6*	*54.4*	*5.0*

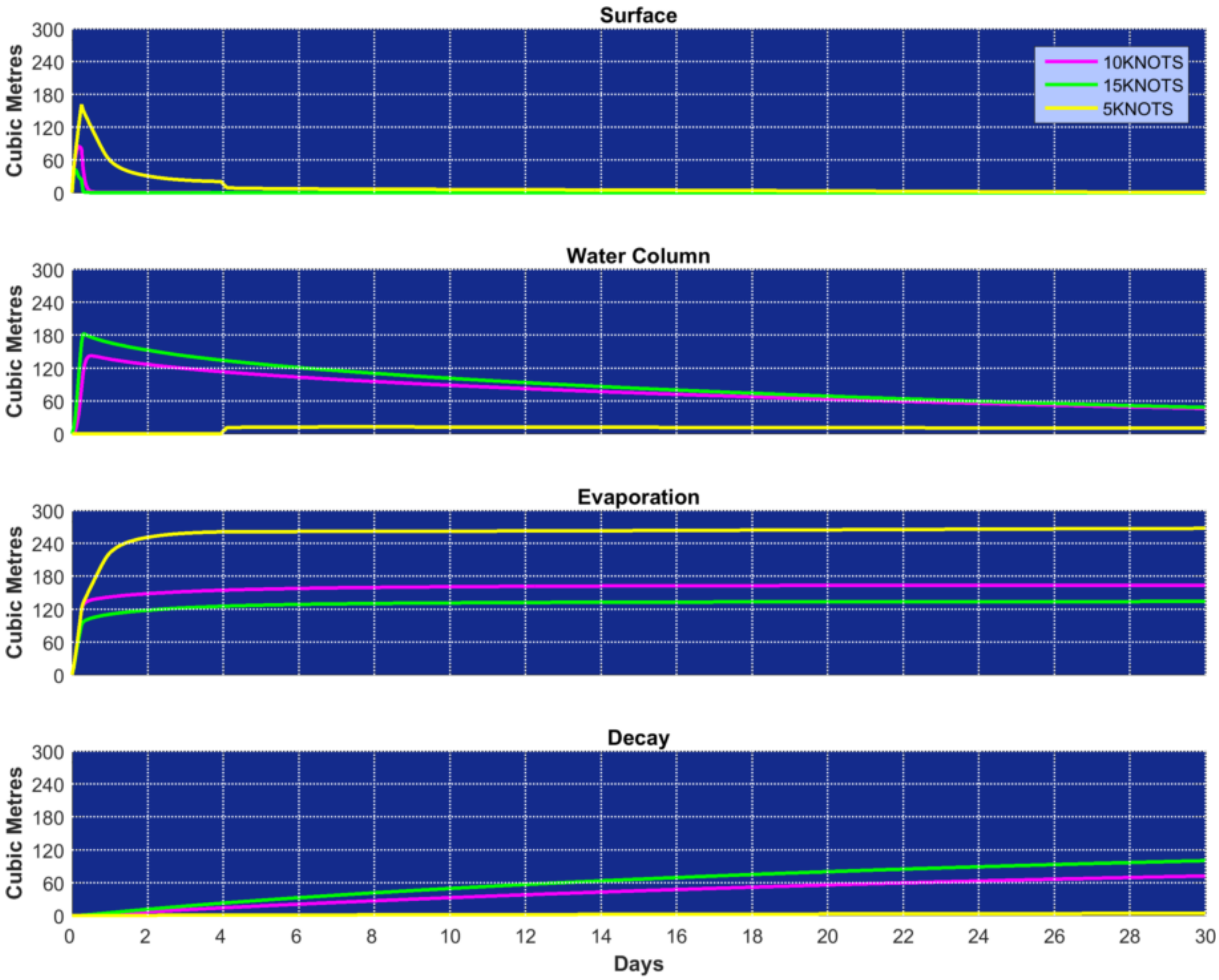


Figure 16 Weathering of MDO under three static winds conditions (5, 10 and 15 knots). The results are based on a 280 m³ surface release of MDO over 6 hours and tracked for 30 days.

6.4 Model Settings

This oil spill modelling study quantified the seasonal risk and potential exposure to the surrounding waters and shorelines for a plausible, yet hypothetical scenario:

- 280 m^3 surface release of MDO over 6 hours resulting from a vessel collision incident at the closest point of the operational area to the Rowley Shoals.

Table 9 provides a summary of the oil spill model settings.

Table 9 Summary of the oil spill model settings

Parameter	Oil Spill Scenario
Scenario description	Vessel Collision
Model period	Summer (December to February) Transitional (March, October and November) Winter (April to September)
Number of randomly selected spill start times and locations per season	100
Oil type	MDO
Spill volume (m^3)	280
Release type	Surface
Release duration	6 hr
Simulation length (days)	30
Surface oil concentration thresholds	1 g/m^2, 10 g/m^2, >25 g/m^2
Shoreline load threshold	10 g/m^2, 100 g/m^2, >1,000 g/m^2
Dissolved aromatic exposure to assess the potential exposure (ppb)	6 ppb, potential low exposure 50 ppb, potential moderate exposure 400 ppb, potential high exposure
Entrained oil exposure to assess the potential exposure (ppb)	10 ppb, potential low exposure 100 ppb, potential moderate exposure 1,000 ppb, potential high exposure
In-water exposure duration	Instantaneous and 48 hr exposure

RPS

7 PRESENTAITON AND INTERPRETATION OF MODEL RESULTS

The results from the modelling study are presented in a number of tables and figures, which aim to provide a comprehensive understanding of the predicted sea-surface and in-water (subsurface) exposure and shoreline contact (if predicted).

7.1 Seasonal Analysis

7.1.1 Figures

The figures are based on the following principles:

- *The* ***potential zones of exposure (surface oil, entrained hydrocarbons and dissolved aromatics)*** – is determined by identifying the maximum loading (surface) or dosage (subsea) within a grid cell and is then classified according to identified surface or subsea thresholds.
- The ***minimum time before oil exposure on the sea surface*** **–** is determined by recording the elapsed time before sea surface exposure to a grid cell, at a specified threshold.
- The ***probability of exposure/contact (surface oil, shoreline oil, entrained hydrocarbon or dissolved aromatic)*** **–** is calculated by dividing the number of spill trajectories passing over that given cell (surface, shoreline or subsea) by the total number of spill trajectories, above the specified threshold value.
- The **Maximum potential shoreline loading –** is determined by identifying the maximum loading within a shoreline cell and is then classified according to the identified thresholds (i.e. 10, 100 g/m^2 and 1,000 g/m^2).

7.1.2 Statistics

The statistics are based on the following principles:

- The ***greatest distance travelled by a spill trajectory*** **–** is determined by a) recording the maximum distance travelled by a single trajectory, within a scenario, from the release location to the identified exposure thresholds.
- The ***probability of shoreline contact*** – is determined by recording the number of spill trajectories to contact the shoreline, at a specific threshold, divided by the total number of spill trajectories within that scenario.
- The ***minimum time before oil exposure*** – is determined by recording the minimum time for a grid cell to record exposure, at a specific threshold.
- The ***average volume of oil ashore for a single spill*** – is determined by calculating the average volume of the all the single spill trajectories which were predicted to make shoreline contact within a scenario.
- The ***maximum volume of oil ashore from a single spill trajectory*** – is determined by identifying the single spill trajectory within a scenario/season, that recorded the maximum volume of oil to come ashore and presenting that value.
- The ***average length of shoreline contacted by oil*** – is determined by calculating the average of the length of shoreline (measured as grid cells) contacted by oil above a specified threshold.
- The ***maximum length of shoreline contacted by oil*** – is determined by recording the maximum length of shoreline (measured as grid cells) contacted by oil above a specified threshold.
- The ***probability of oil exposure to a receptor*** **–** is determined by recording the number of spill

trajectories to reach a specified sea surface or subsea threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.

- The ***minimum time before oil exposure to a receptor*–** is determined by ranking the elapsed time before sea surface exposure, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***probability of oil contact to a receptor* –** is determined by recording the number of spill trajectories to reach a specified shoreline contact threshold within a receptor polygon, divided by the total number of spill trajectories within that scenario.
- The ***minimum time before shoreline contact to a receptor* –** is determined by ranking the elapsed time before shoreline contact, at a specified threshold, to grid cells within a receptor polygon and recording the minimum value.
- The ***average potential oil loading within a receptor*** – is determined taking the average of the maximum loading to any grid cell within a polygon, for all simulations within a scenario/season, that recorded shoreline.
- The ***maximum potential oil loading within a receptor*** – is determined by identifying the maximum loading to any grid cell within a receptor polygon, for a scenario.
- The ***average volume of oil ashore within a receptor*** – is determined by calculating the average volume of oil to come ashore within a receptor polygon, from all the single spill trajectories which were predicted to make shoreline contact within a scenario.
- The ***maximum volume of oil ashore within a receptor*** – is determined by recording the maximum volume of oil to come ashore within a receptor polygon, from all the single spill trajectories which were predicted to make shoreline contact within a scenario.
- The ***average length of shoreline contacted within a receptor*** – is determined by calculating the average of the length of shoreline (measured as grid cells) contacted by oil within a receptor polygon, at a specified threshold, from all the single spill trajectories which were predicted to make shoreline contact within a scenario.
- The ***maximum length of shoreline contacted by oil*** – is determined by recording the maximum length of shoreline (measured as grid cells) contacted by oil within a receptor polygon, at a specified threshold, from all the single spill trajectories which were predicted to make shoreline contact within a scenario.

7.2 Receptors Assessed

A range of environmental receptors summarised in Table 10 and illustrated in Figure 17 to Figure 21 were assessed for sea surface exposure, shoreline contact and water column exposure as part of the study.

Table 10 Summary of receptors used to assess surface, shoreline and in-water exposure to hydrocarbons

Receptor Category	Acronym	Hydrocarbon Exposure Reported for		
		Water column	Sea Surface	Shoreline
Marine National Park (including Australian Marine Parks and Marine Parks)	MNP, AMP, MP	✓	✓	×
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	×
Interim Biogeographic Regionalisation of Australia	IBRA	✓	✓	✓
Key Ecological Feature	KEF	✓	✓	×
Reefs, Shoals and Banks	RSB	✓	✓	×

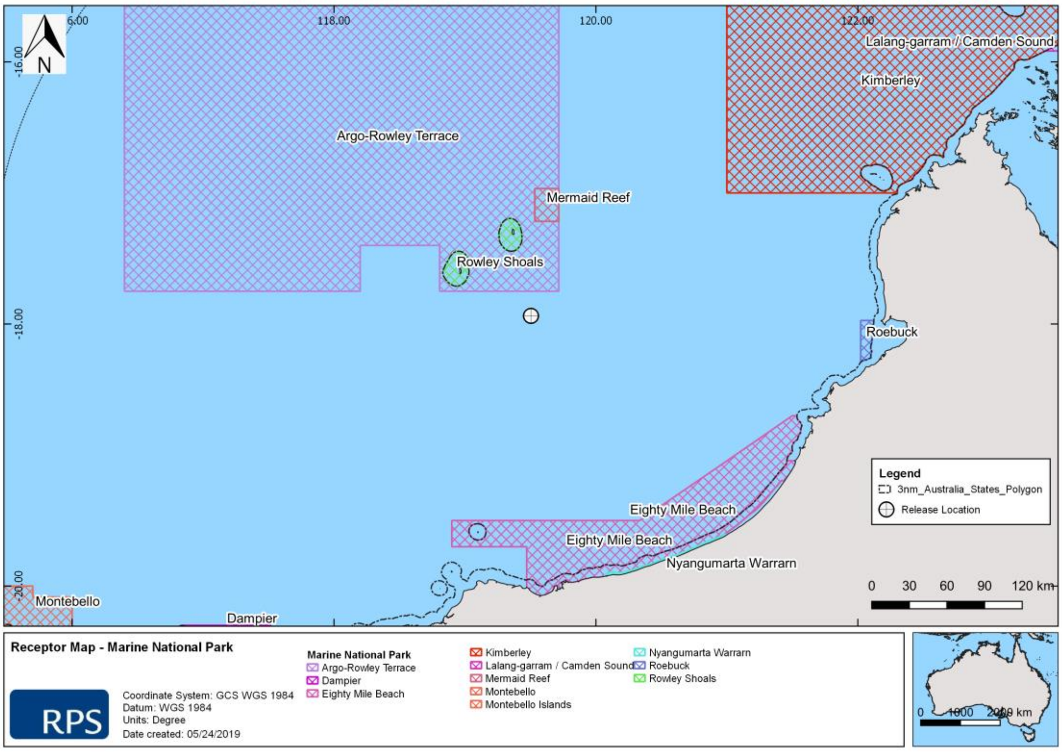


Figure 17 Receptor map illustrating Marine Parks

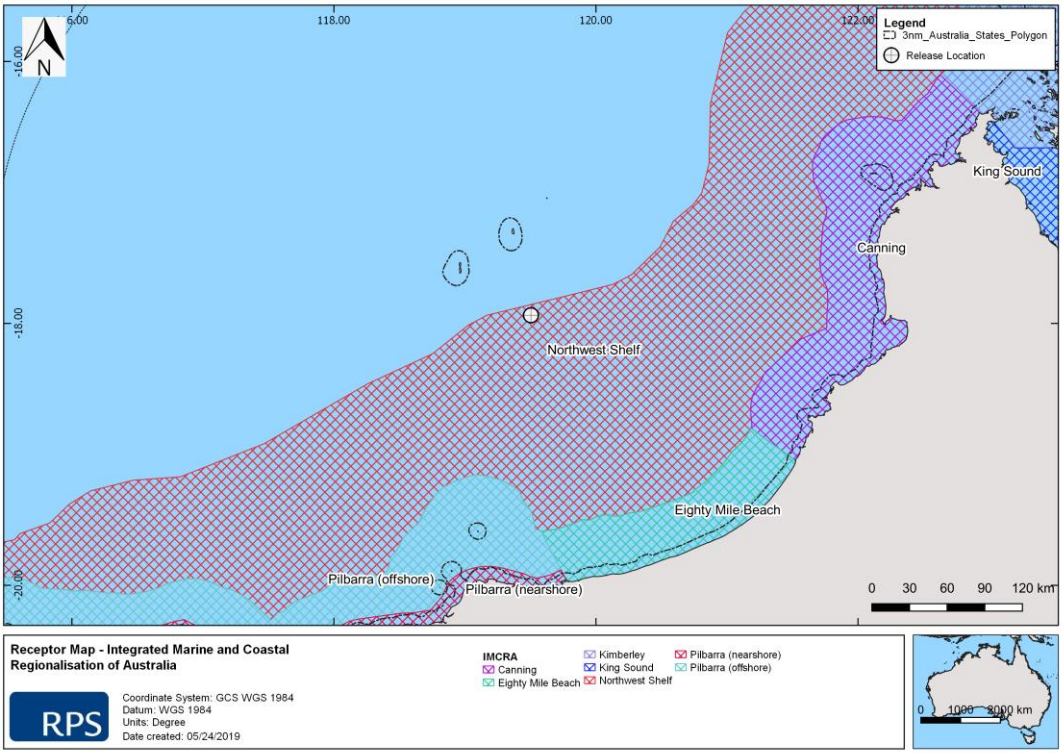


Figure 18 Receptor map illustrating the Integrated Marine and Coastal Regionalisation of Australia (IMCRA)

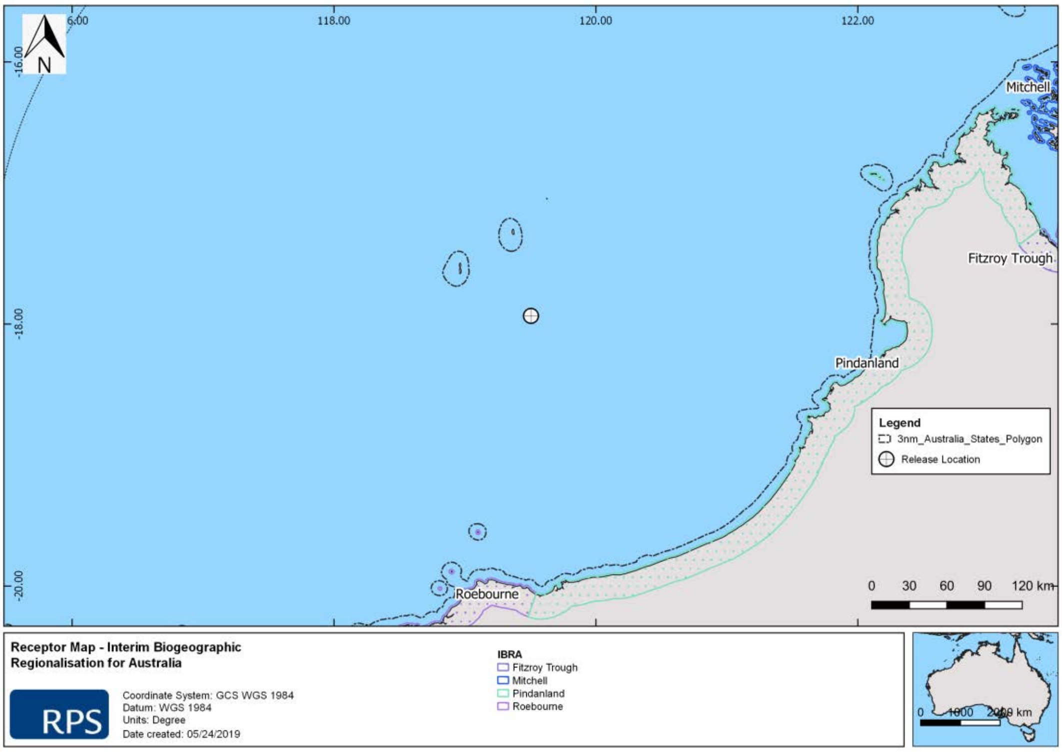


Figure 19 Receptor map illustrating the Interim Biogeographic Regionalisation for Australia (IBRA)

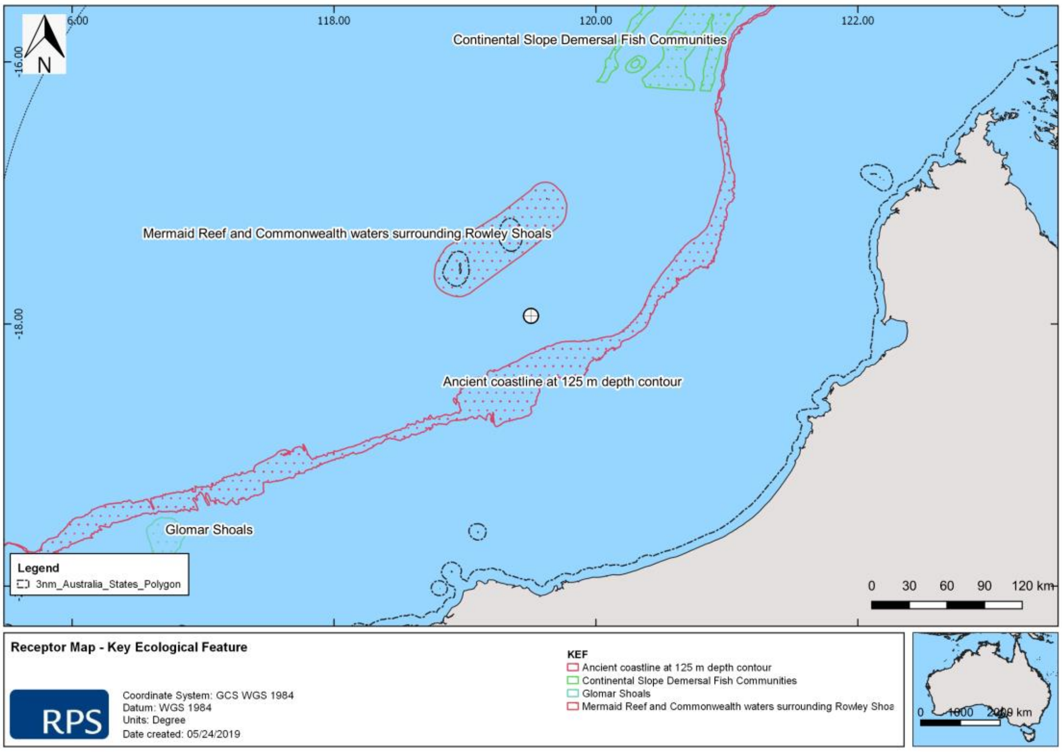


Figure 20 Receptor map illustrating Key Ecological Features (KEF)

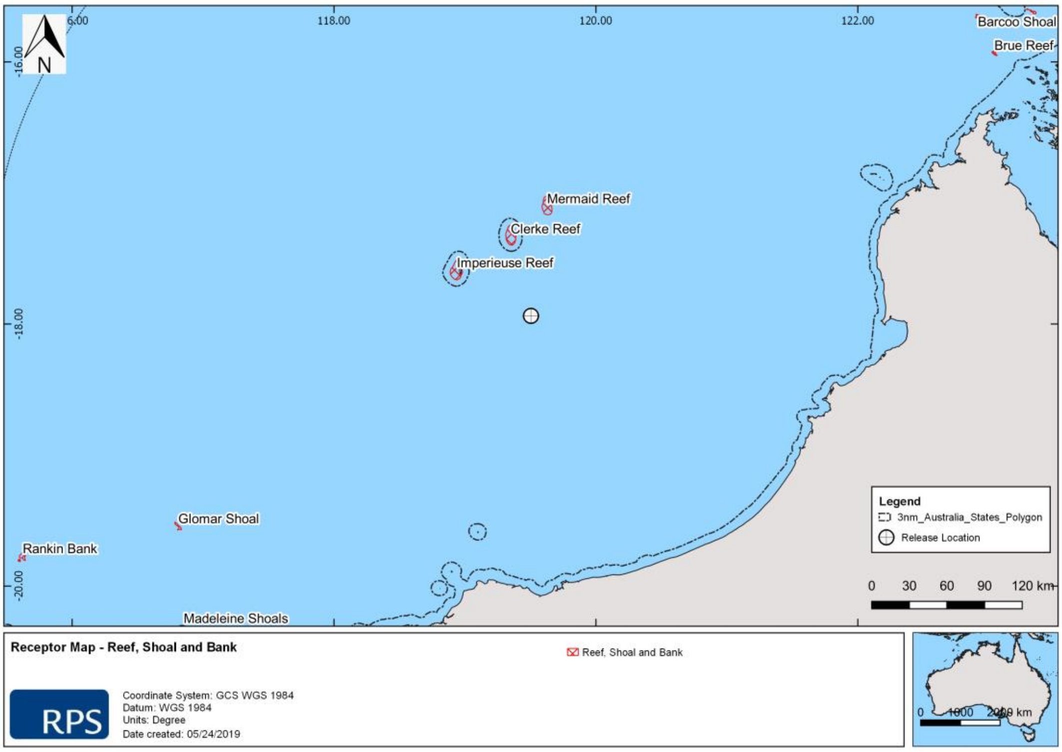


Figure 21 Receptor map illustrating the Reefs, Shoals and Banks

8 RESULTS: 280 M³ SURFACE RELEASE OF MARINE DIESEL OIL

The scenario examined a 280 m^3 release of MDO over 6 hours, tracked for 30 days. A total of 100 spill trajectories were simulated for each of the seasons, summer, transitional and winter.

Section 8.1 presents stochastic results. Note, no shoreline contact was predicted for this scenario.

8.1 Stochastic Analysis

For the modelling study each spill trajectory was tracked to the following minimum thresholds:

- Sea surface oil – 1 g/m^2
- Shoreline contact – 10 g/m^2
- Dissolved aromatics – 6 ppb (instantaneous and over a 48-hour exposure window)
- Entrained hydrocarbons – 10 ppb (instantaneous and over a 48-hour exposure window)

8.1.1 Sea Surface Exposure

Table 11 presents a summary of the maximum distance and direction travelled by oil on the sea surface at the low (1 g/m^2), moderate (10 g/m^2) and high (>25 g/m^2) exposure thresholds for each of the three seasons considered, summer, transitional and winter. Modelling results suggested that surface oil at low, moderate and high exposure levels could potentially travel greater distances during the transitional period. The maximum distance travelled by surface oil for the low, moderate and high threshold was 66 km, 14 km and 7 km, respectively.

Figure 22 to Figure 24 show zones of sea surface exposure for the summer, transitional and winter seasons respectively. While the low exposure surface oil was predicted to travel in any directions from the release site, the moderate and high exposure levels remained along the northwest-southeast axis across all seasons.

Figure 25 to Figure 33 show minimum time to surface exposure at the low, moderate and high thresholds for the summer, transitional and winter seasons respectively. As depicted on these figures, the evaporative nature of MDO and environmental conditions in the area resulted in short-lived surface hydrocarbon exposure, with surface exposure reduced to less than 10 g/m^2 after approximately 12-24 hours.

The weathering plot illustrated in Figure 16 indicates that surface hydrocarbon would drop to negligible volumes between 1 to 4 days depending on the wind conditions.

Table 12 presents the potential sea surface exposure to individual receptors. The results demonstrated a 100% predicted probability of sea surface exposure at the low threshold (1 g/m^2) for Northwest Shelf (IMCRA). As shown in Section 7.2, the release location is situated within this area. No sensitive receptors were predicted to be exposed to surface oil at the moderate and high threshold. Argo-Rowley Terrace (AMP) was the only sensitive receptor showing potential exposure to surface oil at the low threshold, with a low likelihood of 1-2 % (during the summer and winter seasons only).

RPS

Table 11 Maximum distance and direction travelled on the sea surface by a single trajectory from the release location to oil exposure thresholds.

