Capreolus-2 3D Marine Seismic Survey 2020 - 2024

Environment Plan

10 September 2020

Project No.: 0526867

The business of sustainability

Document Details	
Document title	Capreolus-2 3D Marine Seismic Survey 2020 - 2024
Document subtitle	Environment Plan
Project No.	0526867
Date	10 September 2020
Version	3
Author	ERM
Client Name	TGS

Document History

Version	Author	Approval	Date	Comments
0	ERM	TGS	26/02/2020	Submission to NOPSEMA for public review and comment.
1	ERM	TGS	07/04/2020	Submission to NOPSEMA for assessment.
2	ERM	TGS	07/08/2020	Submission to NOPSEMA for repeat public review and comment.
3	ERM	TGS	10/09/2020	Submission to NOPSEMA for assessment.

Distribution List

No:	Recipient
1	Business Manager Australia, PNG and NZ
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3	TGS Client Representative
4	TGS Document Control
5	Master – Seismic Survey Vessel
6	Master - Support Vessel(s)
7	ERM

EP Summary

EP Summary Material Requirement	Relevant EP Section
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Acronyms and Abbreviations

Name	Description
$	Dollars (Australian dollars unless specified otherwise)
%	Percent
°	Degrees
°C	Degrees Celsius
‘	Minutes
“	Seconds
3D	Three dimensional
ABF	Australian Border Force
ACMA	Australian Communications Media Authority
ACPN	Asia Pacific Cable Network
ADF	Australian Defence Force
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AHS	Australian Hydrographic Service
ALARP	As low as reasonably practicable
AMF	Abalone Managed Fishery
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
BMF	Beche de Mer Fishery
BoM	Bureau of Meteorology
BP	British Petroleum
BPMF	Broome Prawn Managed Fishery
BOEM	Bureau of Ocean Energy Management
BWMC	Ballast Water Management Certificate
BWMP	Ballast Water Management Plan
CAES	Catch and Effort System
CFA	Commonwealth Fisheries Association
CFSR	Climate Forecast System Reanalysis
COLREGS	International Regulations for Preventing Collisions at Sea 1972
cP	Centipoise (unit of viscosity)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Client Site Representative

Name	Description
cui	Cubic inches
DoA	Commonwealth Department of Agriculture (*superseded by Department of Agriculture, Water and the Environment*)
DAWE	Commonwealth Department of Agriculture, Water and the Environment (*formerly Department of Agriculture*)
DAWR	Commonwealth Department of Agriculture and Water Resources (*superseded by Department of Agriculture*)
dB	Decibel
DBCA	WA Department of Biodiversity, Conservation and Attractions (*formerly Department of Parks and Wildlife*)
DEC	WA Department of Environment and Conservation (*superseded by the Department of Parks and Wildlife*).
DEH	Commonwealth Department of Environment and Heritage (*superseded by Department of the Environment and Energy*)
DEWHA	Commonwealth Department of Sustainability, Environment, Water, Heritage and Arts (*superseded by Department of the Environment and Energy*)
DMAC	Diving Medical Advisory Committee
DMIRS	WA Department of Mines, Industry Regulation and Safety
DoCA	Commonwealth Department of Communications and the Arts
DoD	Commonwealth Department of Defence
DoE	Commonwealth Department of Environment (*superseded by Department of the Environment and Energy*)
DoEE	Commonwealth Department of the Environment and Energy (*superseded by the Department of Agriculture, Water and the Environment*)
DoNP	Director of National Parks
DoF	WA Department of Fisheries (*superseded by Department of Primary Industries and Regional Development).*
DoIIS	Commonwealth Department of Industry, Innovation and Science
DoT	WA Department of Transport
DPAW	WA Department of Parks and Wildlife (*superseded by the Department of Biodiversity, Conservation and Attractions*)
DPIRD	WA Department of Primary Industries and Regional Development
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (*superseded by Department of the Environment*)
E	East
ECR	Environmental Compliance Register
EEZ	Exclusive Economic Zone
EHS	Health Safety and Environment
EMBA	Environment that may be affected
ENVID	Environmental impact and risk identification
EP	Environment Plan

Name	Description
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPO	Environmental performance outcome
EPS	Environmental performance standard
ERC	Emergency Response Coordinator
ERM	Environmental Resources Management
ERP	Emergency Response Procedure
ESD	Ecologically Sustainable Development
GHG	Greenhouse Gas
g/m^2	Grams per square meter (unit of surface or area density)
GMEM	Gippsland Marine Environmental Monitoring
HCF	Hermit Crab Fishery
HF	High Frequency
hrs	Hours
Hz	Hertz
IAGC	International Association of Geophysical Contractors
IAPP	International Air Pollution Prevention
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMO	International Maritime Organisation
IMS	Invasive Marine Species
IOGP	International Association of Oil and Gas Producers
IOPP	International Oil Pollution Prevention
ISM	International Safety Management
ISPP	International Sewage Pollution Prevention
ITF	Indonesian Throughflow
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
JASCO	JASCO Applied Sciences
JRCC	Joint Rescue Coordination Centre
KEF	Key Ecological Feature
KGBF	Kimberley Gillnet and Barramundi Managed Fishery
km	Kilometre
km^2	Square kilometres
LAT	Lowest Astronomical Tide
LF	Low frequency
m	Metre
m^2	Metres squared
m^3	Metres cubed
M	Million