Season	Distance and direction	Zones of potential sea surface exposure		
		>1 g/m²	>10 g/m²	>25 g/m²
Summer	Max. distance from release site (km)	31	11	4
	Max distance from release site (km) (99th percentile)	28	11	4
	Direction	N	SSE	NW
Transitional	Max. distance from release site (km)	66	14	7
	Max distance from release site (km) (99th percentile)	56	13	7
	Direction	WSW	SSE	SE
Winter	Max. distance from release site (km)	31	12	6
	Max distance from release site (km) (99th percentile)	28	11	6
	Direction	NNE	WNW	NW

Table 12 Summary of the potential sea surface exposure to receptors

Season	Receptor		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (hours)		
			>1 g/m²	>10 g/m²	>25 g/m²	>1 g/m²	>10 g/m²	>25 g/m²
Summer	IMCRA	Northwest Shelf	100	99	56	-	-	-
	AMP	Argo-Rowley Terrace	2	-	-	1	-	-
Transitional	IMCRA	Northwest Shelf	100	100	58	-	-	-
Winter	IMCRA	Northwest Shelf	100	97	45	-	-	-
	AMP	Argo-Rowley Terrace	1	-	-	1	-	-

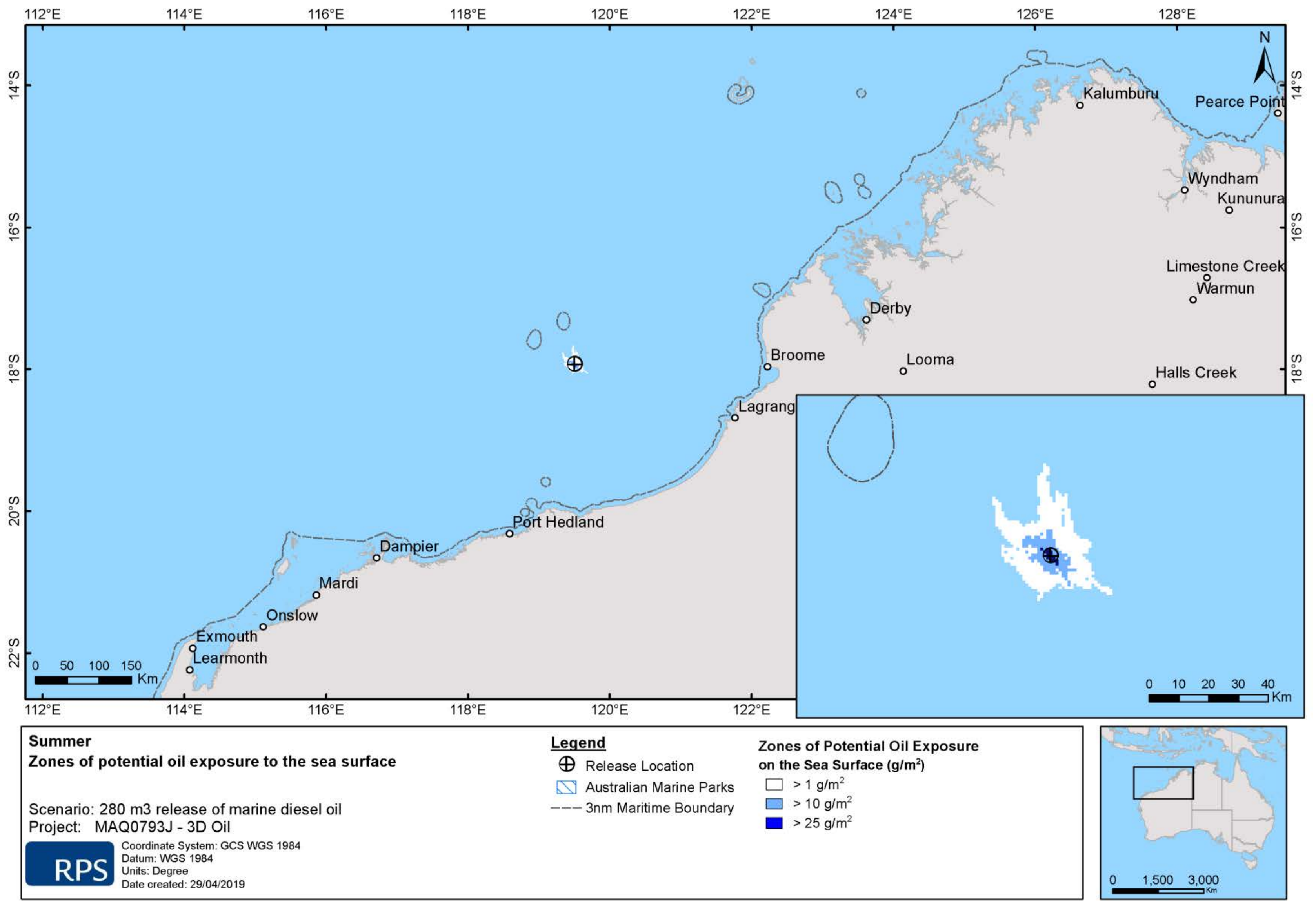


Figure 22 **Zones of potential oil exposure on the sea surface, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer wind and current conditions.**

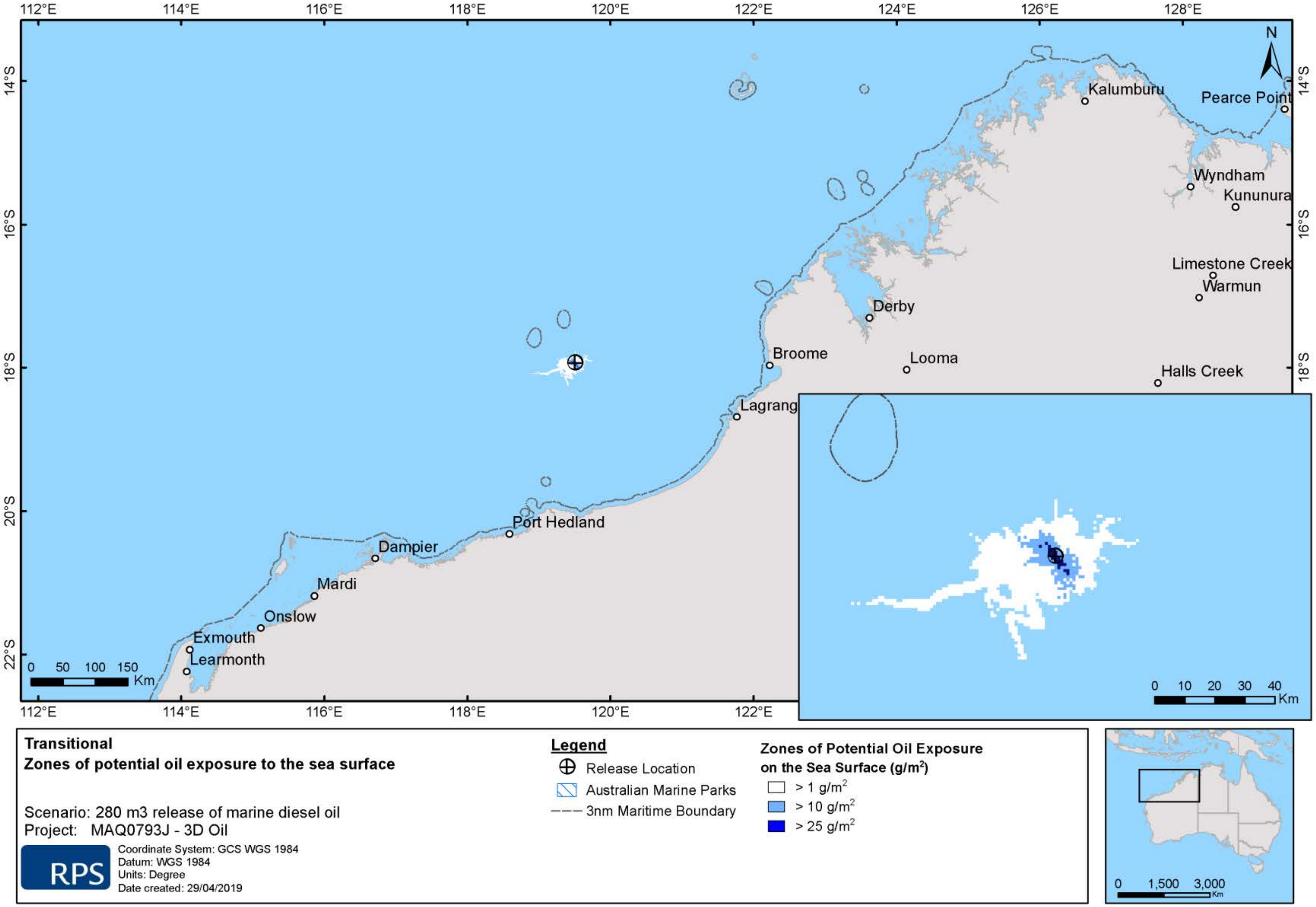


Figure 23 Zones of potential oil exposure on the sea surface, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period wind and current conditions.

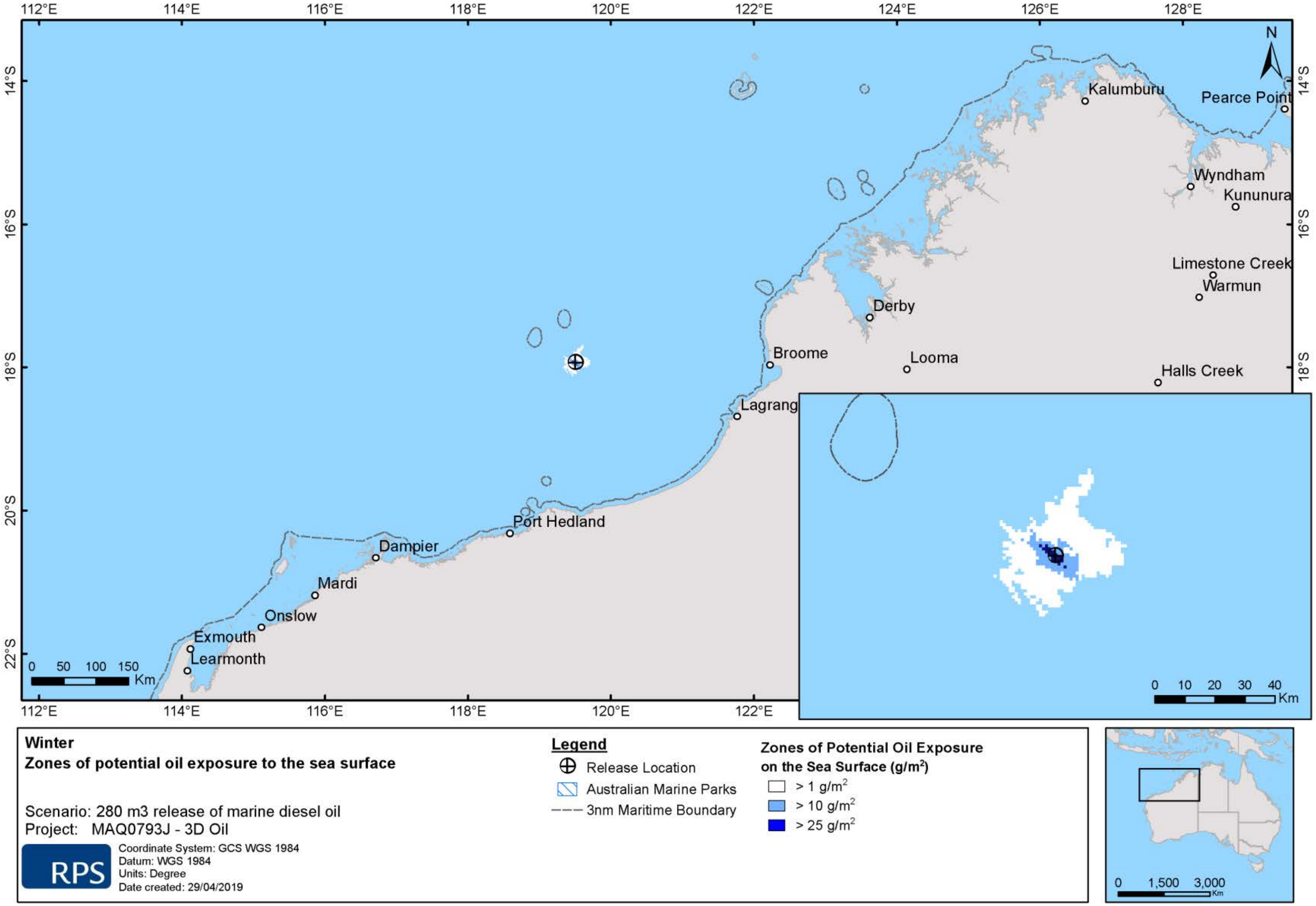


Figure 24 Zones of potential oil exposure on the sea surface, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during winter wind and current conditions.

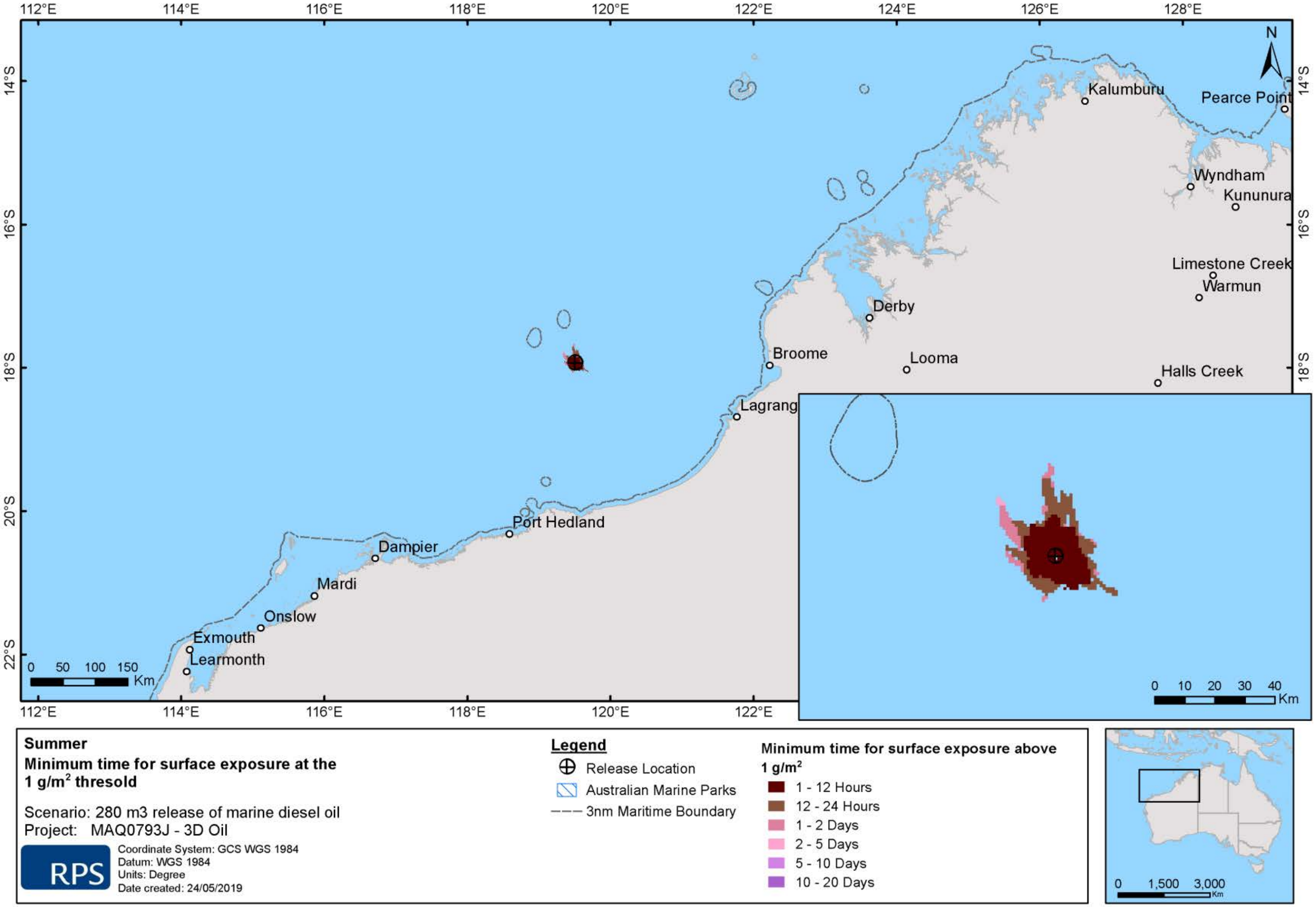


Figure 25 Minimum time for oil exposure on the sea surface at the low (1 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer conditions.

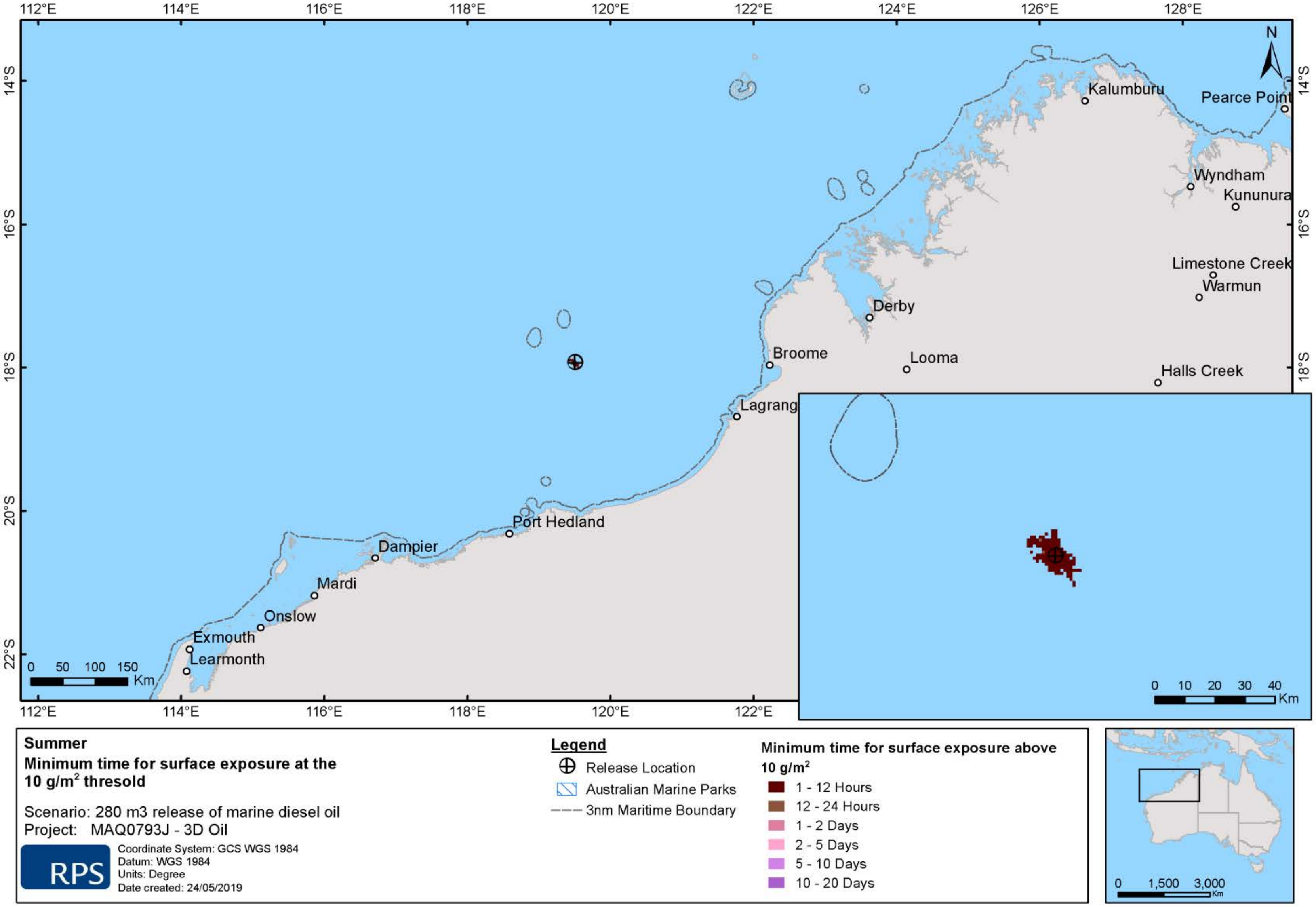


Figure 26 **Minimum time for oil exposure on the sea surface at the moderate (10g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer conditions.**

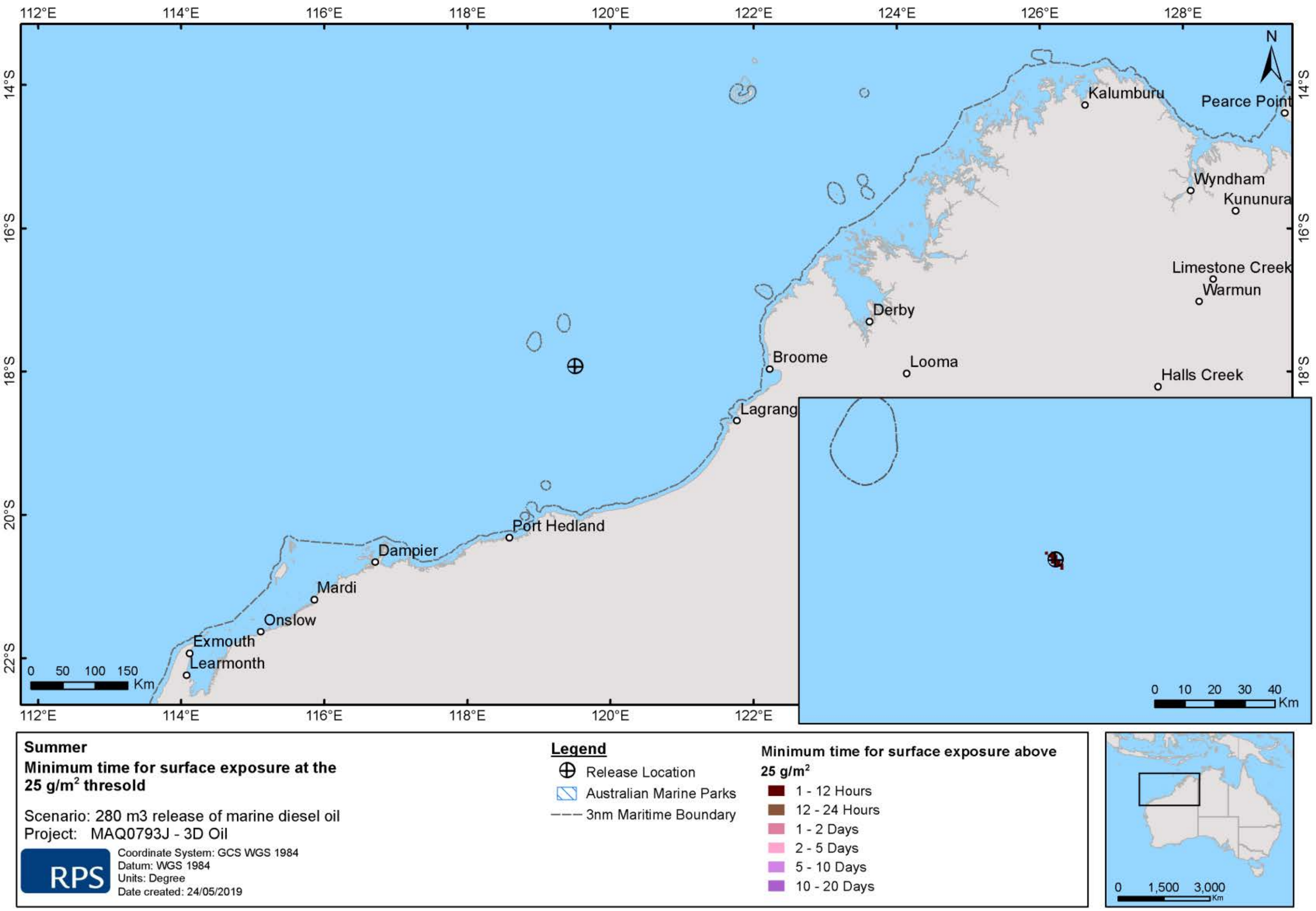


Figure 27 Minimum time for oil exposure on the sea surface at the high (25 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer conditions.

RPS

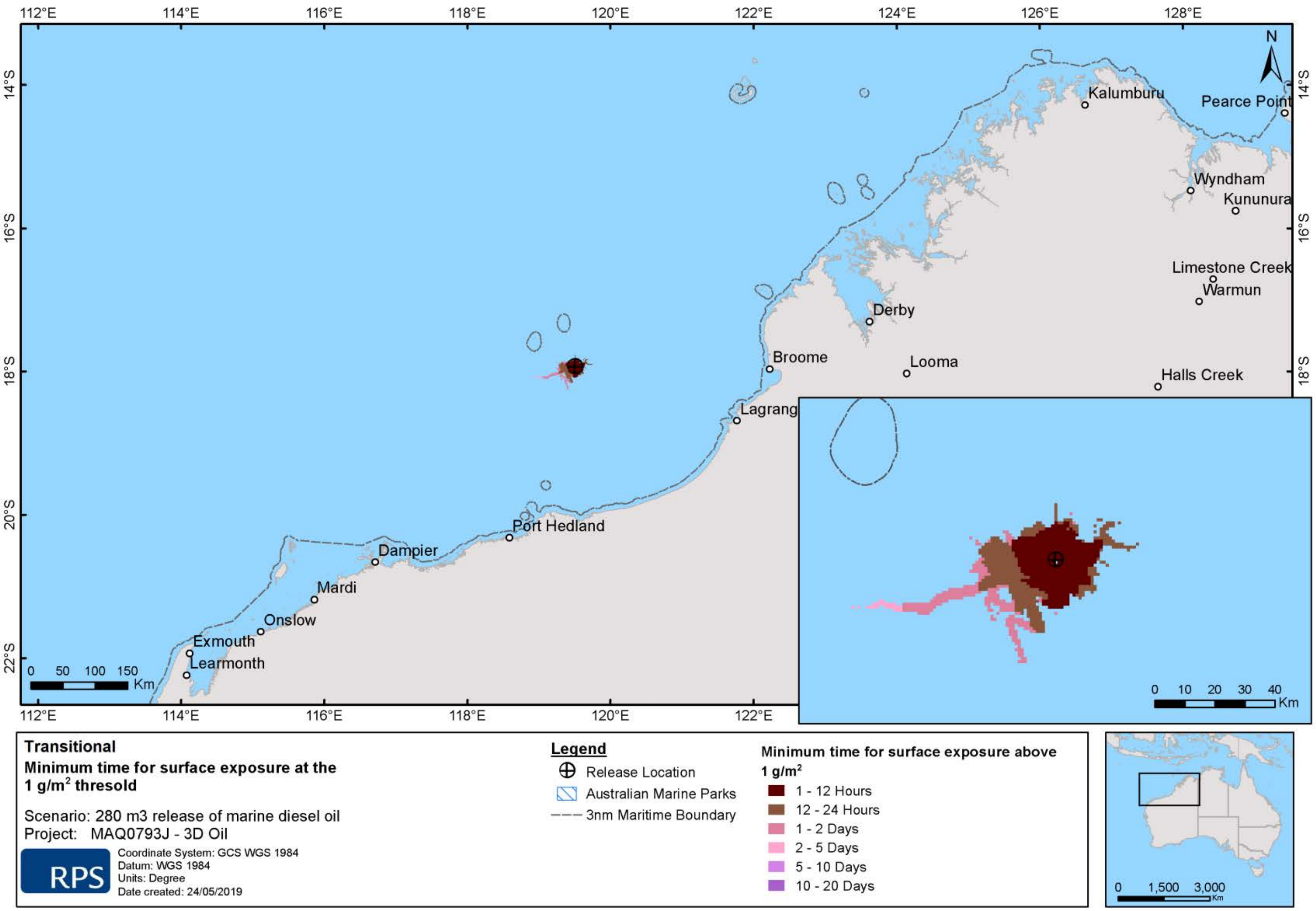


Figure 28 Minimum time for oil exposure on the sea surface at the low (1 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period conditions.

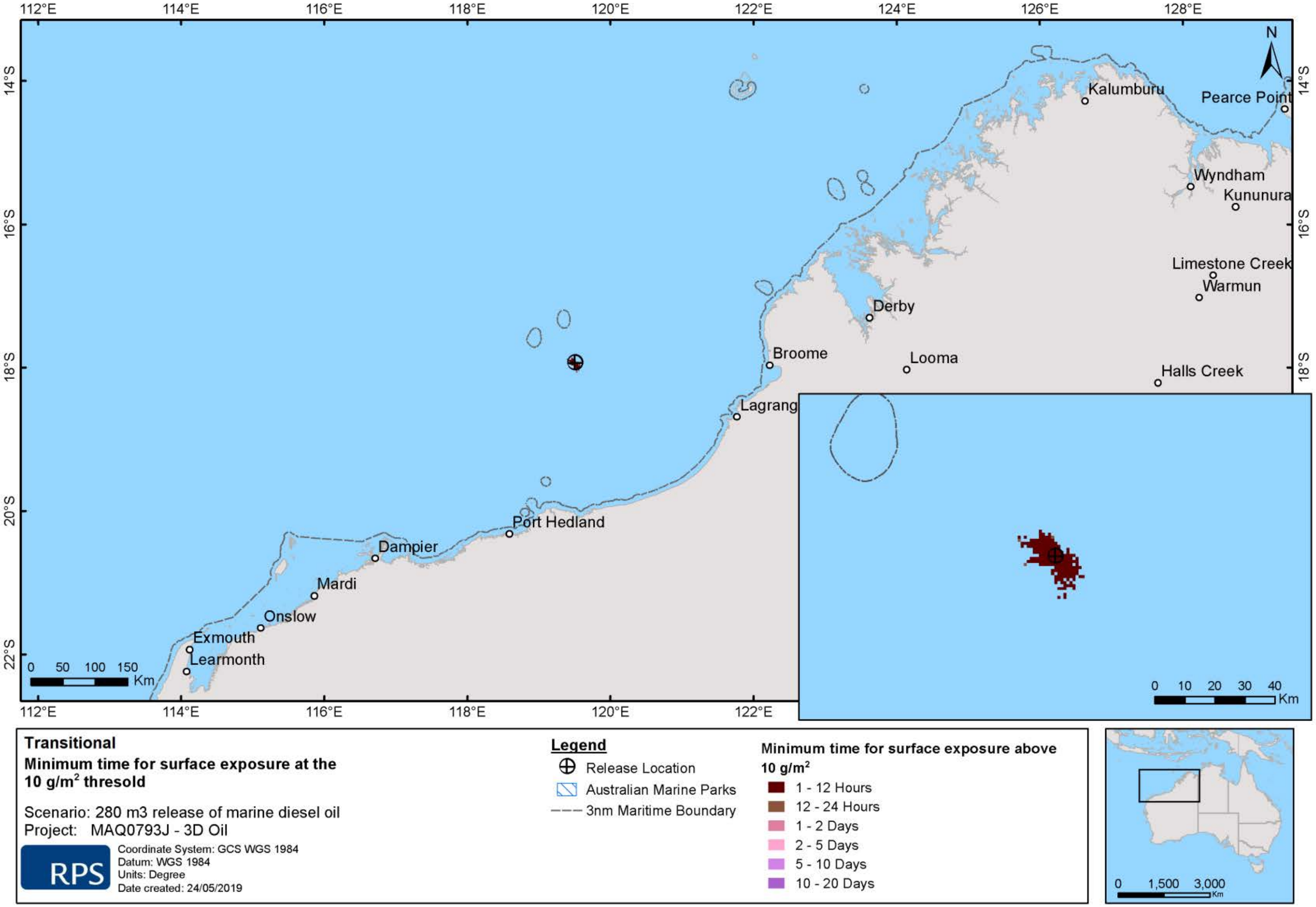


Figure 29 Minimum time for oil exposure on the sea surface at the moderate (10 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period conditions.

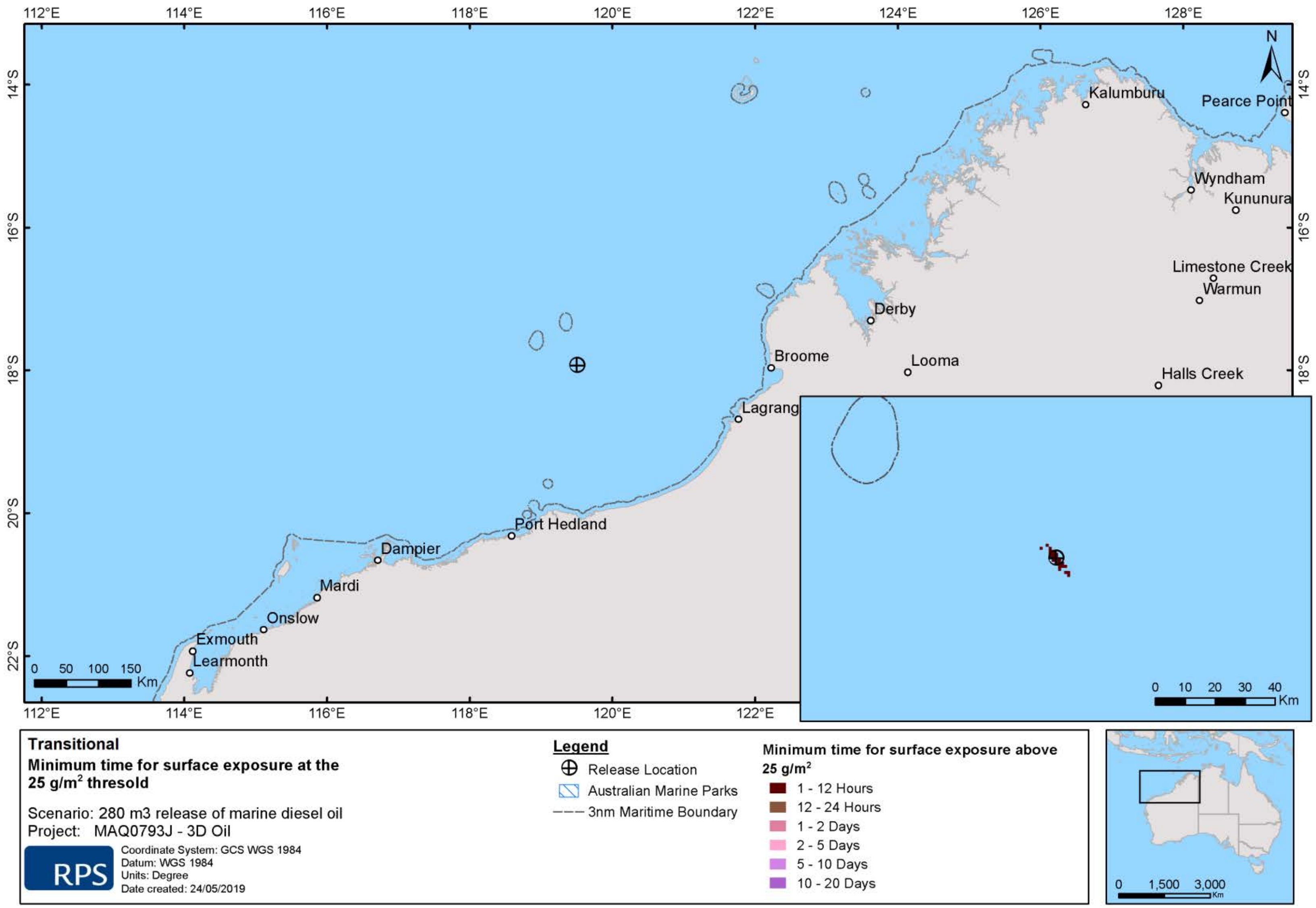


Figure 30 Minimum time for oil exposure on the sea surface at the high (25 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period conditions.

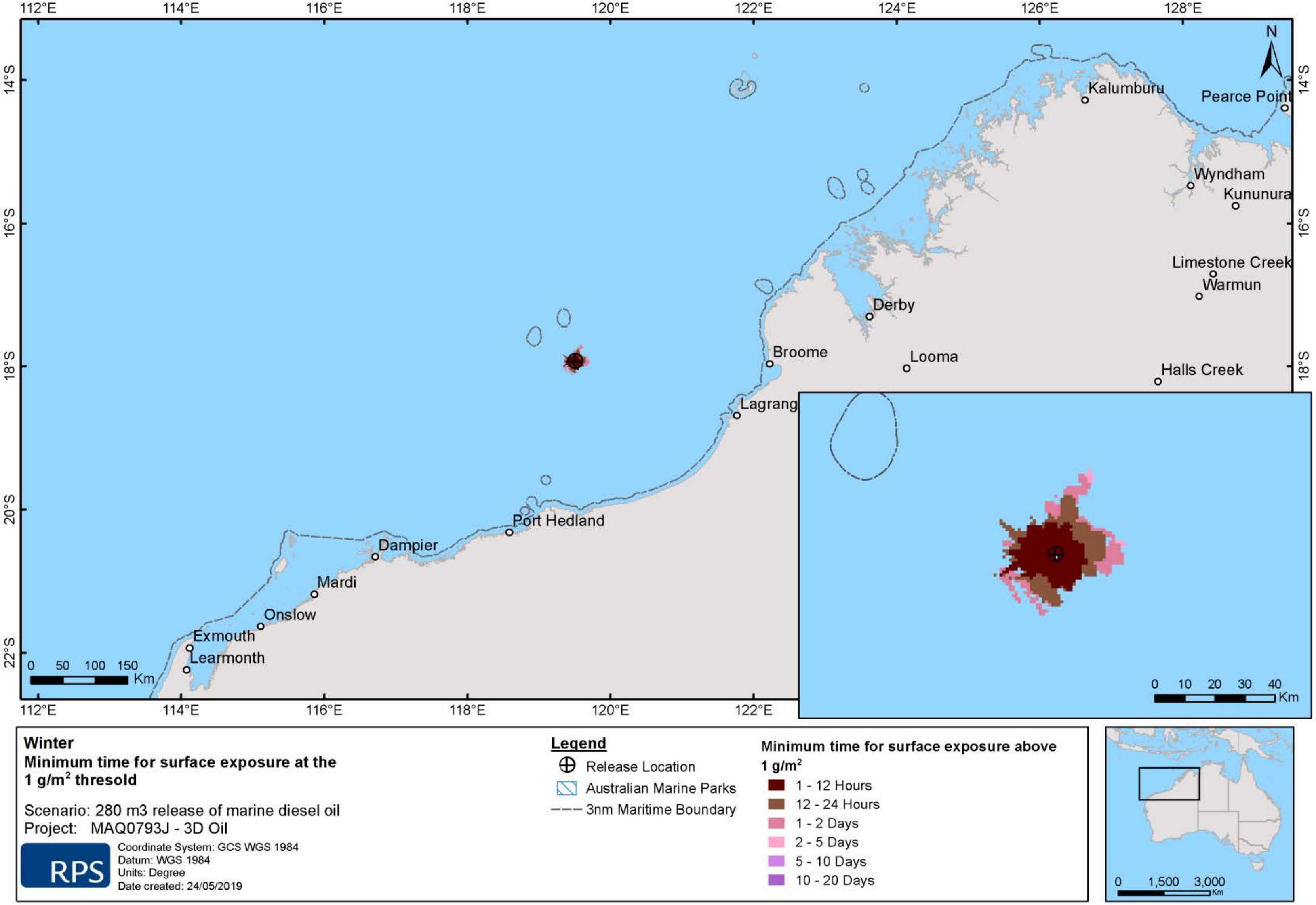


Figure 31 Minimum time for oil exposure on the sea surface at the low (1 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during conditions.

RPS

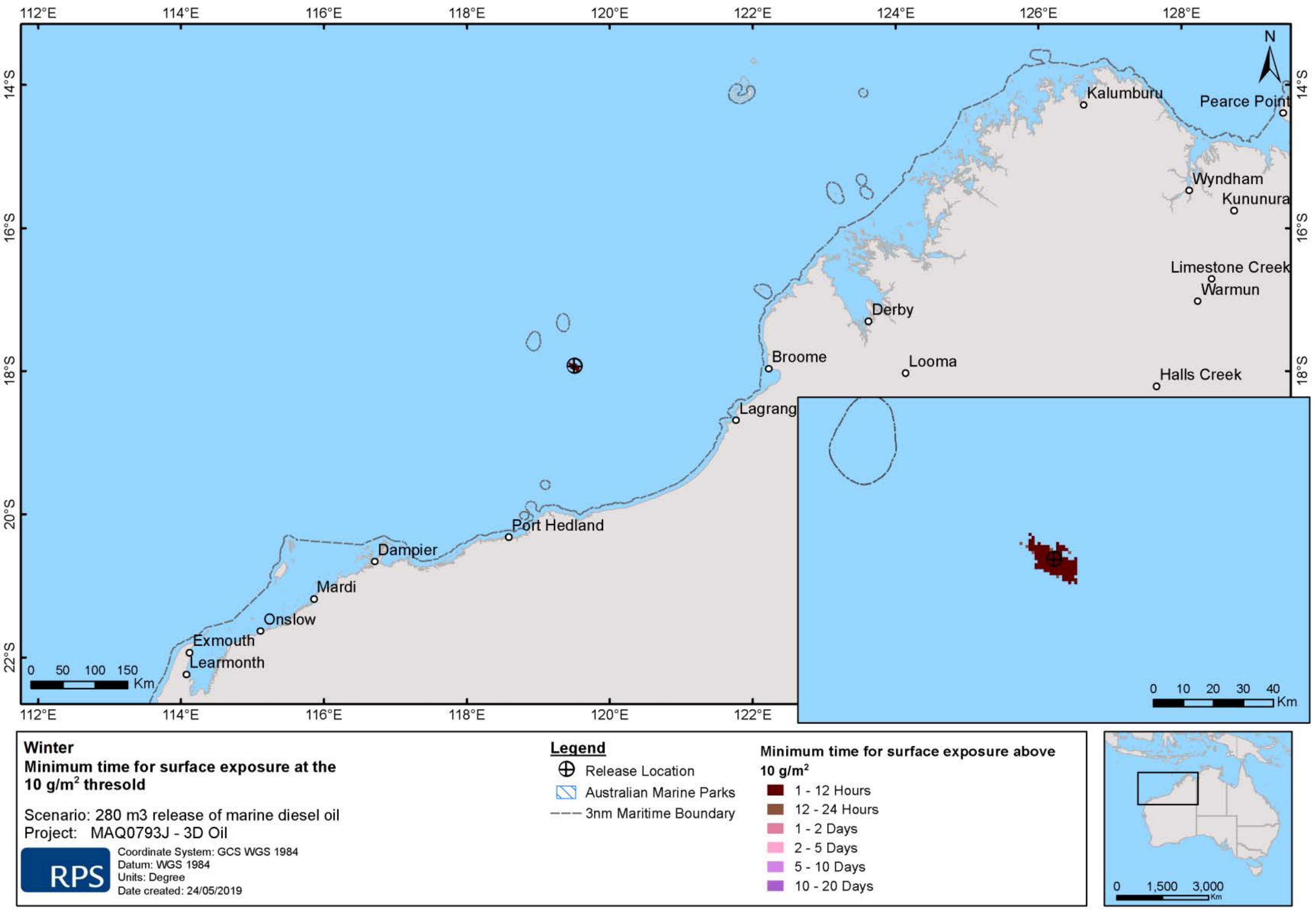


Figure 32 Minimum time for oil exposure on the sea surface at the moderate (10 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during conditions.

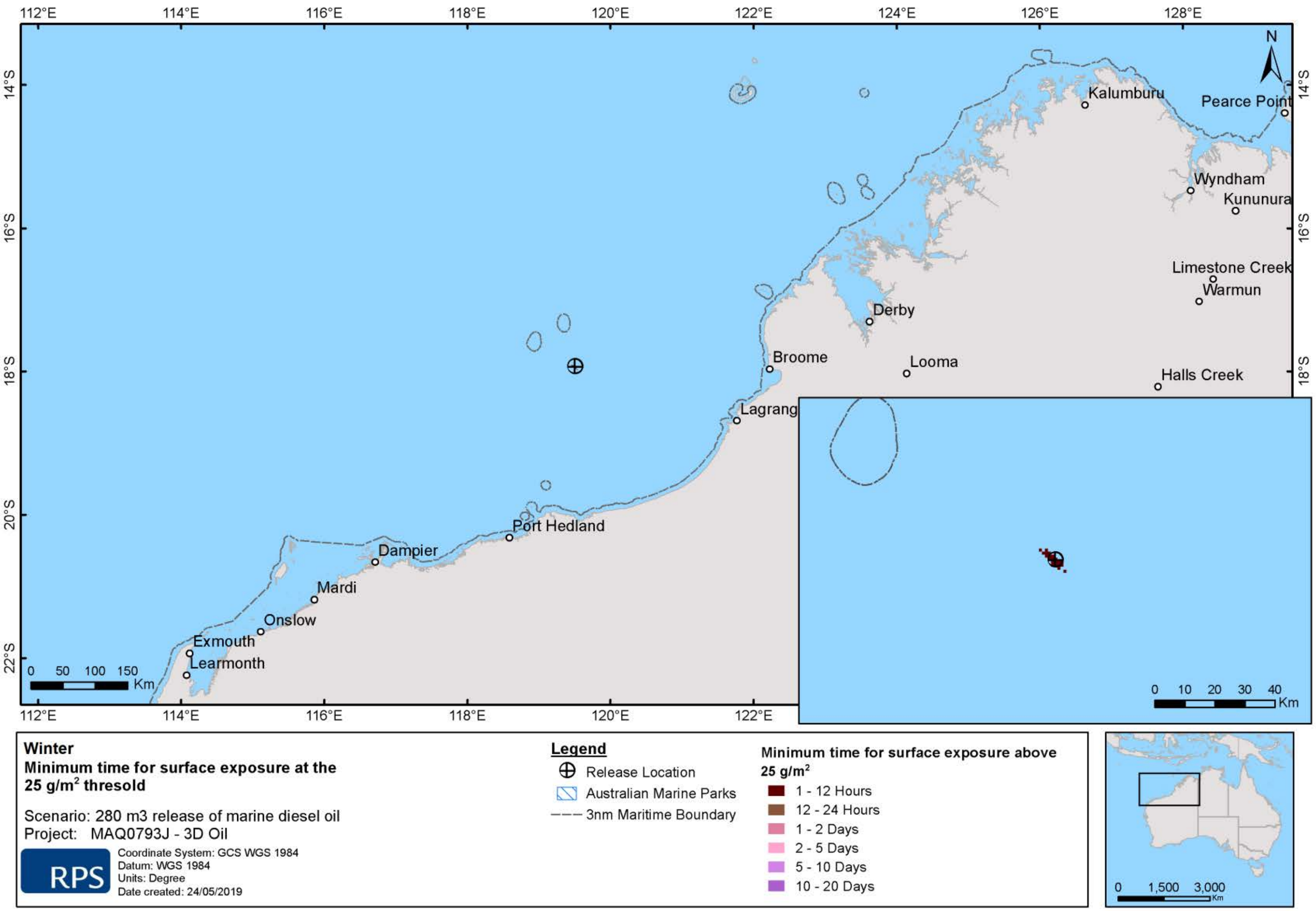


Figure 33 Minimum time for oil exposure on the sea surface at the high (25 g/m^2) threshold, in the event of a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during conditions.

RPS

8.2 Water Column Exposure

8.2.1 Dissolved Hydrocarbons

Table 13 summarises the maximum dissolved hydrocarbon exposure (time-averaged and instantaneous) to receptors in the 0–10 m depth layer at or above the exposure thresholds discussed in Section 6.2 over the seasonal assessments.

At the depths of 0-10 m, the maximum time-averaged exposure to dissolved hydrocarbon over 48 hours remained less than 1 ppb for the winter and transitional seasons while reaching 4 ppb for the summer and winter seasons for various receptors. These concentrations are below the defined low threshold for dissolved hydrocarbons. The maximum instantaneous exposure to dissolved hydrocarbons ranged from 6 ppb to 73 ppb for the transitional and summer seasons respectively. None of the receptors was exposed at the moderate (50 ppb) or high (400 ppb) thresholds or above for instantaneous exposure with the exception of the IMCRA – North West Shelf. This receptor had a 1 % probability of exposure to instantaneous dissolved hydrocarbon during the summer season.

Zones of potential dissolved hydrocarbon for instantaneous exposure are presented for each season in Figure 34 to Figure 36.

There were no zones of potential exposure above the exposure thresholds for the time-averaged exposure discussed in Section 6.2, therefore there are no figures provided in this section.

RPS

Table 13 Predicted maximum instantaneous and time-averaged (48 hr) dissolved hydrocarbon exposure to receptors in the 0–10 m depth layer. Results are based on a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories per season.

Season	Receptor		Maximum time-averaged dissolved hydrocarbon exposure (ppb)	Probability of time-averaged dissolved hydrocarbon exposure			Maximum instantaneous dissolved hydrocarbon exposure (ppb)	Probability of instantaneous dissolved hydrocarbon exposure		
				>6 ppb	>50 ppb	>400 ppb		>6 ppb	>50 ppb	>400 ppb
Summer	IMCRA	Northwest Shelf	4	0	0	0	73	21	1	0
	AMP	Argo-Rowley Terrace	1	0	0	0	8	1	0	0
Transitional	IMCRA	Northwest Shelf	3	0	0	0	37	16	0	0
	AMP	Argo-Rowley Terrace	<1	0	0	0	6	1	0	0
Winter	IMCRA	Northwest Shelf	4	0	0	0	48	36	0	0
	AMP	Argo-Rowley Terrace	1	0	0	0	19	2	0	0
	MP	Rowley Shoals	<1	0	0	0	13	1	0	0
	KEF	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	<1	0	0	0	14	1	0	0

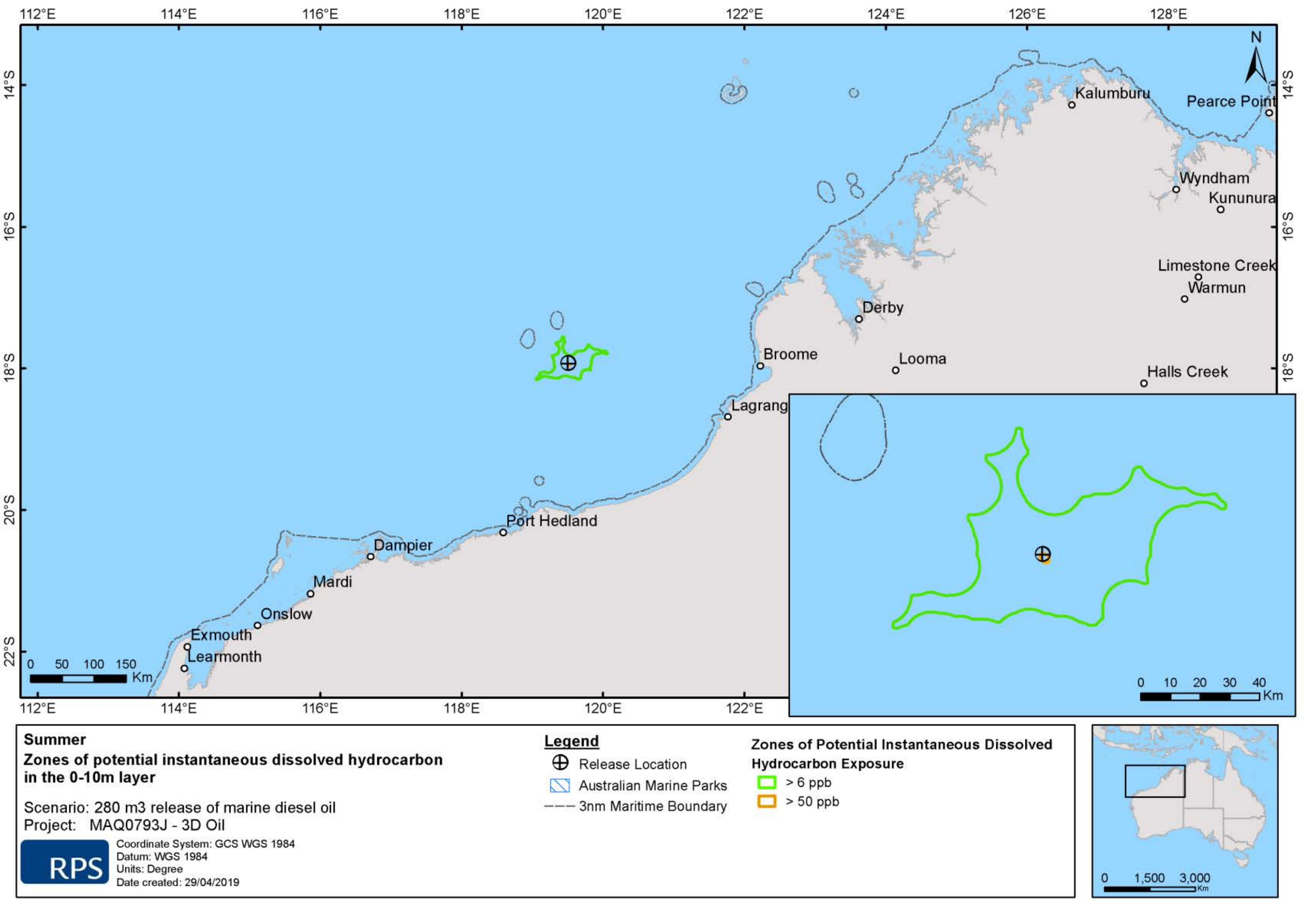


Figure 34 Zones of potential instantaneous dissolved hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer wind and current conditions.

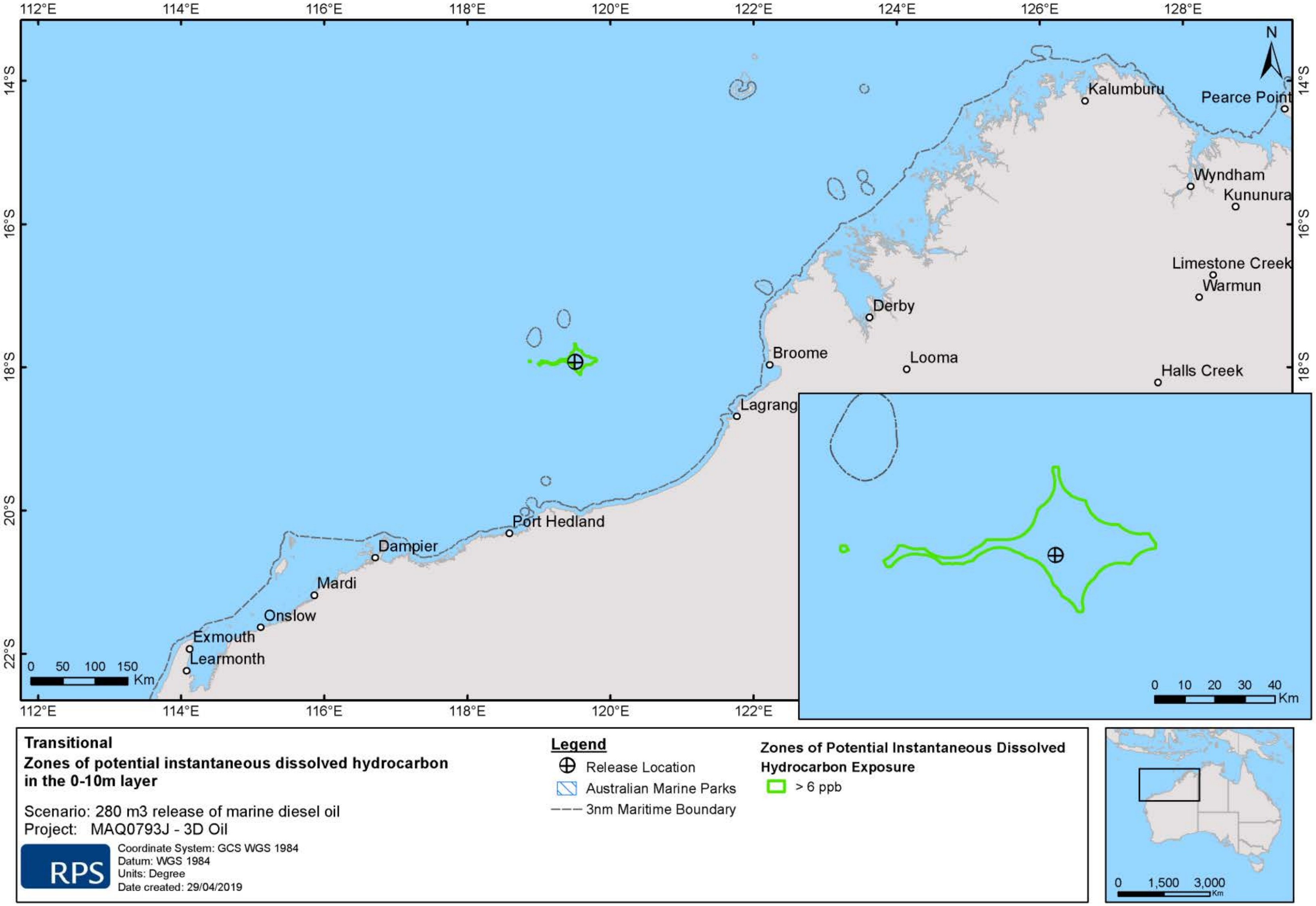


Figure 35 Zones of potential instantaneous dissolved hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period wind and current conditions.

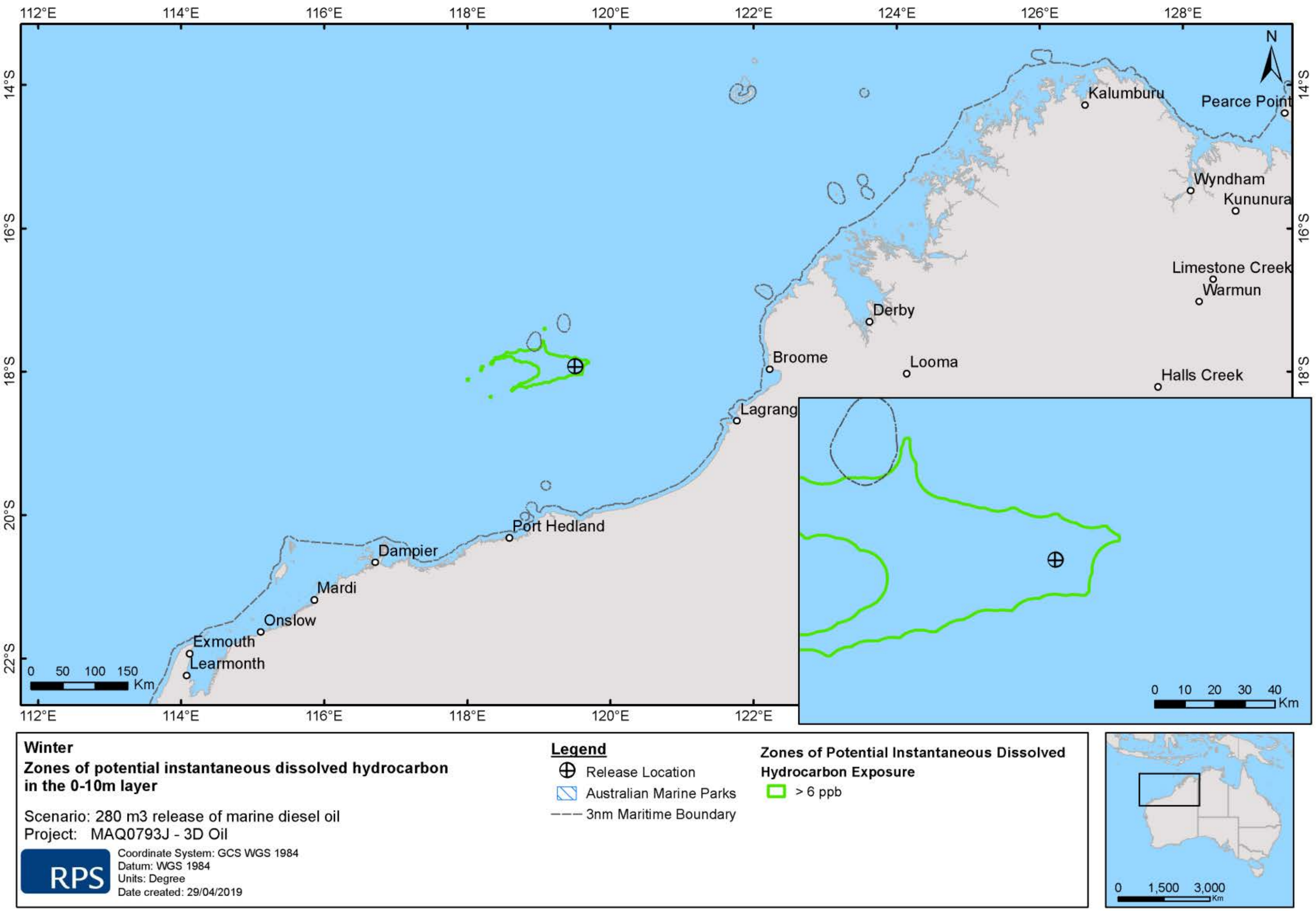


Figure 36 Zones of potential instantaneous dissolved hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during winter wind and current conditions.

RPS

8.2.2 Entrained Hydrocarbons

Table 14 summarises the maximum entrained hydrocarbon exposure (time-averaged and instantaneous) to receptors in the 0–10 m depth layer at, or above the exposure thresholds discussed in Section 6.2 over the seasonal assessment.

The maximum time-averaged exposure over 48 hours to entrained hydrocarbons ranged from 4 ppb to 499 ppb for the transitional and winter seasons respectively. The maximum instantaneous exposure to entrained hydrocarbon was 6,287 ppb for the Northwest Shelf IMCRA during the summer. The IMCRA – North West Shelf was the only receptor exposed at the high threshold (1,000 ppb) or above for instantaneous exposure. Several receptors were exposed and the moderate threshold (100 ppb) or above for instantaneous exposure (i.e. AMP – Argo-Rowley Terrace, AMP – Mermaid Reef, MP – Rowley Shoals, KEF – Mermaid Reef and Commonwealth waters surrounding Rowley Shoals, KEF – Ancient coastline at 125 m depth contour and the RSB – Imperieuse Reef) during different seasons as specified in Table 14

The zone of potential time-averaged entrained hydrocarbon exposure is presented in Figure 37 to Figure 39, while Figure 40 to Figure 42 illustrate the zones of potential instantaneous entrained hydrocarbon exposure for each season.

RPS

Table 14 Predicted maximum instantaneous and time-averaged (48 hr) entrained hydrocarbon exposure to receptors in the 0–10 m depth layer. Results are based on a 280 m^3 surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories per season.

Season	Receptor		Maximum time-averaged entrained hydrocarbon exposure (ppb)	Probability of time-averaged entrained hydrocarbon exposure			Maximum instantaneous entrained hydrocarbon exposure (ppb)	Probability of instantaneous entrained hydrocarbon exposure		
				>10 ppb	>100 ppb	>1,000 ppb		>10 ppb	>100 ppb	>1,000 ppb
Summer	SHORE	Imperieuse Reef	27	4	0	0	57	5	0	0
		Cunningham Island	28	3	0	0	61	7	0	0
		Clerke Reef	14	2	0	0	31	6	0	0
		Mermaid Reef	10	0	0	0	30	1	0	0
	IMCRA	Northwest Shelf	402	66	14	0	6,287	89	74	17
	AMP	Argo-Rowley Terrace	114	11	2	0	607	23	8	0
		Kimberley	10	1	0	0	32	4	0	0
		Mermaid Reef	21	2	0	0	66	3	0	0
	MP	Rowley Shoals	49	5	0	0	185	8	2	0
	RSB	Mermaid Reef	20	1	0	0	55	2	0	0
		Imperieuse Reef	33	4	0	0	59	7	0	0
		Clerke Reef	40	2	0	0	158	7	1	0
	KEF	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	49	5	0	0	213	12	2	0
		Ancient coastline at 125 m depth contour	109	6	1	0	646	11	5	0
Transitional	SHORE	Imperieuse Reef	9	0	0	0	36	6	0	0
		Cunningham Island	27	3	0	0	89	6	0	0
		Clerke Reef	25	6	0	0	81	12	0	0
	IMCRA	Northwest Shelf	499	49	16	0	3,251	79	54	14
	AMP	Argo-Rowley Terrace	89	14	0	0	401	21	6	0
		Kimberley	6	0	0	0	11	2	0	0
		Mermaid Reef	26	5	0	0	76	10	0	0

	MP	Rowley Shoals	30	7	0	0	94	14	0	0
	RSB	Mermaid Reef	8	0	0	0	28	3	0	0
		Imperieuse Reef	26	3	0	0	89	8	0	0
		Clerke Reef	26	6	0	0	84	14	0	0
	KEF	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	73	9	0	0	177	16	2	0
		Ancient coastline at 125 m depth contour	72	6	0		229	7	2	0
Winter	SHORE	Imperieuse Reef	23	4	0	0	76	7	0	0
		Cunningham Island	23	3	0	0	74	5	0	0
		Clerke Reef	6	0	0	0	18	1	0	0
		Mermaid Reef	4	0	0	0	11	2	0	0
	IMCRA	Northwest Shelf	398	64	21	0	4,355	84	70	29
	AMP	Argo-Rowley Terrace	95	13	0	0	338	17	6	0
		Mermaid Reef	18	1	0	0	100	6	1	0
	MP	Rowley Shoals	57	8	0	0	207	17	2	0
	RSB	Mermaid Reef	8	0	0	0	57	3	0	0
		Imperieuse Reef	42	4	0	0	105	11	1	0
		Clerke Reef	7	0	0	0	27	2	0	0
	KEF	Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	57	13	0	0	261	18	6	0
		Ancient coastline at 125 m depth contour	56	2	0	0	111	4	1	0
		Continental Slope Demersal Fish Communities	11	1	0	0	16	1	0	0

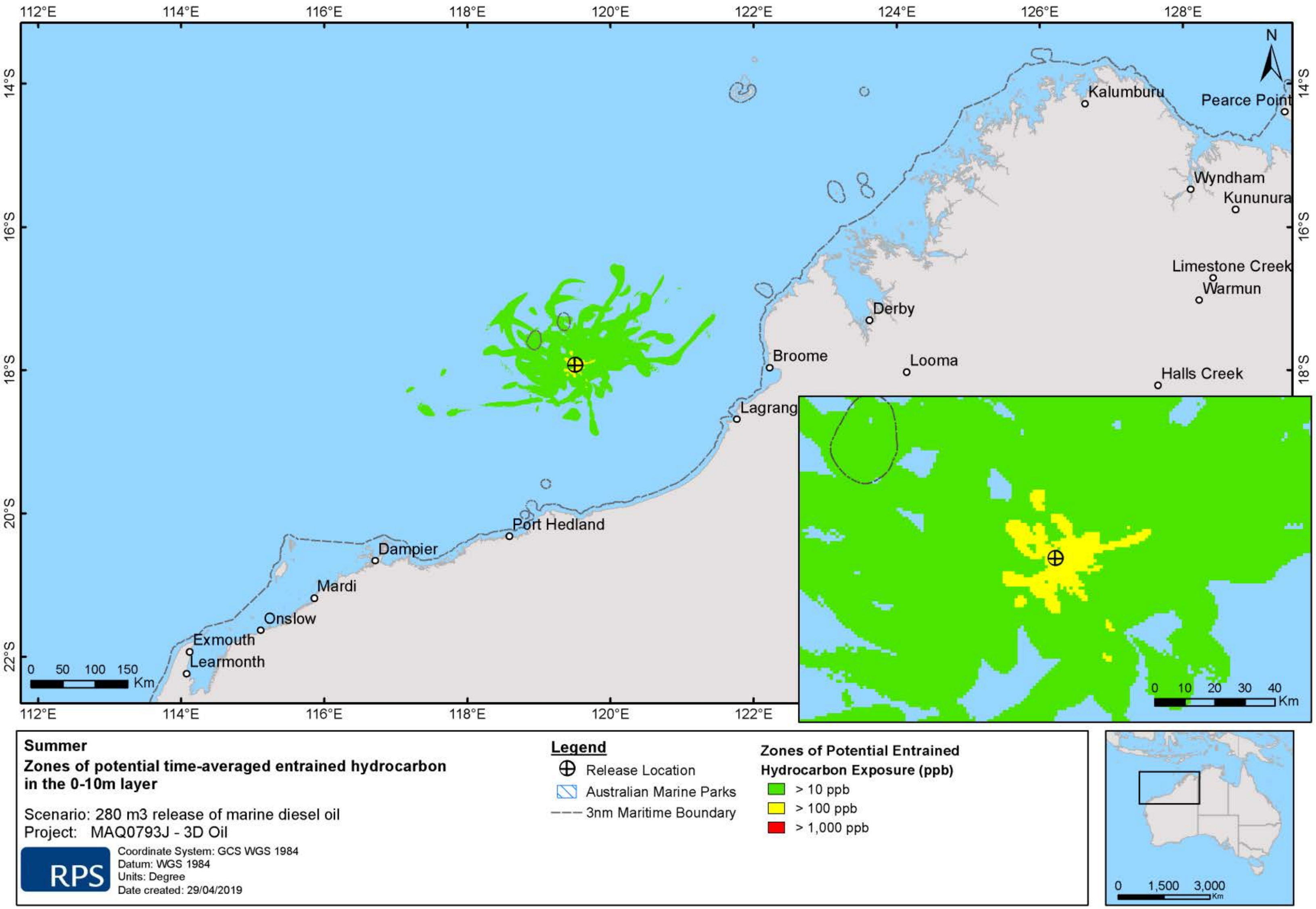


Figure 37 Zone of potential time-averaged entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer wind and current conditions.

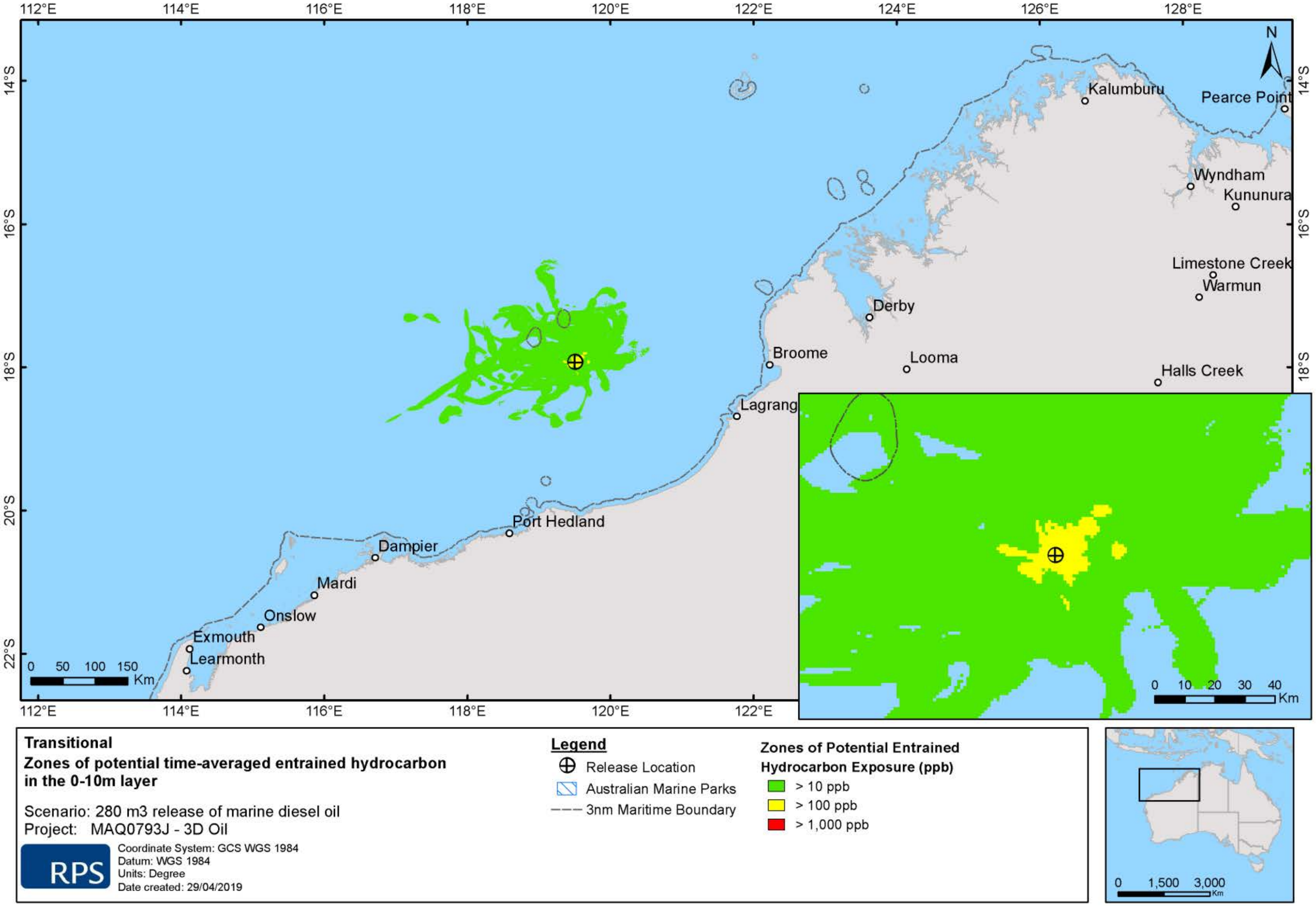


Figure 38 Zone of potential time-averaged entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period wind and current conditions.

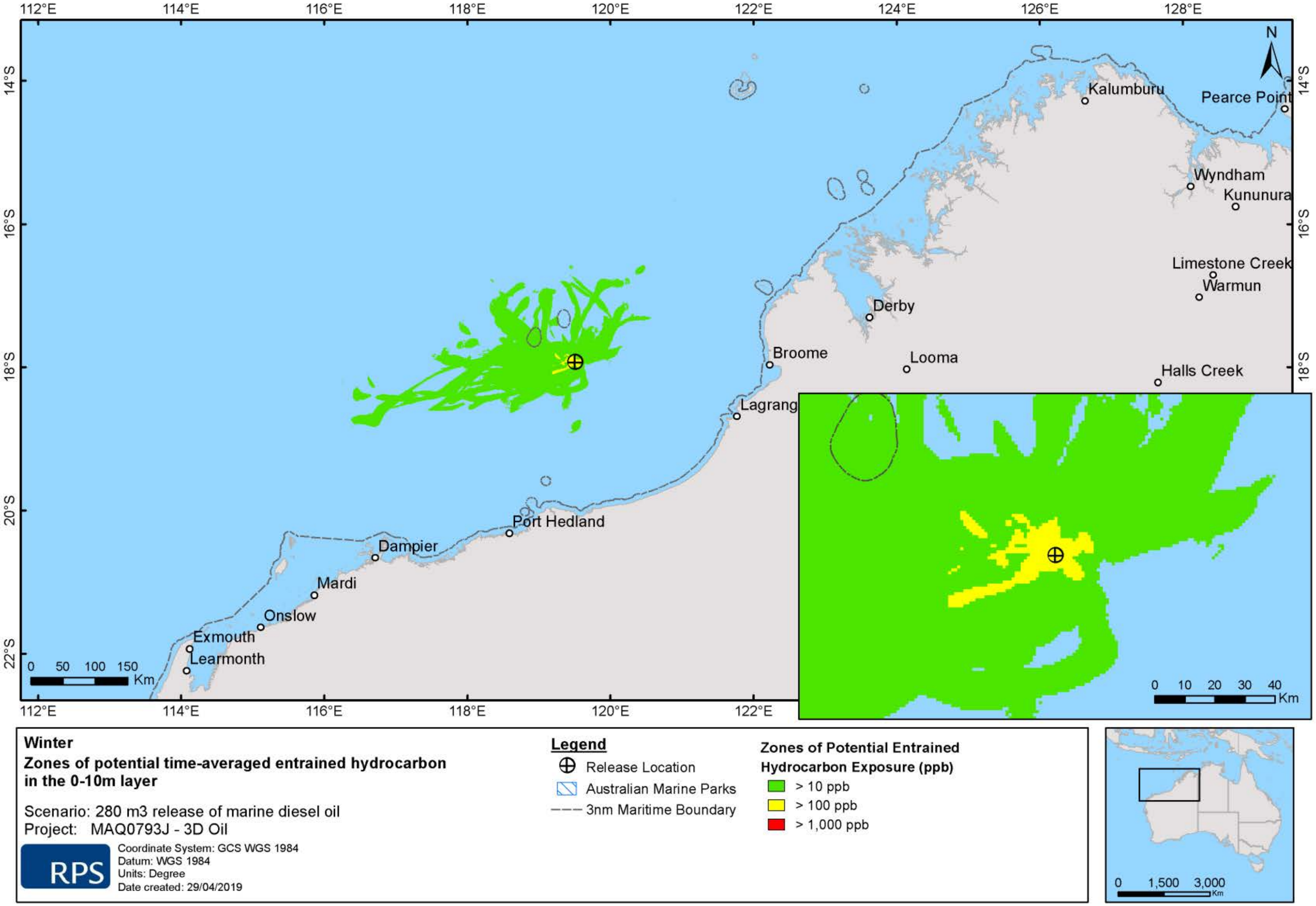


Figure 39 Zone of potential time-averaged entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during winter wind and current conditions.

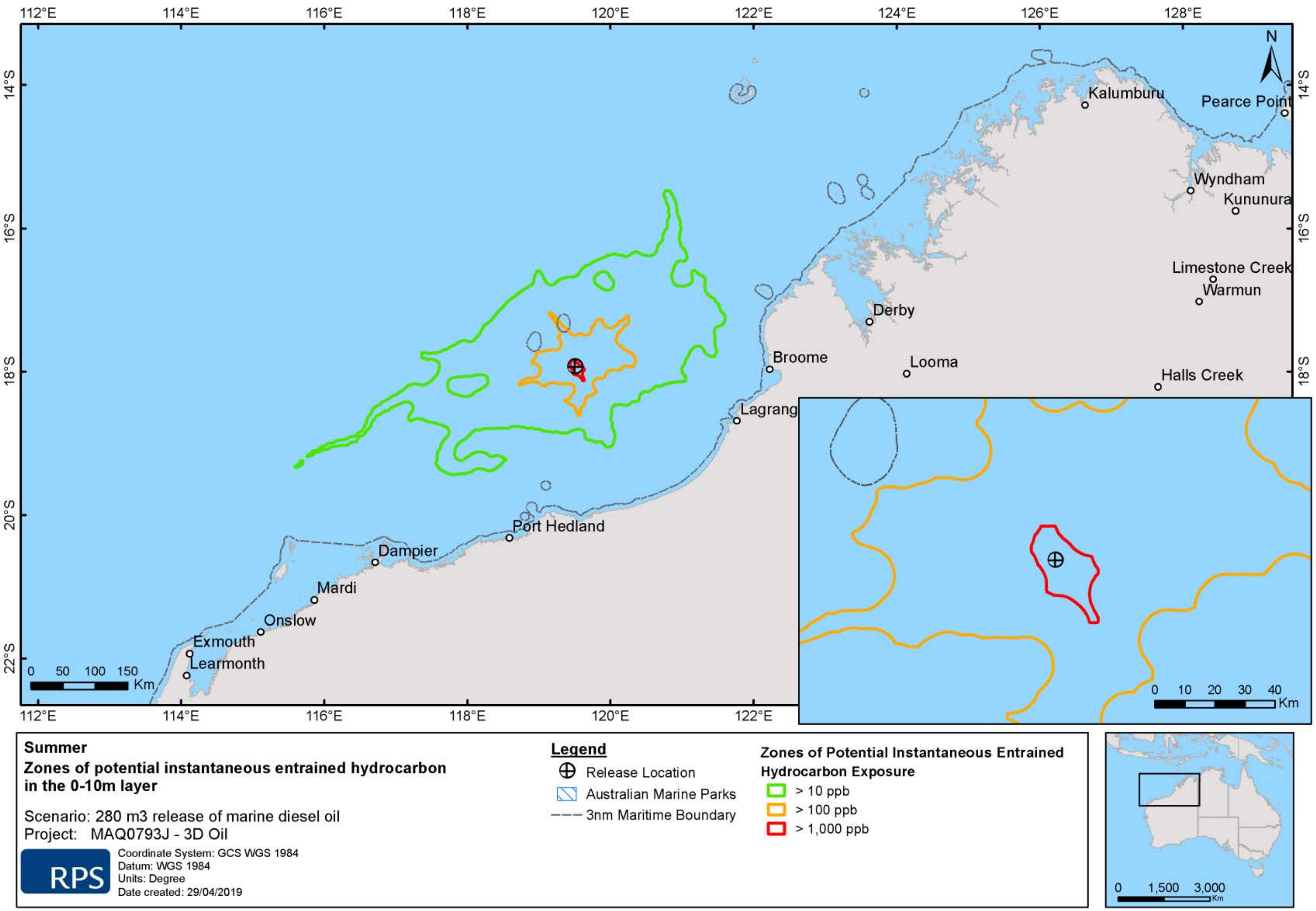


Figure 40 Zone of potential instantaneous entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m[3] of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during summer wind and current conditions.

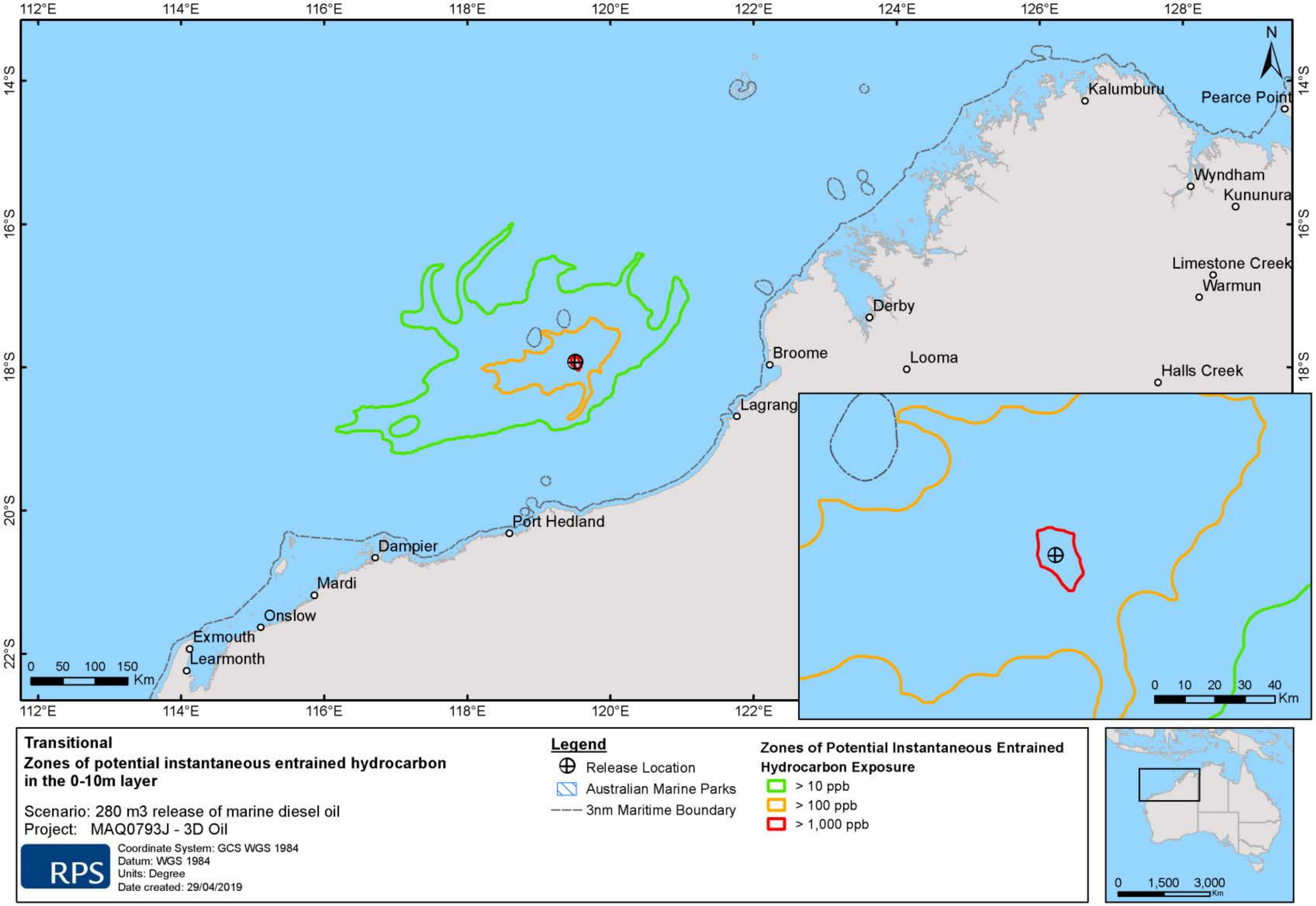


Figure 41 Zone of potential instantaneous entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during transitional period wind and current conditions.

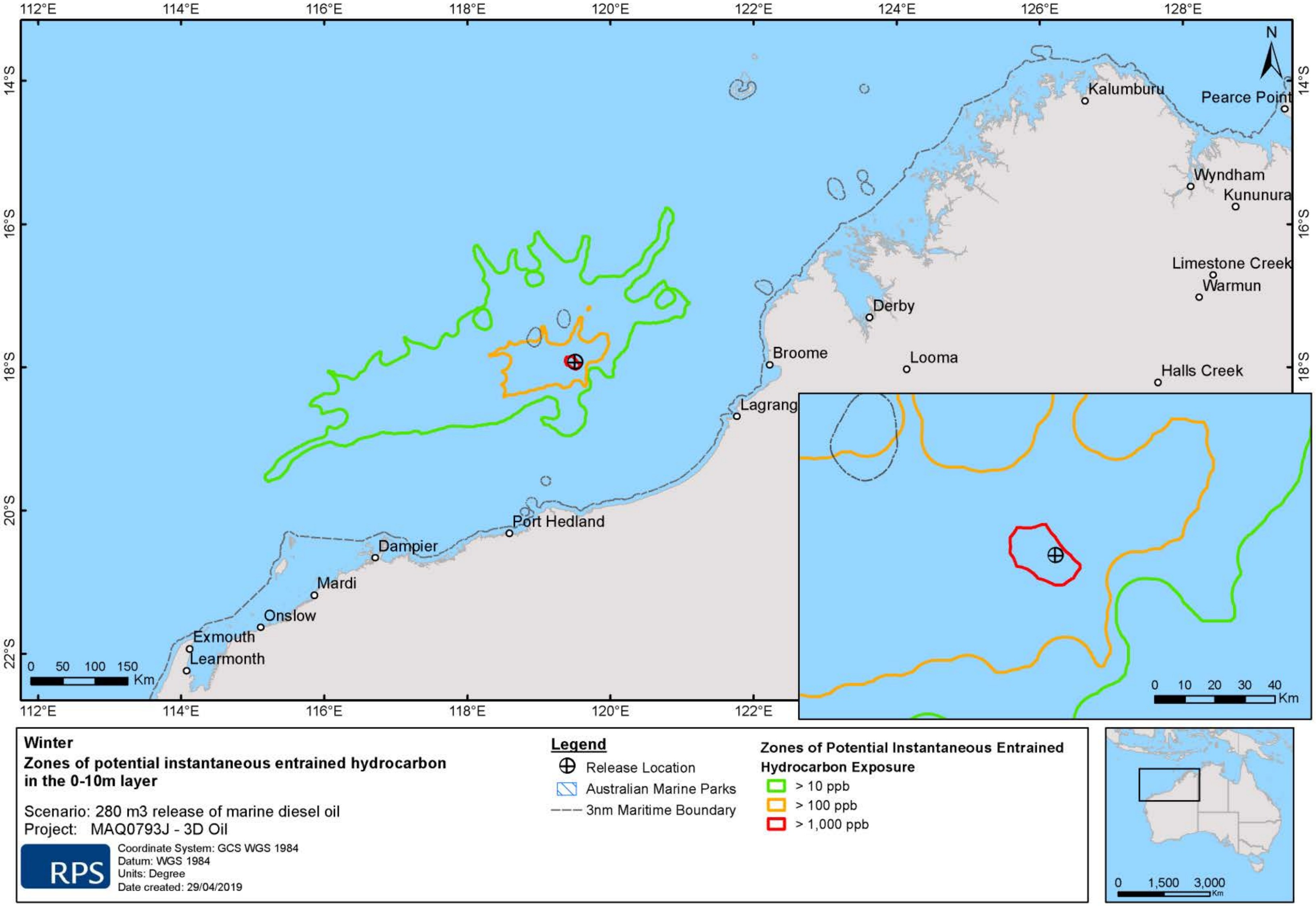


Figure 42 Zone of potential instantaneous entrained hydrocarbon exposure at 0–10 m below the sea surface in the event of a 280 m^3 of surface release of MDO over 6 hours, tracked for 30 days. The results were calculated from 100 spill trajectories simulated during winter wind and current conditions.

RPS

9 REFERENCES

American Society for Testing and Materials (ASTM) 2013, 'F2067-13 Standard Practice for Development and Use of Oil-Spill Trajectory Models', ASTM International, West Conshohocken (PA).

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', Journal of Geophysical Research: Oceans, vol. 100, no. C12, pp. 25249–25259.

Australian Maritime Safety Authority (AMSA) 2015a, Technical Guidelines for Preparing Contingency Plans for Marine and Coastal Facilities.

Australian Maritime Safety Authority (AMSA) 2015b, National Plan - Response, Assessment and Termination of Cleaning for Oil Contaminated Foreshores (NP-GUI-025)

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', Marine Geodesy, vol. 32, no. 4, pp. 355–371.

Bonn Agreement 2009, 'Bonn Agreement aerial operations handbook, 2009 - Publication of the Bonn Agreement', London, viewed 13 January 2015, http://www.bonnagreement.org/site/assets/files/3947/ba-aoh_revision_2_april_2012.pdf

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', Journal of Marine Systems, vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', Oceanography, vol. 22, no. 2, pp. 64–75.

Condie, SA., & Andrewartha, JR (2008). Circulation and connectivity on the Australian Northwest Shelf. Continental Shelf Research, 28, 1724-1739.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

DEWHA, 2007. Characterisation of the marine environment in the north marine region. Marine Division, Department of the environment, water heritage and the arts.

DEWHA. 2008. The North-West Marine Bioregional Plan - Bioregional Profile. Retrieved February 12, 2013, from Australian Government Department of Environment, Water, Heritage and the Arts: http://www.environment.gov.au/coasts/mbp/publications/north-west/pubs/bioregional-profile.pdf

French, D, Schuttenberg, H & Isaji, T 1999, 'Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light', Proceedings of the 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Alberta, pp. 243–270.

RPS

French-McCay, DP 2003, 'Development and application of damage assessment modelling: example assessment for the North Cape oil spill', Marine Pollution Bulletin, vol. 47, no. 9, pp. 9–12.

French-McCay, DP 2004, 'Spill impact modelling: development and validation', Environmental Toxicology and Chemistry, vol. 23, no.10, pp. 2441–2456.

French-McCay, D, Rowe, JJ, Whittier, N, Sankaranarayanan, S, & Etkin, DS 2004, 'Estimate of potential impacts and natural resource damages of oil', Journal of Hazardous Materials, vol. 107, no. 1, pp. 11–25.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', Journal of Physical Oceanography, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO), Environment Canada, Edmonton, pp. 597–610.

International Tankers Owners Pollution Federation (ITOPF) 2014, 'Technical Information Paper 2 - Fate of Marine Oil Spills', International Tankers Owners Pollution Federation td, UK.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', Oceanology, vol. 43, no. 5, pp. 632–642.

Levitus, S, Antonov, JI, Baranova, OK, Boyer, TP, Coleman, CL, Garcia, HE, Grodsky, AI, Johnson, DR, Locarnini, RA, Mishonov, AV, Reagan, JR, Sazama, CL, Seidov, D, Smolyar, I, Yarosh, ES & Zweng, MM 2013, 'The World Ocean Database', Data Science Journal, vol.12, no. 0, pp. WDS229–WDS234.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', Journal of Geophysical Research I, vol. 103, no. C2, pp. 2995–3011.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, 'Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan', Journal of Oceanography, vol. 56, no.5, pp. 567–581.

National Oceanic and Atmospheric Administration (NOAA) 2013, 'Screening level risk assessment package Gulf state', Office of National Marine Sanctuaries & Office of Response and Restoration, Washington DC.

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', Journal of Physical Oceanography, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, 'Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system', Deep-Sea Research II, vol. 57, no. 13, pp. 1098–1110.

Saha, S, Moorthi, S, Pan, H-L, Wu, X, Wang, J & Nadiga, S 2010, 'The NCEP Climate Forecast System Reanalysis', Bulletin of the American Meteorological Society, vol. 91, no. 8, pp. 1015–1057.

Spaulding, ML., Kolluru, VS, Anderson, E & Howlett, E 1994, 'Application of three-dimensional oil spill model (WOSM/OILMAP) to hindcast the Braer Spill', Spill Science and Technology Bulletin, vol. 1, no. 1, pp. 23–35.

Spaulding, MS, Mendelsohn, D, Crowley, D, Li, Z, and Bird A, 2015. Technical Reports for Deepwater Horizon Water Column Injury Assessment- WC_TR.13: Application of OILMAP DEEP to the Deepwater Horizon Blowout. RPS APASA, 55 Village Square Drive, South Kingstown, RE 02879.

Willmott, CJ 1981, 'On the validation of models', Physical Geography, vol. 2, no. 2, pp.184–194.

Willmott, CJ 1982, 'Some comments on the evaluation of model performance', Bulletin of the American Meteorological Society, vol. 63, no. 11, pp.1309–1313.

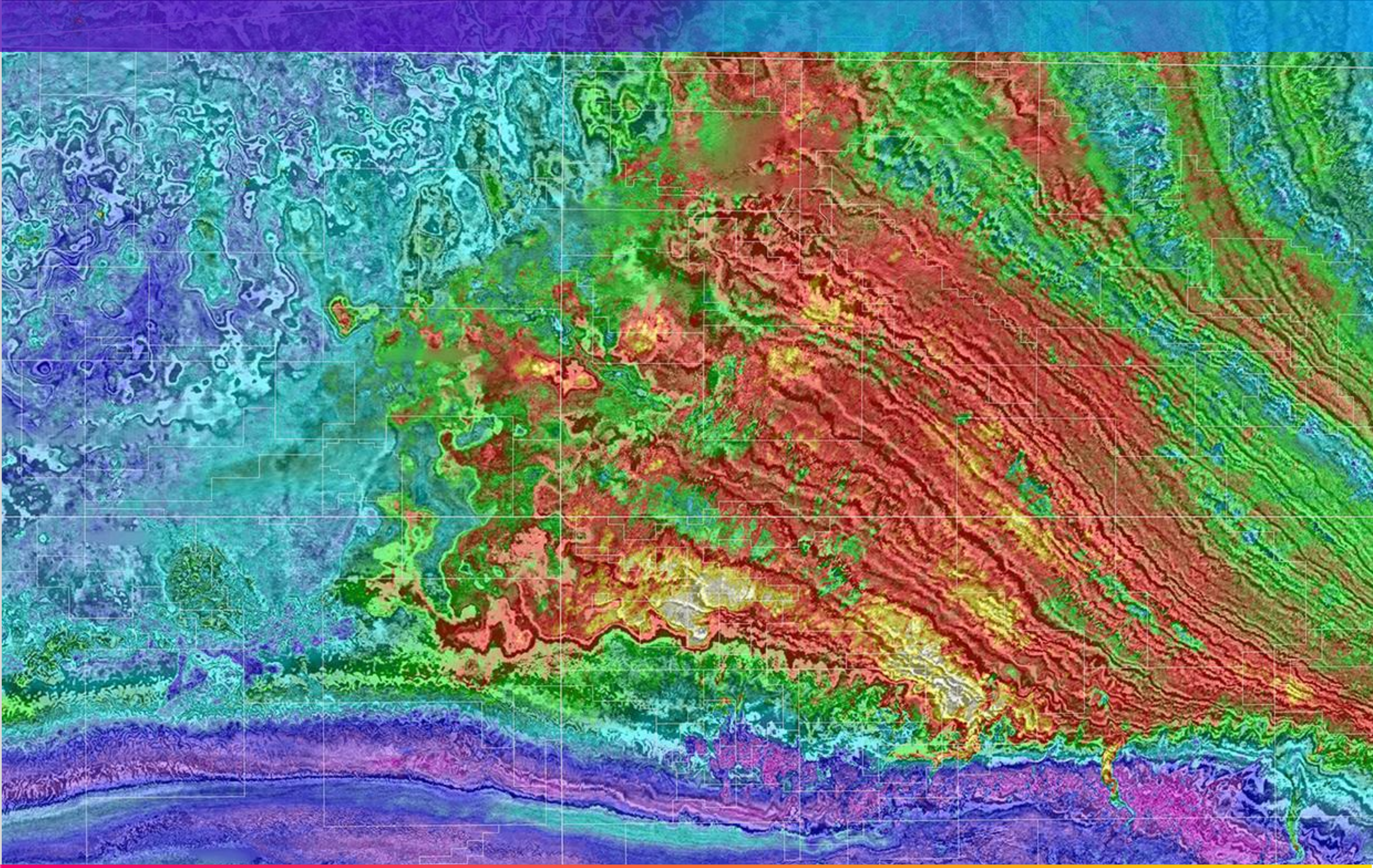
Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink, KM, Legates, DR, O'Donnell, J & Rowe, CM 1985, 'Statistics for the evaluation of model performance', Journal of Geophysical Research, vol. I 90, no. C5, pp. 8995–9005.

Willmott, CJ & Matsuura, K 2005, 'Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance', Journal of Climate Research, vol. 30, no. 1, pp. 79–82.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', Journal of Physical Oceanography, vol. 34, no., 4, pp. 844–855.

Zigic, S, Zapata, M, Isaji, T, King, B, & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference, Institution of Engineers Australia, Auckland, paper 170.

Appendix G:Oil Pollution Emergency Plan



OIL POLLUTION EMERGENCY PLAN

Sauropod 3D Marine Seismic Survey
(WA-527-P)

cgg.com

SEE THINGS DIFFERENTLY

CGG

Document Status					
Version	*Purpose of document*	*Authored by*	*Reviewed by*	*Approved by*	*Review Date*
A	Draft for internal review	RPS	RPS	RPS	15/07/2021
B	Draft for client review	RPS	CGG	CGG	6/08/2021
0	Final for issue	RPS			

PREPARED BY:

MAKING COMPLEX EASY

Level 2, 27-31 Troode Street
West Perth WA 6005

T +61 8 9211 1111
W rpsgroup.com

Table of contents

Figures

Tables

Appendices

Acronyms and Abbreviations

Name	Description
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Authority
CA	Control Agency
CEMT	Crisis and Emergency Management Team (CGG)
CGG	CGG Services Australia
DBCA	Department of Biodiversity Conservation and Attractions
DMIRS	WA Department of Mines, Industry Regulation and Safety
DNP	Director of National Parks
DoEE	Department of Energy & Environment
DoT	WA Department of Transport
EMBA	Environment that maybe affected
EP	Environment Plan
ERG	Emergency Response Group (shoreside vessel contractor)
ERM	Environmental Resources Management
ERP	Emergency Response Plan (vessel emergency response)
ERT	Emergency Response Team (vessel response group)
HSE	Health Safety & Environment
IAP	Incident Action Plan
IMO	International Maritime Organization
ITOPF	International Tanker Owners Pollution Federation
JA	Jurisdictional authority
JRCC	Joint Rescue Coordination Centre
MDO	Marine diesel oil
MFO	Marine fauna observer
MOP	Marine oil pollution
MSS	Marine seismic survey
NEBA	Net Environmental Benefits Assessment
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
OPEP	Oil Pollution Emergency Plan
OSMP	Operational & Scientific Monitoring Plan
POLREP	Pollution Report
SITREP	Situation Report
SOPEP	Shipboard Oil Pollution Emergency Plan
WA	Western Australia

Reference Documents		
Jurisdiction	**Plan Title**	**Function / Application**
Commonwealth of Australia (Commonwealth waters)	National Plan for Maritime Environmental Emergencies (NatPlan)	The NatPlan sets out an effective response to marine pollution events in Commonwealth waters through an integrated arrangement between the federal, state and Northern Territory and the petroleum industry. There are national guidelines for the development of marine oil pollution (MOP) contingency plans. Under the NatPlan states / territories are required to develop operational and tactical plans to deal with oiled wildlife in their jurisdiction.
Western Australia (State waters)	State Hazard Plan for Maritime Environmental Emergencies (state hazard plan)	Replaced the WestPlan – Marine Oil Pollution (MOP) and the WestPlan Marine Transport Emergency. Details the management arrangements for the prevention, preparation, response and recovery for MOP minimise the impacts of marine oil pollution from vessels, offshore petroleum activities and other sources. The rehabilitation of oil-affected wildlife is a recognised response activity under WestPlan-MOP.

First Strike Response

Detailed below is the checklist of first strike response actions in the event of a marine diesel spill (Level 1 or Level 2) from vessels undertaking the Sauropod 3D MSS activity in Exploration Permit WA-527-P.

In a spill event, a response will be activated commensurate to the size and level of risk. As the Sauropod 3D MSS activity is vessel-based in Commonwealth waters, the Control Agency (CA) (i.e. organisation in control of oil spill response) is the Australian Maritime Safety Authority (AMSA). CGG and the vessel contractor will support the oil spill response activities.

This OPEP is activated on the release of any hydrocarbon substance from MSS vessels to the marine environment during survey activities in the Sauropod 3D MSS Operational Area. This OPEP does not apply to vessel spills during transit activities to/from the Sauropod 3D MSS Operational Area, which will be managed via the vessel's Shipboard Oil Pollution Emergency Plan (SOPEP).

The CGG project manager is responsible for activating this OPEP. Notification and callout responsibilities are summarised in Table 0-1. Contact details for these groups/organisations are provided in Appendix 1.

Table 0-1 - Notification and Call-out Authorities

Group/Organisation	Notified/Mobilised by:	Method:	Assembly Point
Vessel Response Crew	Vessel master	Internal (phone/ radio/alarm)	As directed
Vessel Management Emergency Support Group	Vessel master	Telephone	-
CGG project manager	CGG offshore representative	Telephone	CGG Board Room
CGG Emergency/ Crisis Management Team (Level 2 spill)	CGG project manager	Telephone	CGG Board Room
AMSA	Vessel master	AMSA JRCC (phone)	-
NOPSEMA (reportable spill)	CGG managing director	Telephone	-
NOPTA, DNP and DMIRS (reportable spill)	CGG managing director	Email	-
DoT (state waters – Level 2 spill)	CGG project manager	Telephone	-
Stakeholders	CGG project manager	Telephone	-

Table 0-2 - Spill Response Action List – MDO Spill

Response Action (Note: CGG in Support Role Only)			
	Action	Responsibility	Timing
	Initial Emergency Actions		
1.	Sound relevant alarm. vessel master is notified of spill in accordance with SOPEP	Crew member discovering leak	ASAP
2.	Manage safety of all vessel personnel. Secure sources of ignition and alert all personnel (appropriate to level of spill). Implement the relevant emergency response procedures to protect human life and equipment and in particular, those procedures focused at reducing the risk of fire or explosion (i.e. Shipboard Oil Pollution Emergency Plan (SOPEP/ERP)) or equivalent)	Vessel master	ASAP refer SOPEP

Response Action (Note: CGG in Support Role Only)			
	Action	Responsibility	Timing
3.	If safe, stop spill through source control actions. Minimise loss overboard utilising available spill prevention/clean-up equipment on-board.	Vessel master (or delegate)	ASAP refer SOPEP
4.	After safety measures have been implemented, identify the damage, location of incident, proximity to land, other navigational hazards, other traffic in the area, extent of spill (rate/volume) and the weather/current conditions in the area. Estimate the quantity of oil released and provide initial incident information.	Vessel master (or delegate)	ASAP Refer Section 4.2
5.	Notify AMSA immediately and confirm response actions (AMSA JRCC Phone: +61 2 6230 6811 or 1800 641 792). Issue POLREP to AMSA	Vessel master	ASAP Refer Section 2.5.2
6.	As appropriate, issue emergency call-out on marine radio VHF Channel 16 to warn other vessels in the immediate path of the spill. Warning should include the type of accident, such as collision or leak; where the accident has occurred; possible hazards such as risk of fire or explosion; where the slick is moving and recommended actions, for example leaving the area, staying 500 m up-current, up-wind from the spill site and no naked flames.	Vessel master	ASAP
7.	Notify the CGG project manager with spill incident details	CGG Offshore Rep.	ASAP
8.	Notify NOPSEMA verbally WITHIN TWO HOURS of a reportable spill (ph: (08) 6461 7090) and provide written record of notification to NOPSEMA, NOPTA and DMIRS. Notify Director of Marine Parks on ph: 0419 293 465 (24 hr Marine Compliance Officer) if the spill is likely to impact on Australian Marine Parks. Notify: DoT on ph: (08) 9480 992 (24 hr duty officer) if the spill is within or impending on WA state waters.	CGG managing director (or delegate)	Within two hrs Refer Section 2.5.2
	Level 2 Spill:		
9.	On advice from AMSA, initiate response strategy.	vessel master	-
10.	Deploy oil spill tracking buoy to track spill. Provide data to AMSA and DoT (if required).	CGG Offshore Rep.	Within 30 minutes of spill Refer Appendix 2
11.	As directed, monitor leak size, changes to the physical/chemical character of the slick, direction, weather and sea- State conditions providing this information to AMSA and CGG. Formally log and record this data on a time basis. Activate OSMP vessel surveillance and SSM4 (marine fauna monitoring using MFOs) (as directed by AMSA) vessel master / CGG offshore rep.	Refer Section 4.2	
12.	Undertake other stakeholder notifications (as necessary)	CGG MD or CGG project manager	Refer Stakeholder Contacts Directory

	Response Action (Note: CGG in Support Role Only)		
	Action	**Responsibility**	**Timing**
13.	Based on an agreed time frame with AMSA forward regular SITREPs details to AMSA (cc. CGG)	Vessel master / CGG Offshore Rep.	-
14.	Forward copies of SITREPs to NOPSEMA and DoT (if required).	CGG project manager	-
15.	Continue to implement OPEP (or equivalent) procedures	CGG project manager	Ongoing
16.	As directed by AMSA, undertake spill surveillance by support vessel (as appropriate). Continue to monitor the spill providing information on spill amount, trajectory, weather, area of coverage and spill appearance. Information to be provided back to AMSA and CGG. Provide DoT with the information (if required).	Vessel masters / CGG Offshore Rep.	Ongoing
17.	Confirm trajectory (weather conditions and vector analysis) and area impacted. If drifting to WA state waters, request RPS modelling if not requested by AMSA. Identify additional scientific monitoring required and mobilise resources.	Vessel masters / CGG Offshore Rep.	Refer Section 4.2 Refer Section 4.3
18.	Consult with DNP, DoEE and DoT (as appropriate) on: a. Scope of scientific monitoring b. Definition of impact and reference sites	CGG project manager (or delegate)	Refer OSMP
19.	As directed by AMSA, continue routine surveillance to monitor the effectiveness of natural weathering strategy (i.e. monitoring and surveillance strategy) utilising the following effectiveness criteria: a. Trajectory is in line with manual estimates and predicted weathering b. No new environmental sensitivities are being threatened	Vessel master / Support vessel master	
20.	If natural weathering strategy is determined as not effective, confirm with AMSA the revised response strategy based on environmental resources at risk (as appropriate). Provide support where directed	Vessel master / CGG Offshore Rep.	
21.	Coordinate oil spill response activities (response equipment deployment, aerial surveillance, oil spill trajectory modelling (as necessary).	AMSA	
22.	Continue to advise marine stakeholders on the progress of the spill response	Vessel master / CGG project manager (CEMT) / AMSA	Refer Section 2.5.3
23.	Advise AMSA of any observed changes or increased threats to environmental sensitivities (as relevant).	Vessel master	
	Response termination		
24.	The oil spill response termination criteria will be determined and advised by AMSA. Water monitoring (oil-in-water sheen) will continue until termination criteria are achieved. AMSA will advise vessel master and CGG when the response is terminated	AMSA	
25.	CGG to advise NOPSEMA of spill response termination	CGG MD (or delegate)	
26.	Continue with scientific monitoring until OSMP termination criteria has been met for individual studies	CGG project manager	Refer OSMP

1 Introduction

1.1 Purpose, Scope and Objectives

This OPEP details the oil spill response arrangements to be undertaken by CGG to mitigate impacts and risks to the marine environment arising from an oil spill incident from the Sauropod 3D MSS located in Exploration Permit WA-527-P.

The objectives of this OPEP are to ensure that:

- The oil spill response processes/structures used by CGG are consistent with those used in applicable plans such as the NatPlan and the State Hazard Plan.
- CGG has assessed the potential support required during a Sauropod 3D MSS spill event and has timely access to appropriately trained people and resources in order to assist with an effective response.
- There is effective integration and use of industry/government response efforts and resources in responding to a Sauropod 3D MSS spill.

This OPEP covers hydrocarbon spills from vessels involved in the Sauropod 3D MSS located in WA-527-P. This OPEP is to be read in conjunction with the Sauropod EP when considering the existing environment, environmental impacts, risk management, performance standards, reporting compliance, and the decision processes that will apply in the event that a spill occurs.

Any spill originating from vessels outside the Sauropod 3D MSS Operational Area or when transiting to or from the project are managed via their respective Shipboard Oil Pollution Emergency Plans (SOPEPs) as regulated by The Australian Maritime Safety Authority (AMSA) under the *Commonwealth Protection of the Seas (Prevention of Pollution by Ships) Act 1983*.

1.2 Activity Overview and Location

CGG Services (Australia) Pty Ltd (CGG) is proposing to undertake the Sauropod 3D marine seismic survey (hereafter referred to as the Sauropod 3D MSS) in exploration permit area WA-527-P, which is located on the North West Shelf in the Roebuck Basin. An Environment Plan (EP) was previously accepted by NOPSEMA for this activity on 13 July 2020. It was developed and submitted by 3D Oil Limited (3D Oil). CGG is now planning to conduct and manage the survey in WA-527-P under a revised and updated EP. The purpose of the Sauropod 3D MSS is to collect three-dimensional (3D) geophysical data about the underlying rock types to inform oil and gas exploration.

The Sauropod 3D Marine Seismic Survey (MSS) will take place within Commonwealth waters off the north-west Western Australian (WA) coast within the Roebuck Basin in exploration permit area WA-527-P.

The survey will be undertaken within an ‘Acquisition Area’, where seismic data acquisition will occur. The Acquisition Area will be located within a broader ‘Operational Area’, which includes additional space for vessel activities such line turns, run-ins, run-outs, soft-start procedures and seismic source testing.

The Acquisition Area will be up to a maximum of approximately 3,500 km^2, with an Operational Area of approximately 6,000 km^2 (Figure 1-1). At its closest point the Operational Area is approximately:

- 63 km and 67 km from Clerke Reef and Imperieuse Reef respectively (the Rowley Shoals)
- 90 km from Bedout Island
- 120 km from the WA coast at Eighty Mile Beach
- 190 km from Port Hedland
- 230 km from Broome.

Water depths in the Acquisition Area range from approximately 95 to 172 m.

The 3D seismic survey will take a maximum of 60 days to acquire and will be undertaken within the period of January to May 2022.

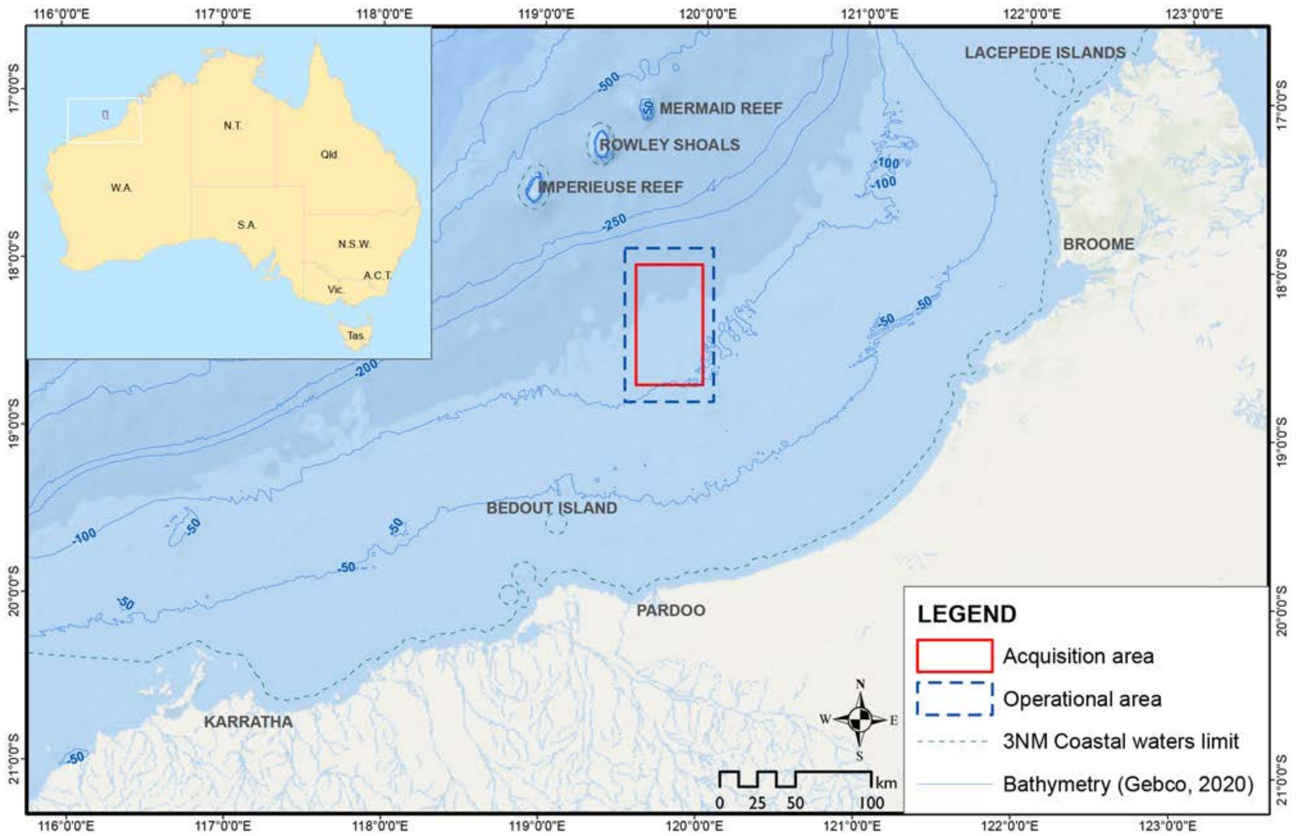


Figure 1-1 - Location of Sauropod 3D Marine Seismic Survey

1.3 Relationship to Other Plans

Oil spill response arrangements detailed in this OPEP integrate with the following CGG and seismic contractor plans, which support the Sauropod 3D MSS activities (refer Figure 1-2):

- Vessel-specific Crew HSE Plan which includes Emergency Response Procedures
- Sauropod 3D MSS Project Specific HSE Plan
- Vessel's SOPEP
- Seismic Contractors' Emergency Response/Crisis Plans.

The support and chase vessels will have SOPEP or SOPEP–equivalent documents according to the size and classification of the vessel. These plans ensure timely response to emergencies and effective management of oil spills.

In addition, this OPEP is consistent with the following government response plans:

- National Plan for Maritime Environmental Emergencies (NatPlan)
- WA State Hazard Plan for Maritime Environmental Emergencies (State Hazard Plan)
- WA Oiled Wildlife Response Plan.

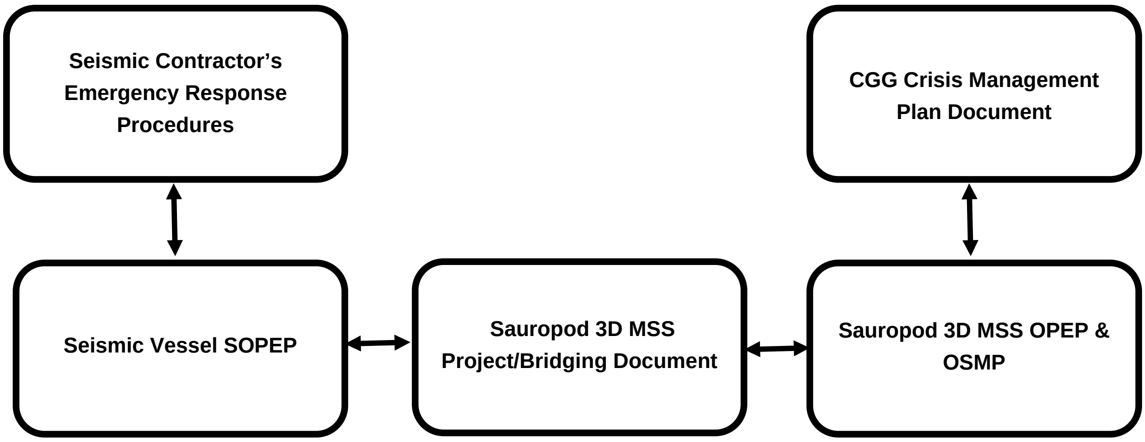


Figure 1-2 - Inter-relationship between CGG and Seismic Contractors Emergency Plans

1.3.1 Vessel SOPEP

As required under MARPOL 73/78 Annex I (Regulation 37), all ships greater than 400 gross tonnes must carry a shipboard oil pollution emergency plan (SOPEP), as required by the International Maritime Organization (IMO). For all ships in Australian waters, the NatPlan also applies. The SOPEP recognises the divisions of responsibility as defined under NatPlan to provide effective response to marine pollution incidents.

SOPEP's, the principal working document for vessel and crew in the event of a marine oil spill, provides for the following specific management response provisions to mitigate and combat oil spills originating from vessels:

- The procedure to be followed by the vessel master to report an oil spill incident, the list of authorities to be contacted (i.e. AMSA JRCC) and the oil spill details to be provided (i.e. forms)
- A detailed description of action to be taken by the personnel on board to reduce or control the discharge (actual or probable) following the incident (i.e. operational spill prevention)
- Roles and responsibilities of all personnel (master, radio officer, chief officer, chief engineer, etc.,) with respect to the particular oil spill incident experienced
- Procedures and point of contact on the ship for coordinating shipboard activities with national and local authorities
- Details of SOPEP equipment held on-board the vessel
- Vessel drawings (drainage and layout)
- SOPEP testing and drill requirements.

The SOPEP also includes specific emergency procedures including steps to control discharges for bunkering spills, hull damage, grounding and stranding, fire and explosions, collisions, tank failure, sinking and vapour release. The typical structure and content of a SOPEP is provided in Table 1-1.

CGG, as part of seismic contractor selection, will confirm the vessel has an IMO certified SOPEP (or equivalent document according to vessel class); equipment and resources as described in the SOPEP are available; and that all scheduled drills and exercises have been undertaken against the documented testing program in the SOPEP.

Table 1-1 - Contents of a Typical SOPEP

Section	Section Title	Content
1	General purpose and introduction	Details the custodian of the manual and its purpose
2	Reporting requirements	Reporting procedures, when and what to report Information requirements, actual/probable discharges Lists of people to contact including coastal ports; coastal State and vessel interested contacts
3	Steps to control/prevent discharges	Types of operational spills (pipes, tank leakage, spills from equipment) and types of spills from accidents and groundings (prevention of fire/explosion, extent of damage containment, reduction of spill volumes, securing the vessel). Priority actions followed by mitigation actions, transfer of bunker/lightering, hull stress assessment Responsibilities of the master and designated Officers General Responsibilities of crew
4	National and local coordination	master to coordinate all activities with the coastal state Communication procedures for assistance/liaison with the coastal state
5	Other relevant information	Local requirements Insurance policy details Owner/operator policies Reference material
Appendices	Appendix 1: Initial Notification Appendix 2: Coastal State Contacts (Focal Points) Appendix 3: Port Contacts Appendix 4: Ship Interest Contacts Appendix 5: Ship Plans and Drawings Appendix 6: On-board Spill Equipment Appendix 7: Records on Oil Pollution Drills	

1.3.2 NatPlan

The National Plan for Maritime Environmental Emergencies (NatPlan) sets out national arrangements, policies and principles for the management of maritime environmental emergencies.

The NatPlan integrates Commonwealth and state government response oil spill response frameworks to facilitate effective response to marine pollution incidents. AMSA manages NatPlan, working with state governments (who have equivalent state plans which integrate into NatPlan); the shipping, petroleum, chemical industries; and emergency services to maximise Australia's marine pollution response capability to incidents.

NatPlan applies to all hydrocarbon spills in Commonwealth waters seaward of the state waters limit and the State Hazard Plan applies in state waters within 3 nm of the territorial sea baseline.

1.3.3 State Hazard Plan

The WA state Hazard Plan for Maritime Environmental Emergencies (State Hazard Plan) provides an overview of arrangements for the management of marine oil pollution and marine transport emergencies in Western Australia and contains information on prevention, preparedness, response and recovery.

The State Hazard Plan prescribes the management arrangements for the prevention of, preparation for, response to and recovery from a MOP incident in order to minimise the impacts of MOP from vessels, offshore petroleum activities and other sources in state waters.

In accordance with the plan, where state waters are impacted by a Level 2/3 MOP incident resulting from an offshore petroleum activity in Commonwealth waters, the Western Australia Department of Transport (DoT) will assume the role of CA for the portion of the response activity that occurs within state waters.

Note that oil spill modelling results indicate a low likelihood of oil spill residue intersection with Western Australian state waters.

1.3.4 WA Oiled Wildlife Response Plan

Oiled wildlife response is an integral part of a Maritime Environmental Emergency response. The Western Australian Oiled Wildlife Response Plan for a Maritime Environmental Emergency is administered by the Department of Biodiversity, Conservation and Attractions (DBCA).

During a Maritime Environmental Emergency, DBCA will lead the oiled wildlife response under the control of the appointed CA.

1.4 Review and Update

This OPEP is required to be reviewed, and if applicable updated, to ensure that all relevant information is accurate and that new information or improved technology is evaluated and used to adapt and improve the management of spills.

Any revisions to this OPEP will be undertaken utilising CGG's Management of Change process observing the EP revision triggers in the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.

Trigger thresholds for an EP revision include:

- Inclusion of a new activity
- If there is a significant modification or new stage to an activity
- If a significant new environmental impact or risk, or significant increase in existing environmental impact or risk identified for the Sauropod 3D MSS activity
- If there is a series of new environmental impacts or risks or a series of increases in existing environmental impacts or risks, which when taken together, results in a significant new environmental impact or risk; or a significant increase in existing environmental impact or risk no provided for in the EP; or
- If there is a change in titleholder that results in a change in the manner in which environmental impacts and risks are managed.

This OPEP will be distributed to all relevant CGG Sauropod 3D MSS participants, the seismic contractor and relevant government authorities after acceptance of the Sauropod 3D MSS EP.

2 Response Arrangements

2.1 Jurisdictional Authority and Control Agency

The NatPlan defines two levels of responsibility:

- Jurisdictional Authority (JA), having the jurisdictional or legislative responsibility to ensure there is adequate prevention of, preparedness for, response to and recovery from an oil spill incident
- Control Agency (CA) having the responsibility to take operational control and respond to an oil spill in the marine environment.

Table 2-1 provides details of the JA and CA with respect to a marine oil spill from vessels and petroleum activities in Commonwealth waters. A spill from Sauropod 3D MSS activities would be classed as an offshore petroleum vessel-based incident, as shaded in the table.

Table 2-1 - Jurisdictional Authority and Control Agency (source: AMSA 2018)

Spill Location	Spill Source	Jurisdictional Authority	Control Agency
Commonwealth waters	Vessel-based Incident	AMSA	AMSA
	Offshore petroleum vessel-based incident (including seismic and support vessels)	NOPSEMA and AMSA*	AMSA
	Petroleum activity – facility or infrastructure	NOPSEMA	Petroleum titleholder

* NOPSEMA has legislative responsibilities for oversight of offshore petroleum activities. AMSA has legislated responsibility for all vessels in Commonwealth waters.

CGG recognises the legislated responsibility of AMSA as CA for vessel-based marine oil spills in Commonwealth waters, and AMSA will assume control of the incident as CA for vessel-based spills associated with the Sauropod 3D MSS. However, CGG will monitor and liaise with AMSA, the vessel master and seismic contractor and provide assistance as required.

AMSA will implement NatPlan in the event of a vessel-based spill in Commonwealth waters in accordance with the spill level descriptions contained in Figure 2-2.

AMSA will maintain control of the response until relevant termination criteria are achieved, or in the event that the spill enters state waters, CA responsibility may transfer to DoT.

2.1.1 Commonwealth Waters

AMSA is both the JA for ensuring suitable vessel-sourced spill response arrangements and the CA responsible to respond to vessel-based spills in Commonwealth waters in accordance with the NatPlan. For the purposes of oil spill contingency planning, vessels are considered part of the 'petroleum activity' while they are in the Sauropod 3D MSS Operational Area. If a vessel-sourced spill occurs when undertaking MSS activities, this OPEP will be activated to support the spill, however AMSA, as CA, will remain in control of the response activities with CGG providing available support to AMSA.

Any spill originating from vessels outside the Sauropod 3D MSS Operational Area or when transiting to or from the area are not 'petroleum activities;' and are managed via their respective Shipboard Oil Pollution Emergency Plans (SOPEPs) as regulated by AMSA under the *Commonwealth Protection of the Seas (Prevention of Pollution by Ships) Act 1983*.

2.1.2 State Waters

DoT is the JA and CA responsible for managing MOP emergencies in state waters, in accordance with the State Hazard Plan. The CA has overall responsibility for ensuring there is an adequate response to a MOP incident in state waters, including those from a petroleum activity originality in Commonwealth waters. If a vessel-based spill occurs during the Sauropod 3D MSS (and enters state waters), this OPEP will be activated to support the spill, however DoT, as CA, will remain in control of the response activities within the portion of the response in state waters. CGG will provide support to DoT (as necessary).

2.2 Emergency Response Organisation

Figure 2-1 provides the Sauropod 3D MSS emergency reporting structure for marine emergencies/oil spills. Table 2-2 details the responsibilities of response teams with regard to oil spill response. Notification responsibilities are contained in Section 2.5.

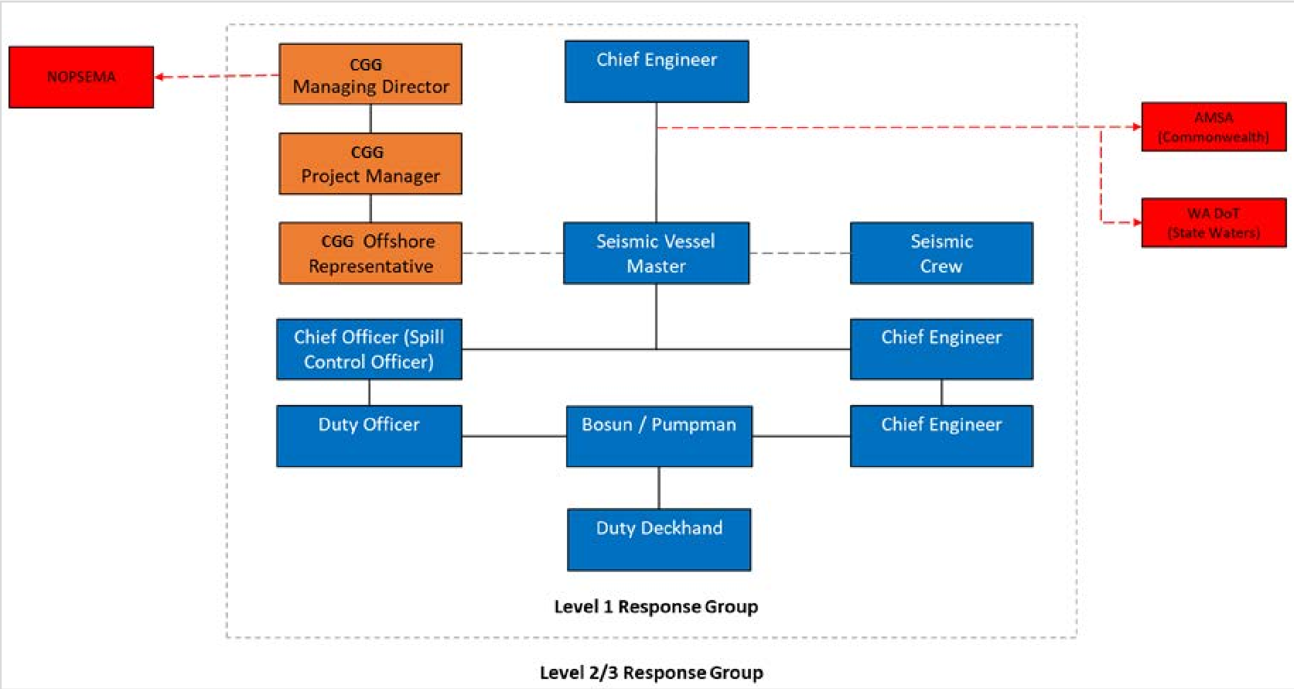


Figure 2-1 - Sauropod 3D MSS Emergency Reporting Structure

Table 2-2 - Response Teams and Responsibilities

Team	Responsibility
MSS Vessel Emergency Response Team (ERT)	The ERT is responsible for initiating the Incident Action Plan (refer Immediate Actions – First Strike Response) and emergency procedures as detailed in the vessel's SOPEP. The major roles within the ERT are as follows: The vessel master has overall control of the on-board operations and has the responsibility of reporting the incident, without delay, to AMSA. The master oversees any stability computations/evaluations, direct damage controls; initiates incident investigations and coordinates response activities with AMSA (as appropriate). The chief engineer, in charge of the engine room and bunkering activities, coordinates spill response activities within the engine room and ensures that all available engine room staff are mobilised for containment and clean-up activities. The duty engineer ensures engine room services are available to deck personnel engaged in clean-up operations (e.g. air, water, power). The chief officer is responsible for containment and clean-up activities, checking stability criteria and keeping the master informed and updated. The duty officer assists the chief officer as required, and alerts and mobilises all off-duty personnel. The duty deckhand alerts all personnel as soon as possible and will attempt to contain any oil spill on deck, and prevent oil from going over the side by using available sorbents or sawdust, rags, scuppers, etc.

Team	Responsibility
	Duty rating(s) alerts officer(s) on duty immediately of an oil leakage. Positions sorbent materials/clean-up material to prevent any oil from escaping overboard and commences clean-up by using the available equipment on-board the vessel. Other crew responsibilities follow the instructions of the chief officer and carry out containment and clean-up operations as directed
Seismic contractor company Emergency Response Group (ERG)	Primary duty is to ensure that the master is fully supported and to engage with regulatory authorities and relevant resources as detailed in the SOPEP. This may include logistics support and telecommunications; safety; planning; finance; insurance and legal support. The seismic vessel manager normally represents the ERG.
CGG Crisis and Emergency Management Team (CEMT)	The CGG managing director normally represents the CGG CEMT and maintains contact with NOPSEMA after initial incident notification (and provides regular interval updates). The CEMT monitors the incident and provides support (as required). The CEMT also provides updates to affected stakeholders (as necessary). Note, in the event of a Level 2 oil spill from Sauropod 3D MSS vessels, CGG will monitor for oil impacts to environmental sensitivities and if oil is detected at levels which may cause environmental impact to the particular sensitivity and will undertake any additional scientific monitoring considered necessary (e.g. wildlife monitoring).

2.3 Spill Level Classification

The level of spill response depends on the nature and scale of the spill, whether on-site resources can manage the response or additional support resources are required, and the environmental sensitivities at risk. Figure 2-2 provides NatPlan guidance for spill level classification. The CGG project manager shall make an initial assessment of the spill level based upon the initial guidance information provided and NatPlan criteria.

Characteristic	Level 1	Level 2	Level 3
MANAGEMENT			
Jurisdiction	Single jurisdiction	Multiple jurisdictions	Multiple jurisdictions, including international
Delegation	Incident Controller responsible for all functions	Some functions delegated or Sections created	All functions delegated and/or divisions created
Number of agencies	First-response agency	Routine multi-agency response	Agencies from across government and industry
Incident Action Plan	Simple/Outline	Outline	Detailed
Resources	Resourced from within one area	Requires intra-state resources	Requires national or international resources
TYPE OF INCIDENT			
Type of response	First-strike	Escalated	Campaign
Duration	Single shift	Multiple shifts Days to weeks	Extended response Weeks to months
Hazards	Single hazard	Single hazard	Multiple hazards
RESOURCES AT RISK			
Human	Potential for serious injuries	Potential for loss of life	Potential for multiple loss of life
Environment	Isolated impacts or with natural recovery expected within weeks	Significant impacts and recovery may take months. Remediation required	Significant area and recovery may take months. Remediation required
Wildlife	Individual fauna	Groups of fauna or threatened fauna	Large numbers of fauna
Economy	Business level disruption	Business failure	Disruption to a sector
Social	Reduced services	Ongoing reduced services	Reduced quality of life
Infrastructure	Short term failure	Medium term failure	Severe impairment
Public Affairs	Local and regional media coverage	National media coverage	International media coverage

Figure 2-2 - NatPlan Guidance on Spill Level Classification

For a Level 1 response:

- The spill can be managed by the vessel master with on-board equipment and trained vessel crew members. These are small spills which will not impact shorelines or other sensitive resources.
- The vessel master is responsible for notifying the JA (AMSA). The vessel master (or delegate) shall monitor the spill and notify AMSA of the situation status. AMSA, as CA for Level 1 spills in Commonwealth waters will monitor and continue to assess this level of spill.

For a Level 2/3 Response:

- A Level 2/3 spill cannot be managed by the vessel master or may have serious impacts on the environment.
- The vessel master will notify AMSA as soon as possible. AMSA will assume control of the spill incident and respond. The responsibilities of the CA under a Tier 2/3 spill scenario include:
  - Monitoring the spill, its weathering and proximity to environmentally sensitive locations and developing an oil spill response strategy to mitigate impacts to protection priorities in the spill-affected area
  - Undertaking oil spill trajectory modelling (as necessary) to predict slick movement
  - As required, and after a NEBA assessment, deploy appropriate resources or equipment to protect identified sensitive environmental resources (i.e. primarily marine fauna).

On-site resources will continue to provide status updates (SITREPs), regardless of the spill level, at the direction of AMSA, throughout the response activity.

2.4 Spill Response Management Team – Level Structures

2.4.1 Level 1 Structure

The vessel master will mount the first response to the spill incident in accordance with the vessel's SOPEP using the resources immediately available to the vessel. The master will also immediately notify any spill to the Rescue Coordination Centre (AMSA). Refer to Section 2.5 for regulatory notification responsibilities.

The CGG offshore representative is responsible for notifying the CGG project manager of the spill. For this spill level, while the CGG managing director will be internally notified, full mobilisation of the CGG CEMT is not anticipated.

The vessel master (or delegate) shall monitor the spill and provide updated reports to AMSA of the spill situation to inform AMSA on the adequacy of the spill response strategy. Updates will occur at frequencies determined by AMSA, until the spill is effectively dispersed or evaporated, with oversight by, and in close cooperation with, AMSA.

AMSA, as CA for Level 1 spills in Commonwealth waters will monitor and continue to assess this level of spill. Note that AMSA can reassess the response at any time and escalate the level as required.

2.4.2 Level 2/3 Structure

A Level 2 spill cannot be managed by on site resources and/or could have serious impacts on the environment.

The vessel master, after ensuring safety of crew, fire prevention and notification to AMSA JRCC, will implement the SOPEP and consider actions to reduce the oil volume released to the environment (refer Section 5.1 for typical SOPEP responses to vessel spill scenarios). AMSA will assume control of a Level 2/3 spill incident and response in Commonwealth waters. If the spill enters state waters, DoT will assume the role of CA for the portion of the response activity that occurs within the state waters. A high-level coordination between DoT, AMSA and CGG would be required in the event of cross-jurisdictional incidents.

The CGG offshore representative will notify the CGG project manager of the spill. Full mobilisation of the CGG CEMT may occur as a result of a Level 2 spill. CGG will notify NOPSEMA, NOPTA, DMIRS, DNP and DoT (for state waters) of the incident.

AMSA (CA) will determine the appropriate response strategies depending upon the protection priorities at risk within the affected spill area. AMSA will determine the need for oil spill trajectory modelling (OSTM) to confirm areas at risk from the spill; and initiate possible sea/aerial surveillance to confirm/inform trajectory predictions. All selected response strategies will be in accordance with NatPlan and a Net Environmental Benefits Assessment (NEBA) for the specific spill scenario. This will include an assessment of all available response strategies, the effectiveness of the response for the oil type, and their associated risk to protection priorities in the affected area. CGG will consult with AMSA during this assessment.

The vessel master is responsible for providing SITREPs to AMSA to inform the spill response strategy.

AMSA will maintain CA responsibility for the response until relevant termination criteria are achieved.

A Level 3 spill response is not considered credible for the Sauropod 3D MSS activities, due to the limited spill size, fuel type and location of activity.

2.5 Notification and Reporting Requirements

This section provides a summary of the internal and external notifications for any hydrocarbon release from vessel activities in the Sauropod 3D MSS Operational Area.

The vessel master shall ensure that all port and emergency agency contact lists are complete, listed and posted in key locations on the vessel and that all relevant notifications have been provided to these agencies prior to the survey commencement.

2.5.1 Internal

Spill Notification: All spill events to the marine environment will be notified to the CGG project manager regardless of the volume. Information to be supplied with the notification to allow the CGG project manager to assess the response level is contained in Table 2-3.

Table 2-3 - Notification Information

Details
What is the source of the spill and the location of the spill?
What type of hydrocarbon has been released?
How much material has been released (e.g. estimated size based on a ‘known’ hydrocarbon inventory or an estimate based upon the appearance and area of oil on the sea surface (refer Section 5.2)?
Has the SOPEP been implemented and has the source been contained or is it continuing?
What is the worst-case scenario?
What are the weather conditions – wind speed and direction, swell and current speed and direction?

2.5.2 External

Regulatory Authorities: All Level 2 spills must be notified to the relevant JA as soon as practicable but within two hours of the event (or becoming aware of the event). Regulatory notification and reporting requirements for vessel spills are provided in Table 2-4.

It is important that information generated during an initial response is accurately recorded, transmitted, acted upon and ultimately stored for future use. The information most important to capture is:

- Incident details – where, what, when, how, why (where possible)
- Extent of spill (volume, hydrocarbon type, continuing release)
- Immediate actions taken.

Table 2-4 - Notification Requirements for a Vessel Spill

From	To	Method	Timing	Additional Information
CGG offshore representative	CGG project manager	Verbal	Immediately	Details in Table 2-1
Vessel master	Vessel manager	Verbal	Immediately	-
	AMSA	Verbal	Immediately	Report verbally to AMSA: Ph: +61 2 6230 6811
		Written notification (POLREP)	ASAP	Online: https://amsa-forms.nogginoca.com/public/
		Written updates (SITREP)	As requested, or every 24 hours	Online: https://amsa-forms.nogginoca.com/public/
CGG project manager	CGG Crisis/ Emergency Management Team (CEMT)	Verbal	ASAP	CEMT callout list (refer Appendix 1)
CGG managing director (or delegate)	For Level 2 (Reportable) Spill: NOPSEMA	Verbal	ASAP but not later than two hrs of the incident occurring	Notify verbally: Ph: +61 8 6461 7090
		Written notification	ASAP after verbal notification	NOPSEMA Form N-3000-FM0831 available at https://www.nopsema.gov.au/environmental-management/resources/ Email: submissions@nopsema.gov.au

From	To	Method	Timing	Additional Information
		Written incident report	Within three days of incident	Written incident report: submissions@nopsema.gov.au
	For Level 2 (Reportable) Spill: NOPTA	Written notification	As soon as practicable after NOPSEMA notification	Copy of NOPSEMA Form N-3000-FM0831 Email: reporting@nopta.gov.au
		Written incident report	Within seven days of written report submission to NOPSEMA	Written incident report: reporting@nopta.gov.au
	For Level 2 (Reportable) Spill: DMIRS	Written notification	As soon as practicable after NOPSEMA notification	Copy of NOPSEMA Form N-3000-FM0831 Email: petroleum.environment@dmirs.wa.gov.au
		Written incident report	Within seven days of written report submission to NOPSEMA	Written incident report: petroleum.environment@dmirs.wa.gov.au
	Director of National Parks	Verbal	ASAP - For any spill release within a marine park or likely to impact on a marine park:	Notify verbally: Ph: 0419 293 465 (24 hr marine compliance duty officer Information to include: Title holder details Time and location of incident (including marine park likely to be affected) Proposed response Contact details of the response coordinator Email: marineparks@environment.gov.au
	For Level 2 Spill: DoT	Verbal	Within two hours – for all actual or impending spill incidents that are in, or may impact, state waters	Verbal notification to maritime environmental emergency response (MEER) duty officer via the 24-hour reporting number (08) 9480 9924.
		Written notification (POLREP)	Following verbal notification	Initial notification to be followed by detailed MOP Incident Report Form (POLREP) accessed at: www.transport.wa.gov.au/imarine/report-marine-oil-pollution.asp Report submitted to: marine.pollution@transport.wa.gov.au

2.5.3 Supplementary

Table 2-5 provides additional external notifications (excluding response resources) which may be required depending upon the nature and scale of the spill incident (specified scenarios).

Table 2-5 - Additional External Notifications

Stakeholder	Issue	Spill Level	Time Frame	References
Commercial Fishing Licence holders	Protection from spill impacts	Level 2/3	Within four hours	Refer stakeholder contacts directory
Adjacent petroleum titleholders	Spill notification	Level 2/3	Within four hours	Refer Appendix 1
Department of Energy and Environment	Damage to wildlife of national environmental significance	Any	Within 72 hours	Refer Appendix 1

2.6 Oil Spill Response Resources

2.6.1 Seismic and Support Vessels

General Equipment: The response equipment for the prevention / minimisation of loss of oil to sea during the proposed Sauropod 3D MSS will include the vessel's on-board spill response kit equipment. Typical contents include:

- Absorbent materials and kits
- Scupper and drain plugs
- Hand shovels and scoops
- Protective clothing
- Portable pumps
- Portable containers
- Portable radios.

This equipment is stored in dedicated lockers located on the vessel and identified as spill equipment (as outlined in the Vessel's SOPEP).

All relevant crew are trained in the use of the vessel equipment listed above and the PPE required to appropriately respond to the spill (as contained in Safety Data Sheets).

Sauropod Resources: For the Sauropod 3D MSS, the following additional resources are also available to assist in oil spill response activities:

- A support and scout vessel (slick monitoring)
- Marine fauna observers (MFOs) on the MSS vessel to monitor for oil spill impacts on fauna
- An oil spill trajectory monitoring buoy to be released from the MSS vessel in the event of a Level 2 spill to assist with slick monitoring
- Access to OSTM services (not 24 hour/emergency)
- Scientific monitoring resources.

2.6.2 NatPlan Resources

AMSA as CA in Commonwealth waters has the capability of mobilising resources for the following activities:

- Trained personnel to support oil spill response activities
- NatPlan equipment (Dampier is the closest national equipment stockpile)
- Oil-industry based Australian Marine Oil Spill Centre (AMOSC) equipment and 'core-group' personnel
- Oil spill trajectory modelling services
- Aerial surveillance via Dornier aircraft (if no conflict with search and rescue activities)
- OSRA resources.

2.6.3 State Hazard Plan

The DoT maintains a database of Maritime Environmental Emergency response equipment managed by DoT, the port authorities, port facility operators and boat harbour operators.

Each port, port operator, port facility operator and boat harbour operator is required at a minimum to hold and maintain a stockpile of Level 1 response equipment commensurate with their identified risk.

3 Response Option Assessment

3.1 Hydrocarbon Spill Scenarios

Credible spill scenarios identified for the Sauropod 3D MSS activity are broadly divided into two categories:

- Small spill quantities from uncontained deck spills/leaks or refuelling to the marine environment
- Larger spills resulting from vessel failure (e.g. vessel collision).

In accordance with NatPlan/State Hazard Plan, the following strategy should be adopted by the CA, depending on the circumstances of the spill and the conditions prevailing:

- If possible, control or stop the outflow of oil from the source
- If coastal or marine resources are not threatened or likely to be threatened, monitor the movement and behaviour of the spill
- If coastal and marine resources are threatened, where practicable, activate response operations to protect sensitive resources
- If possible, contain the spread of oil
- If, due to weather and se conditions, response at sea is not feasible or protection of sensitive areas is not feasible, or these have already been affected, determine appropriate clean-up priorities and other response measures.

3.2 Hydrocarbon Characteristics (MDO)

Vessels engaged in the Sauropod 3D MSS will use marine diesel oil (MDO) which is classified as Group II oil. The properties of MDO are described in Table 3-1.

MDO has the following behaviour at sea:

- The hydrocarbon spreads very rapidly to thin thicknesses elongated in the direction of the wind and current.
- Evaporation is the dominant process contributing to the removal of spilled MDO from the sea surface and can account for 60–70% loss (depending upon wind conditions and sea temperature).
- MDO residues usually consist of heavy components which may persist for longer and tend to disperse as oil droplets in the upper layers of the water column in the presence of waves but can refloat to the surface if wave energies abate.

Table 3-1 - MDO Fuel Properties (ITOPF, 2011)

Oil type	SG (at 25 °C)	Viscosity (cP at 25 °C)	Pour Point (°C)	Flash Point (°C)	API Gravity	Oil Persistence Category/ Classification
MDO	0.83	4.0	-14.0	61.5	37.6	Group II (Light Persistent Oil)

The prevailing weather conditions will influence the weathering and fate of the MDO. Under lower wind speeds (five knots), the MDO will remain on the surface longer, spread quicker, and in turn increase the evaporative process. Conversely, sustained stronger winds (>15 knots) will generate breaking waves at the surface, causing a higher amount of MDO to be entrained into the water column and reducing the amount available to evaporate. Figure 3-1 provides the predicted weathering and fate graphs as a percentage of a single instantaneous surface spill of 280 m^3 MDO under three static wind conditions (five, ten and 15 knots).

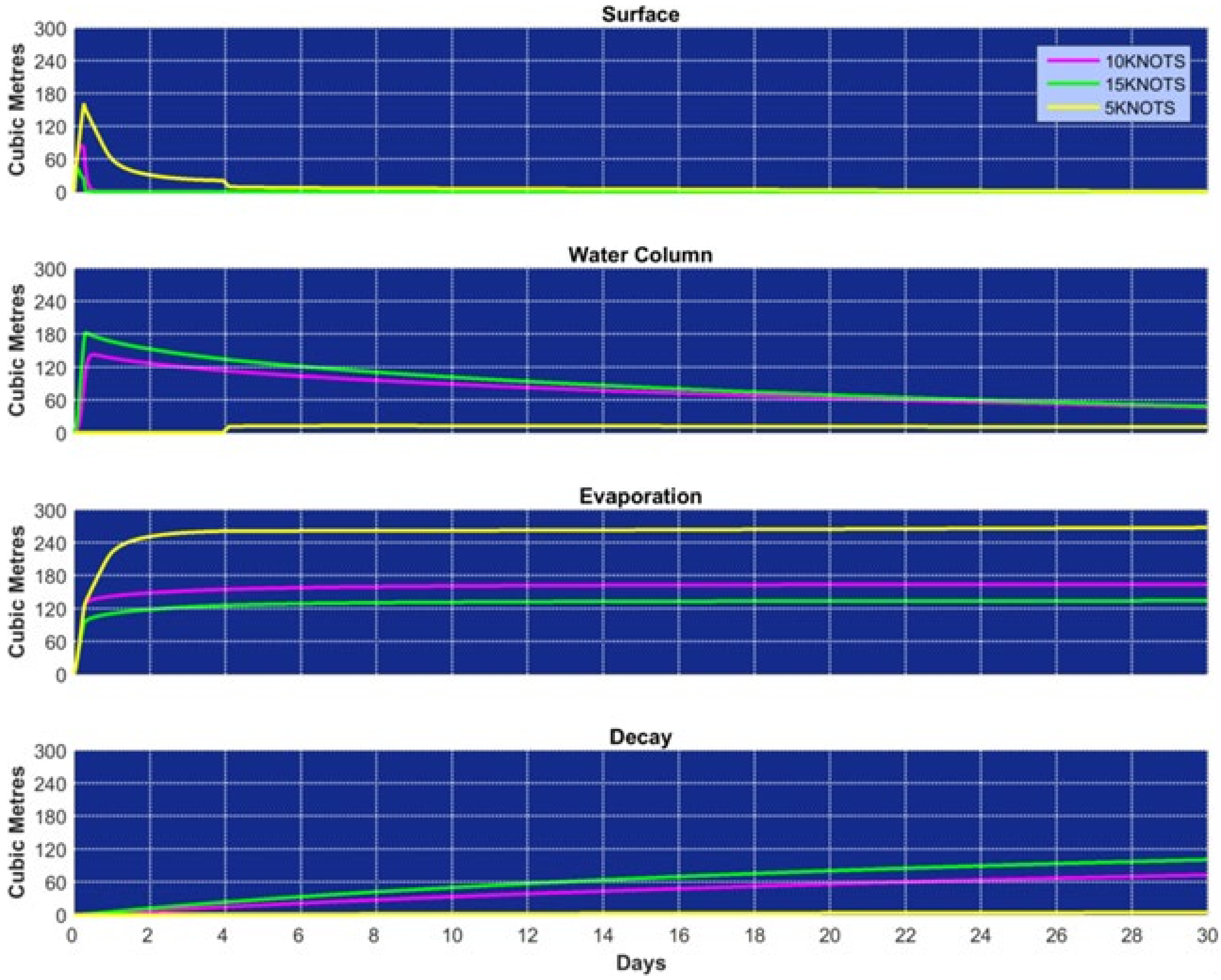


Figure 3-1 - Weathering of MDO Under Three Static Winds Conditions (Five, Ten and 15 Knots). The Results Are Based on a 280 m^3 Surface Release of MDO over Six Hours and Tracked for 30 Days

3.3 Oil Spill Modelling

3D Oil commissioned RPS to model the worst case (credible) oil spill scenario for the Sauropod 3D MSS, using the oil spill dispersion model SIMAP. 3D Oil conducted hydrocarbon spill modelling for the largest fuel tank size in their planned vessel type (of 280 m^3). Although the specific vessel for the survey has yet to be determined, this scenario is used for the basis of this risk assessment as it is greater than the largest single fuel tank size for the vessels proposed for this survey (257 m^3) and therefore is considered to be a conservative assessment. SIMAP's stochastic model was used to quantify the probability of exposure to the sea surface and water column and probability of shoreline contact from hypothetical spill scenarios.

The model considered the following hypothetical, yet plausible scenario:

- A 280 m^3 release of marine diesel oil resulting from a vessel collision incident at the closest point of the operational area to the Rowley Shoals.

The key findings of the modelling, included:

- No shoreline contact above the low (10 g/m^2) threshold was predicted for the scenario.
- Modelling results demonstrated that surface oil at low (1 g/m^2), moderate (10 g/m^2) and high (25 g/m^2) exposure levels could potentially travel greater distances during the transitional period, compared to the summer and winter periods. The maximum distance travelled by surface oil for the low, moderate and high threshold was 66 km, 14 km and 7 km, respectively.

- While the low exposure surface oil was predicted to travel in any directions from the release site, surface oil above the moderate and high exposure levels remained along the north-west to south-east axis across all seasons.
- The modelling results demonstrated a low likelihood (1–2%) of low surface oil exposure to the Argo-Rowley Terrace Australian Marine Park.
- The maximum time-averaged exposure to dissolved hydrocarbon at the depths of 0–10 m remained less than 1 ppb for the winter and transitional seasons while reaching 4 ppb for the summer and winter seasons for various receptors. The maximum instantaneous exposure to dissolved hydrocarbons ranged from 6 ppb to 73 ppb for the transitional and summer seasons, respectively.
- There were no zones of potential time-averaged exposure to dissolved hydrocarbon above the low exposure threshold (6 ppb).
- The maximum time-averaged exposure to entrained hydrocarbons ranged from 4 ppb to 499 ppb for the transitional and winter seasons respectively.
- The maximum instantaneous exposure to entrained hydrocarbon was 6,287 ppb for the North West Shelf.

3.3.1 Geographic Response Area

The environment that may be affected (EMBA) and geographic response area is based on spill modelling for the worst-case credible spill scenario during the Sauropod 3D MSS. Modelling was conducted for a spill scenario at the north-west corner of the Operational Area. The EMBA is defined by the furthest extent that may be reached by entrained hydrocarbons (>10 ppb) in the event of a surface release of 280 m^3. It is important to note that the EMBA covers a much larger area than the area that is likely to be affected during any one single spill event. The modelling was run for a variety of weather and metocean conditions (300 simulations in total), and the resulting EMBA for the north-west corner of the Operational Area was extrapolated to the three other corners.

Figure 3-2 provides the predicted geographic area covered by this OPEP based upon the environment which may be affected (EMBA) from spills during Sauropod 3D MSS activities.

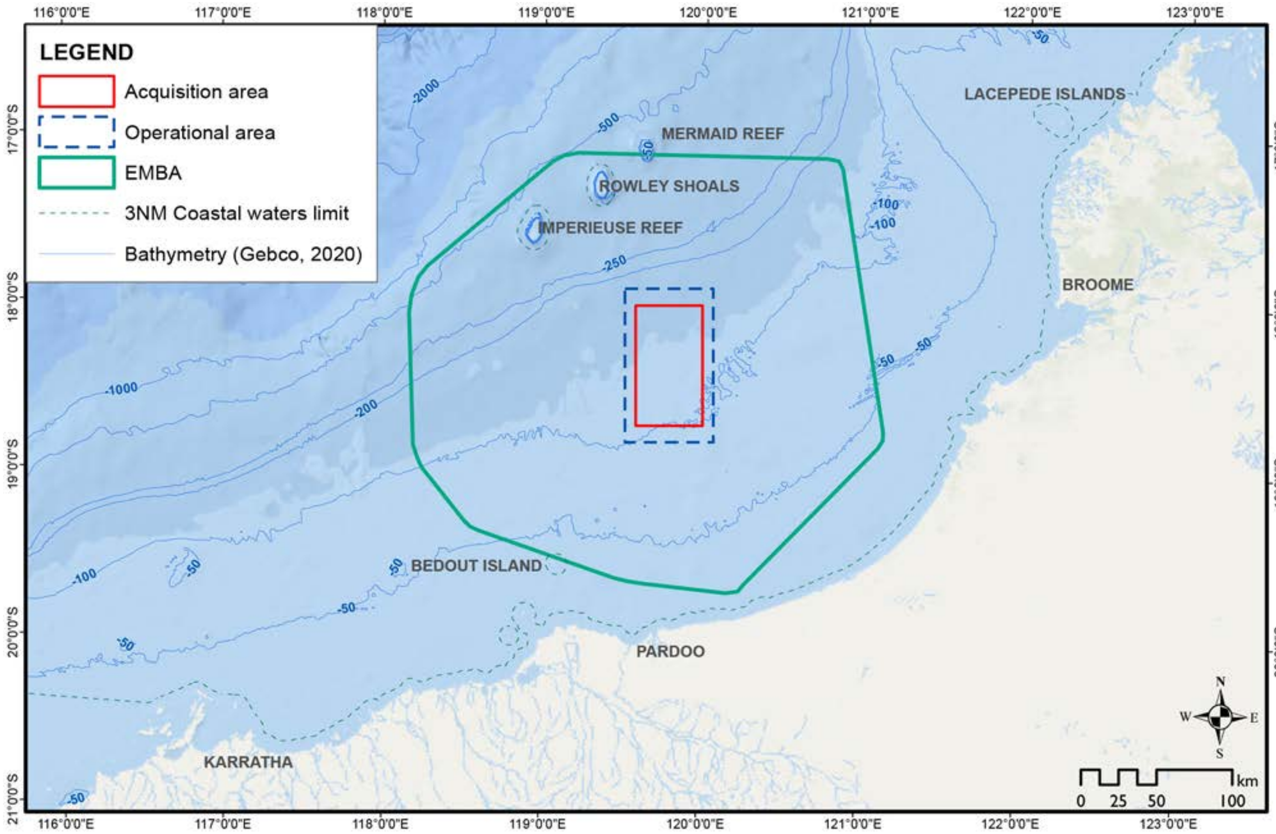


Figure 3-2 - Predicted Geographic EMBA

3.4 Response Option Effectiveness

A preliminary assessment of the suitability and operational effectiveness of response options to MDO has been undertaken in Table 3-2.

Given the rapid evaporation/volatilisation of MDO when released, the rapid spreading rate of MDO, and the small amounts of residual hydrocarbon reaching shorelines, the primary response strategy is to initiate source control and then monitor and evaluate the spill (natural weathering). Additional measures may be adopted to protect specific environmental sensitivities within the spill response EMBA.

The response strategy selected during a real-life spill event will be determined by the CA (AMSA in Commonwealth waters and DoT in state waters).

Table 3-2 - Preliminary Response Option Assessment

Response Option	Description	Sauropod 3D MSS MDO Assessment	Suitability
Source control	Stop or limit flow of oil to the environment.	Achievable in accordance with vessel-specific SOPEP.	✓
Monitor and evaluate	Direct observation (aerial or marine) Spill trajectory / vector calculations Oil spill trajectory modelling Satellite tracking buoys.	To maintain situational awareness all monitor and evaluate options are suitable. Aerial is more effective than vessel surveillance to inform spill response. MSS vessels may provide support with observations.	✓
Natural weathering	This response option is adopted with a monitor and evaluate surveillance strategy when sensitive environmental resources are not considered ‘at risk’ from a marine oil spill, or where other response options are not practicable or will not achieve a net benefit.	MDO evaporates rapidly leaving only small levels of persistent residues after 24-48 hrs of weathering. No toxic components are predicted to be present in concentrations which would affect marine fauna after approximately 24 hours. Response option is preferred for MDO spills as it avoids other additional hazards associated with intervention.	✓
Dispersant application	Application (i.e. spraying) of oil dispersant agents onto oil from an aircraft or vessel may breakdown surface oil slicks and draw droplets into upper layers of water column. Increases biodegradation and weathering.	MDO is not amenable to dispersant application. MDO, while having a small persistent fraction, spreads rapidly to thin layers. Dispersant application can result in punch-through where dispersant passes into the water column without breaking oil layer down. This response option is unsuitable for MDO.	X
In-situ burning	Controlled in-situ burning involves the controlled burning of hydrocarbons in order to rapidly reduce the volume of oil on the water’s surface, thereby reducing its potential to spread to sensitive receptors.	In-situ burning is only suitable for use on hydrocarbons >1–2 mm think with calm sea and light winds. It also requires fire-resistant booming. MDO spreads rapidly to less than 10 g/m^2 (0.01 mm), which makes this response option unsuitable for MDO.	X
Contain and recover	Booms and skimmers to contain surface oil for mechanical or manual recovery and disposal. Relies on calm conditions and thicknesses >10 g/m^2 in order to be effective.	MDO spreads rapidly to less than 10 g/m^2 thicknesses within 24–48 hours. Given the time to mobilise resources to the spill site (>24 hrs), this response option is unsuitable for an MDO spill.	X

Response Option	Description	Sauropod 3D MSS MDO Assessment	Suitability
Protect and deflect	Booms deployed to protect environmental sensitivities. Environmental conditions (e.g. currents and waves will limit application)	MDO spreads rapidly to less than 10 g/m^2 thicknesses within 24–48 hours. Given the time to mobilise resources to the spill site (>24 hrs), booms will have limited, if any, effect. Surface / shoreline receptors within the EMBA are limited. Shorelines or emergent reefs are not predicted to be exposed to MDO from a spill during the Sauropod 3D MSS. Booms have the potential to damage coral reef during deployment.	X
Shoreline assessment and clean-up	Where shoreline impacts are predicted or have occurred, a shoreline assessment may be initiated. Subject to the outcome of a shoreline assessment and a NEBA, shoreline clean-up may be initiated. This may include manual or mechanical removal of oiled substrate, physical washing or jetting of shorelines, or chemical cleaning.	Note shoreline assessment will depend on the mobilisation and safety of trained personnel in remote locations. No shorelines are predicted to be contacted by MDO from a spill during the Sauropod 3D MSS. In the highly unlikely event that a real-life spill event results in oil contacting shorelines / emergent reef at the Rowley Shoals or Bedout Island, quantities will be small and the state of weathering of the MDO will be advanced. Leaving remaining traces of MDO to weather and disperse is likely to have a greater net environmental benefit than clean-up, which may remove or disturb shoreline habitats. The remote locations also limit the ability for this option to be initiated safely and effectively.	X
Oiled wildlife response	Consists of capture, cleaning and rehabilitation of oiled wildlife. May include hazing or pre-spill captive management. In WA this is coordinated by DoT and DBCA. Mobilisation and safety of trained personnel in remote locations, as well as the limited potential to recover wildlife from the water, significantly limit the potential effectiveness of this option.	Given limited spill volume and rapid spreading and weathering of MDO, a large-scale wildlife response is not predicted. There is potential for a small number of individual birds or other fauna to be affected in the immediate vicinity of the spill. Limited	

3.5 Net Environmental Benefits Assessment

This section provides details on the environmental sensitivities at specific locations within the Sauropod 3D MSS EMBA where spill response may offer a net environmental benefit. Based upon this assessment, protection priorities and preliminary location-specific response strategies have been identified.

Table 3-3 provides the sensitivity criteria adopted in the prioritisation of environmental sensitivities.

An assessment of effective spill mitigation techniques and the net benefit they offer to specific environmental sensitivities within the Sauropod 3D MSS EMBA is provided in Table 3-4. This planning NEBA is used to compare the environmental and socio-economic benefits of implementing a response option against a 'do-nothing' (monitor and evaluate and natural weathering) strategy to arrive at a response strategy for the location which results in the lowest overall environmental and socioeconomic impacts.

Table 3-3 - Sensitivity Prioritisation

Sensitivity	Code	Criteria
High	S1	Identified marine sanctuary or reserve. Presence of known threatened species feeding, breeding, nesting or aggregation areas. Areas of national significance or biological processes for species of national significance (e.g. breeding sites and national and state parks, Commonwealth heritage listed areas). Region of known sensitive habitat (coral reef, mangrove, salt marshes, and sheltered tidal flats) which if impacted may have significant impacts and long recovery periods.
Medium	S2	Region of known moderately sensitive habitats (sheltered rocky rubble coasts, exposed tidal flats, gravel beaches, mixed sand and gravel beaches) that have a medium recovery period (~2–5 years). Presence of known threatened species or cultural heritage impacted. Presence of non-threatened species feeding, breeding, nesting or aggregation. Region of significant commercial activity (e.g. fishing, tourism). Places of public interest such as beaches.
Low	S3	Region of known low sensitivity habitat (fine grained beaches, exposed wave-cut platform and exposed rocky shores) which have a rapid recovery period (~ year). Minimal impact to marine life, business, public areas or cultural heritage items.

Receptor	Sensitivity	Environmental Sensitivities That May be Exposed to a Surface MDO Spill										Oil Type	Response Option			
		Marine	Mermaid Reef	Clerke Reef	Imperieuse Reef	Bedout Island	Argo-Rowley Terrace AMP	Mermaid Reef AMP	Eighty Mile Beach AMP	Rowley Shoals MP (State)	Mermaid Reef and Cwlth Waters KEF	MDO	Source Control ✓	Monitor and Evaluate ✓	Natural Weathering ✓	OWR Limited potential
Marine Ecology																
Marine mammals (protected)	S1	✓										↑	-	-		
Marine birds (protected)	S1	✓										↑	-	-	↑	
Marine reptiles (protected)	S1	✓										↑	-	-	↑	
Sharks and rays (protected)	S2	✓										↑	-	-		
Fish assemblages	S3	✓										↑	-	-		
Commercially targeted fish stocks	S3	✓										↑	-	-		
Benthic communities	S3	✓										↑	-	-		
Plankton communities	S3	✓										↑	-	-		
Coastal Habitats																
Sandy islands	S2		✓	✓	✓	✓						↑	-	-		
Coral reefs	S1		✓	✓	✓	✓						↑	-	-		
Socio-economic																
Tourism / recreation	S2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	↑	-	-		
Commercial fishing	S2	✓	✓	✓	✓	✓	✓	✓	✓		✓	↑	-	-		
Commercial shipping	S3	✓										↑	-	-		
Petroleum activities	S3	✓										↑	-	-		
Marine archaeology (shipwrecks)	S3	✓	✓			✓				✓		↑	-	-		
Australian Marine Parks	S1	✓					✓	✓	✓			↑	-	-		
State protected areas	S1	✓								✓		↑	-	-		
Commonwealth heritage site	S1	✓										↑	-	-		
Key Ecological Features	S1	✓									✓	↑	-	-		

Legend:
↑ Net benefit
- No net benefit or detriment ('do-nothing' – monitor and evaluate and natural weathering strategy)
↓ Net detriment

Table 3-4 - Environmental Sensitivities and NEBA

3.6 Protection Priorities and Preliminary Response Strategies

Based on the sensitivity prioritisation and NEBA provided in Table 3 4, protection priorities have been identified as follows:

- Protected marine fauna (e.g. birds, reptiles, mammals)
- Rowley Shoals (comprising emergent coral reef Imperieuse Reef, Clerke Reef, Mermaid Reef) and surrounding Rowley Shoals Marine Park (state), Mermaid Reef AMP, Argo-Rowley Terrace AMP, and the Mermaid Reef and Commonwealth waters KEF
- Bedout Island (state) and surrounding Eighty Mile Beach AMP.

Note that the stochastic spill modelling did not predict any shoreline contact at the Rowley Shoals or at Bedout Island. Worst-case predicted hydrocarbon exposures in state waters at these locations include low surface (>1 g/m^2), dissolved (>6 ppb) or entrained (>10 ppb) hydrocarbons.

Table 3-5 provides an assessment of the response strategies which might be adopted at sensitive locations and within designated/protected areas affected by MDO residues from a Sauropod 3D MSS MDO spill.

Table 3-5 - Protection Priorities and Preliminary Response Strategies

Location	Protection Priority	Source Control	Monitor and Evaluate (Natural Weathering)	OWR
Marine	Protected fauna (birds, turtles, mammals)	✓	✓	✓
Rowley Shoals and surrounding state and Commonwealth waters	Mermaid Reef	✓	✓	✓
	Clerke Reef	✓	✓	✓
	Imperieuse Reef	✓	✓	✓
	Rowley Shoals Marine Park (state)	✓	✓	✓
	Mermaid Reef AMP	✓	✓	✓
	Argo-Rowley Terrace AMP	✓	✓	✓
	Mermaid Reef and Commonwealth waters KEF	✓	✓	✓
	Mermaid Reef – Rowley Shoals Heritage	✓	✓	✓
Bedout Island and surrounding state and Commonwealth waters	Bedout Island	✓	✓	✓
	Eighty Mile Beach AMP	✓	✓	✓

The following response strategies are considered viable and may have a net environmental benefit in a Sauropod 3D MSS MDO spill:

- Source control
- Monitor and evaluate (via vessel/aerial surveillance, oil spill trajectory modelling, oil spill tracking buoys)
- Oiled wildlife response (if oiled wildlife is observed and a response is practicable).

The Sauropod 3D MSS Operational and Scientific Monitoring Plan (OSMP) will also be activated in the event of a Level 2 spill incident.

3.7 Operational NEBA, Incident Action Planning and Effectiveness Monitoring

AMSA (for Commonwealth waters) and DoT (for WA state waters) as CAs for these geographical areas are responsible for undertaking a NEBA to determine the appropriate response strategy for a Sauropod 3D MSS Level 2 spill. At the time of the spill, an operational NEBA will be completed to confirm net benefits based upon the spill volume, spill type, spill location, weather conditions, weathering and trajectory predictions (including any surveillance output), and the sensitivities requiring protection. For all response activities the safety and protection of field personnel shall be a primary consideration in implementing response activities for identified protection priorities. When finalised the Incident Controller shall endorse the NEBA. This document shall be used to develop the Incident Action Plan (IAP) for the incident.

The IAP details short-term (i.e. hours to days) operational objectives, response options and priority areas for protection based on the actual circumstances of the event, considering weather conditions and safety considerations. The IAP is relevant over a specified, short-term period. Initially this may be for a few hours only, but once the operation is underway it is likely to address the activities required over each of the following 24-hour periods or longer.

During the incident response, the response effectiveness will be assessed by the CA using the NEBA process.

4 Response Strategies

4.1 Source Control

The vessel SOPEP contains vessel-specific actions to contain and mitigate oil spills for identified credible oil spill threats. Table 4-1 provides a summary of the typical source control actions to be taken by a vessel master in the event of an oil spill incident. The vessel SOPEP will be implemented to limit spill volumes and mitigate spill impacts.

Table 4-1 - Source Control Actions

Release Type	Action
Bunkering overflow/ transfer system leak	Immediately stop the transfer; report the discharge; contain the spill; evaluate the cause and corrective actions to be undertaken; undertake on-board clean-up; and obtain permission to resume operations
Hull failure/leak	Where possible stop/reduce outflow; take appropriate safety action; contain the spill (as practical); report the spill/threat; evaluate the cause and corrective actions to be undertaken; initiate on-board clean-up; identify leaking tank (consider internal transfer if leak can be identified, else consider reducing level in all tanks in the vicinity giving careful consideration to hull stress and stability)
Collision:	Immediate notification; determine tanks penetrated (above and below water line) and any other oil spilled by vessel; assess consequences of separating two interlocked vessels causing ignition; reducing buoyancy/sinking; awareness that action may have a larger spill; assess the potential danger to other vessel traffic and manoeuvrability after separation; consider bringing vessel upwind of the oil slick; isolating penetrated tanks; and making ready for towing or lightering
Fire and explosion	Fight fire; notify incident; bring vessel upwind of oil slick; isolate damaged tanks; undertake damage assessment and repair; initiate on-board clean-up; carryout hull leak prevention; make ready to tow or bunker transfer
Equipment failure (propulsion, steering	Notify incident; determine cause of failure; determine possibility, methods and duration of repairs; determine proximity of navigational hazards (i.e. shoreline, reefs); determine likely drift due to wind, tide and currents; determine availability of tugs, salvage equipment; assess future weather conditions; consider the potential for pollution; consider the timeframe for assistance to arrive or the possibility of assistance from other nearby vessels

4.2 Monitor and Evaluate

The following section provides details of the techniques which may be utilised to gain situational awareness of a spill, predict the movement of the spill and observe the weathering of the spill material. Monitoring and evaluation will be coordinated by the CA (AMSA or DoT). CGG will participate in monitoring and evaluation, as directed by the CA.

Note: All surveillance monitoring results will be provided to both AMSA and DoT (as necessary).

4.2.1 Oil Spill Trajectory Calculation

Spill Movement: The movement and behaviour of an oil slick may be manually estimated by undertaking vector calculations. Manual calculations can commence as soon as the preliminary information on the spill is known. For spills in close proximity to shore and where oil spill tracking buoys are utilised, this method may provide the best option for predicting the likely spill trajectory and timeframes before protection priorities are impacted.

Prior to commencing the calculation, the wind and current data is required. This can be accessed via:

- Currents: Oil spill tracking buoy or from the vessels in the field
- Winds: Bureau of Meteorology Met-eye (http://www.bom.gov.au/australia/meteye).

The calculation is based on the spill moving 100% of the current vector and 3% of the wind vector, as shown in Figure 4-1.

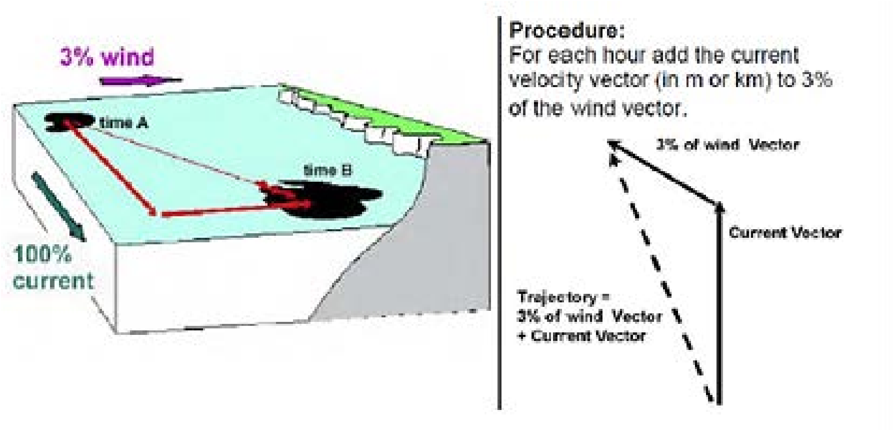


Figure 4-1 - Spill Vectoring Overview

Spill Size Estimation: The spill size may be determined based upon the estimated amount of hydrocarbon released from a ‘known’ hydrocarbon inventory; an estimate of release rates from time of the commencement of the incident; or an estimate of the appearance of oil on the sea surface based upon the likely thickness and type of oil (refer Table 4-2 and Figure 4-2 below).

Hydrocarbon Weathering: The Automated Data Inquiry for Oil Spills (ADIOS) can be used to provide weathering predictions of hydrocarbon types for spill volumes at different wind speeds and water temperatures. This computer-based oil spill response tool is available to download from http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/response-tools/downloading-installing-and-running-adios.html.

4.2.2 Visual Monitoring Surveillance (Aerial/Vessel)

To gain situational awareness and inform the spill response, observation should be carried out via aerial surveillance. Aerial surveillance will be commissioned by the incident controller. Trained aerial observers may be sourced through AMOSC (staff/core group members) and AMSA (NRT members) and it is expected that observations will be undertaken over the spill location and any predicted areas of shoreline contact.

CGG shall participate in vessel-based surveillance as directed by AMSA or DoT. Monitoring and evaluation will be undertaken to assess the natural weathering process and identify the location of the slick. In all cases this will involve visual monitoring from vessels immediately following a spill incident. Spill observers may include CGG project team members and vessel crews.

Coarse estimates of spill volume can be made on the basis of its appearance at sea, using the area covered and colour of spill (refer Table 4-2). Examples of appearance are provided in

. AMSA provides guidance called ‘Identification of Oil on Water – Aerial Observation and Identification Guide (Jan 2014)’ which can be found at: https://www.amsa.gov.au/marine-environment/pollution-response/identification-oil-water.

Table 4-2 - Guidelines for Estimating Spill Volume

Code	Description of Appearance	Approximate Thickness (μm)	Approximate litres per km^2
1	Sheen	0.04 to 0.30	40-300
2	Rainbow	0.3 to 5.0	300-5,000
3	Metallic	5.0 to 50	5,000-50,000
4	Discontinuous true oil colour (heavy oil)	50 to 200	50,000 – 200,000
5	Continuous true colour (heavy oil)	>200	>200,000
Other	Mousse or emulsion		

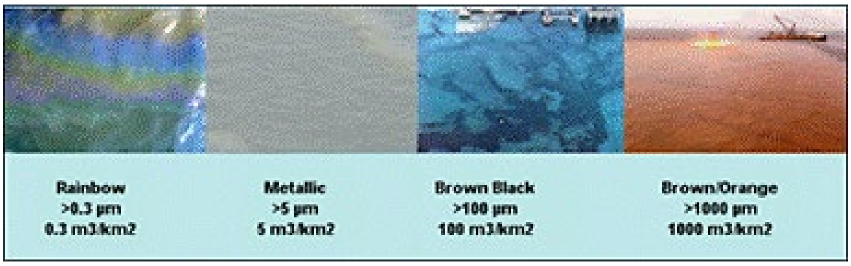


Figure 4-2 - Bonn Agreement Oil Appearance Code (Examples)

4.2.3 Satellite Tracking Drifter Buoys

The Sauropod 3D MSS vessel will carry a satellite tracking drifter buoy for deployment in the event of a significant spill. Instructions will be provided for the deployment of the buoy to the vessel master (refer Appendix 2). At the time of a spill, the drifter buoy will be activated and deployed overboard to allow for real-time satellite tracking of the spill direction and speed (Level 2 only). The buoys' location will be monitored real-time and through regular data downloads.

4.2.4 Oil Spill Trajectory Modelling

The movement of a hydrocarbon slick can be estimated in real time using computerised oil spill trajectory modelling (OSTM). Under the NatPlan, AMSA and DoT have 24/7 access to oil spill trajectory modelling (OSTM. The vessel master / CGG offshore representative may assist AMSA / DoT to complete the OSTM request proforma; the by providing observational data on the oil slick behaviour and wind conditions.

CGG also has access to OSTM capability, provided by RPS. CGG has utilised RPS to undertake the predictive modelling for the Sauropod 3D MSS. CGG has the capacity to extend the existing contract with RPS to provide deterministic modelling in the event of an oil spill, if required. This capability is not on an emergency callout basis (as per the current AMSA agreement). Preliminary modelling results are generally available within four hours after simulation commencement.

During the spill, RPS will utilise all available information from operational surveillance monitoring and from satellite imagery (as available) to refine forecasts.

Contact details for RPS:

Nathan Benfer

Email: nathan.benfer@rpsgroup.com.au

Phone: (07) 3124 9459 / 0411 627 740

4.3 Oiled Wildlife Response

All oiled wildlife response activities will be coordinated and implemented by the CA.

No CGG or MSS crew personnel shall interfere with any oiled wildlife. Oiled wildlife observations will be reported to the CA.

4.4 Scientific Monitoring

4.4.1 Scope of Studies

The Sauropod 3D MSS Operational and Scientific Monitoring Plan (OSMP, supports this OPEP. The OSMP provides a framework for the monitoring programs that may be implemented in the event of a Level 2 spill from the Sauropod 3D MSS activity.

The objectives of the OSMP are to:

- Identify high priority protection areas within the EMBA in real time
- Specify monitoring methodologies
- Detail the process CGG will follow to determine the monitoring studies that will be implemented in order to:
  - Provide situational awareness and assist in planning and execution of spill response to minimise environmental harm

- Provide for short-term and long-term environmental damage and recovery assessments.

4.4.2 Consultation

CGG will consult with Commonwealth and state authorities affected by spill residues to ensure that scientific monitoring is undertaken to the satisfaction of the Commonwealth and state.

CGG will notify relevant authorities on a Level 2 spill event and provide operational data to the authorities relevant to the spill level. CGG will consult with these authorities at the commencement of a Level 2 spill on any proposed baseline/ scientific studies and control sites to allow for feedback and OSMP study modification to fulfil all state requirements (e.g. on-the-day sampling design, modified scope).

Available operational monitoring results collated by CGG resources will be provided throughout the response to allow for continued feedback and modification of baseline/scientific requirements. Other critical liaison points will be established between relevant authorities through the spill consultation process.

4.5 Response Termination

The decision to terminate spill response actions is made by the CA Incident Controller when the response is not returning any tangible benefit. This may include a gradual downsizing of response teams and resources or complete termination of the response. Decision factors to terminate will include:

- The efficacy and benefit of the response options implemented against natural weathering
- The significance of the environmental receptor impacted
- Potential for environmental damage due to further clean-up efforts weighed up against other risk factors; or
- Termination criteria, as adopted by the CA, have been met.

The CA incident controller will ensure that all relevant organisations, stakeholders and personnel are notified to stand down once the decision to terminate or the termination criteria have been satisfied.

5 Response Training

5.1 Testing of Response Arrangements

A desktop OPEP drill of the Sauropod MSS OPEP, including the vessel SOPEP, will be conducted to assess the effectiveness of the arrangements, considering the nature and scale of the risk of a hydrocarbon prior to the survey commencing.

Specifically, the OPEP drill will test the following:

- Roles and responsibilities of those involved in oil spill response are clear and understood
- Communication sequence from the vessel master to vessel-contractor onshore management and the CA, including notification of the AMSA JRCC is adequate, current and includes all relevant details
- Communication between the CGG offshore representative and CGG project manager and subsequent notification authorities is adequate and timely
- Ensures Type 1 operational monitoring such as spill surveillance and tracking is appropriate, understood and practiced
- Equipment and procedures intended for source control on-board the vessel are available for use as outlined in the vessel SOPEP.

The outcomes of the Sauropod 3D MSS OPEP drill will be documented, reviewed and improvements identified (as needed). Should any inadequacies, altered contractual arrangements or improvements to arrangements be identified via testing, these corrective actions will be registered as a non-conformance and the EP/OPEP will be amended for these items via a Management of Change process.

The OPEP will be tested on the following triggers:

- Prior to the survey commencing
- Following any significant amendment of the arrangements.

These arrangements for testing the OPEP are commensurate with the nature and scale of the worst-case oil spill scenario and the short duration of the MSS activity.

The vessel master must ensure that all relevant vessel personnel are inducted and familiar with the contents of this OPEP and accompanying SOPEP; and trained to carry out their individual responsibilities.

6 References

Australian Maritime Safety Authority (AMSA). 2017. National Plan for Maritime Environmental Emergencies. Available at https://www.amsa.gov.au/marine-environment/nationalplan-maritime-environmental-emergencies/national-plan-maritime.

Australian Maritime Safety Authority (AMSA). 2018. Australian Government coordination arrangements for maritime environmental emergencies, NP-GUI-020. Australian Government, Canberra. Available at: https://www.amsa.gov.au/marine-environment/national-plan-maritime-environmental-emergencies/np-gui-020-national-plan.

International Tanker Owners Pollution Federation (ITOPF) Limited. 2011. Fate of Oil Spills, Technical Information Paper No. 2. Available at: http://www.itopf.com/information-services/publications/documents/TIP2FateofMarineOilSpills.pdf.

Western Australian Department of Transport (WA DoT). 2018. State Hazard Plan Maritime Environmental Emergencies. Accessed 15 March 2018 at https://www.transport.wa.gov.au/mediaFiles/marine/MAC_P_stateHazardPlanMaritimeEnviroEmergMEE.pdf.

Western Australian Parks and Wildlife (WA DPaW). 2014. Western Australian 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.

Appendix 1 – Contact Directory

Organisation	Position	Contact Details	
		Telephone	Email
CGG	Offshore representative	TBC	TBC
	Project manager	TBC	TBC
Seismic vessel	Vessel master	TBC	TBC
Support vessel	Vessel master	TBC	TBC
Chase vessel	Vessel master	TBC	TBC
Seismic vessel management	Vessel manager	TBC	TBC
Regulators			
NOPSEMA		+61 8 6461 7090	submissions@nopsema.gov.au
DMIRS		+61 419 960 621	petroleum.environment@dmirs.wa.gov.au
NOPTA		NA	reporting@nopta.gov.au
DNP		+61 419 293 465	marineparks@environment.gov.au
DoEE		+61 2 6274 1111	EPBC.permits@environment.gov.au
AMSA		+61 2 6230 6811	https://amsa-forms.nogginoca.com/public/polrep.html
DoT		+61 8 9480 9924	marine.pollution@transport.wa.gov.au
Scientific Resources			
RPS Spill Modelling	Nathan Benfer	+61 7 3124 9459 0411 627 740	nathan.benfer@rpsgroup.com.au
For other stakeholders – refer to the stakeholder consultation log			