Name	Description
m/s	Metres per second
MAFMF	Marine Aquarium Fish Managed Fishery
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978
MC	Measurement Criteria
MDO	Marine Diesel Oil
MEPC	Marine Environment Protection Committee
MF	Medium Frequency
MFO	Marine Fauna Observer
MMF	Mackerel Managed Fishery
MMSI	Maritime Mobile Service Identity
MNES	Matters of National Environmental Significance
MOD	Maximum-over-depth
MP	Marine Park
MPA	Marine Protected Area
MSS	Marine Seismic Survey
MTWA	Marine Tourism Western Australia
MUZ	Multiple Use Zone
N	North
NBPMF	Nickol Bay Prawn Managed Fishery
NCEP	National Centre for Environmental Prediction
NDSMF	Northern Demersal Scalefish Managed Fishery
NES	National Environmental Significance
nm	Nanometre
NMFS	National Marine Fisheries Service
NNTT	National Native Title Tribunal
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NRSMPA	National Representative System of Marine Protected Areas
NWCS	North West Cable System
NWMR	North-west Marine Region
NWS	North West Shelf
NWSTF	North West Slope Trawl Fishery
OBN	Ocean Bottom Nodes
OPGGS	Offshore Petroleum and Greenhouse Gas Storage Act 2006
OPEP	Oil Pollution Emergency Plan
OPIC	Offshore Petroleum Incident Coordinator
OPMF	Onslow Prawn Managed Fishery

Name	Description
OPPT	Oil Pollution Prevention Team
OPRC	Oil Pollution Preparedness, Response and Cooperation
OSRC	Oil Spill Response Coordinator
PAM	Passive Acoustic Monitoring
PCMF	Pilbara Crab Managed Fishery
PDSF	Pilbara Demersal Scalefish Fishery
PERR	Post-survey Environmental Review Report
PFTIMF	Pilbara Fish Trawl Interim Managed Fishery
PK	Peak Pressure Levels
PLMF	Pilbara Line Managed Fishery
pm	Picometre
PMI	Potential mortality injury
PMS	Planned Maintenance System
PMST	Protected Matters Search Tool
POB	Persons on board
POLREP	Oil Pollution Report
POMF	Pearl Oyster Managed Fishery
PPA	Pearl Producers Association
PPA	Pilbara Ports Authority
ppb	Parts per billion
Psi	Pounds per square inch
PSMA	Department of the Prime Minister and Cabinet Australia
PSU	Practical salinity unit
PTMF	Pilbara Trap Managed Fishery
PTS	Permanent threshold shift
RPS	RPS Group
S	South
SBTF	Southern Bluefin Tuna Fishery
SDS	Safety Data Sheet
SEA	Survey Environmental Adviser
SEL	Sound exposure levels
SIMAP	Spill Impact Mapping Analysis Program
SITREP	Situation Report
SOLAS	International Convention for the Safety of Life at Sea
SOP	Standard Operating Procedure
SOPEP	Shipboard Oil Pollution Emergency Plan
SPL	Sound Pressure Levels
SPRAT	Species Profile and Threats

Name	Description
SRD	Streamer Recovery Devices
SSMF	Specimen Shell Managed Fishery
STCW95	International Convention on Standards of Training Certification and Watch Keeping for Seafarers
STF	Skipjack Tuna Fishery
SWCSF	South West Coast Salmon Fishery
TEC	Threatened Ecological Community
TGS	TGS-NOPEC Geophysical Company Pty Ltd
THC	Total Haemocyte Count
TTS	Temporary Threshold Shift
µg/l	Micrograms per litre
UNCLOS	United Nations Convention of the Law and of the Sea
UNESCO	United Nations Educational, Scientific and Cultural Organization
µPa	Micropascals
UXO	Unexploded Ordinance
VOC	Volatile Organic Compounds
W	West
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council
WAM	Western Australian Museum
WCDSCM	West Coast Deep Sea Crustacean Managed Fishery
WDCS	Whale and Dolphin Conservation Society
WTBF	Western Tuna Billfish Fishery
WWF	World Wildlife Fund for Nature

1. INTRODUCTION

1.1 Purpose

This Environment Plan (EP) has been prepared to meet the requirements of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations) (refer to Section 2.1). It aims to demonstrate that the Capreolus-2 3D MSS will be undertaken in a manner consistent with the principles of ecologically sustainable development (ESD) and carried out such that environmental impacts and risks will be reduced and managed to as low as reasonably practicable (ALARP) and acceptable levels.

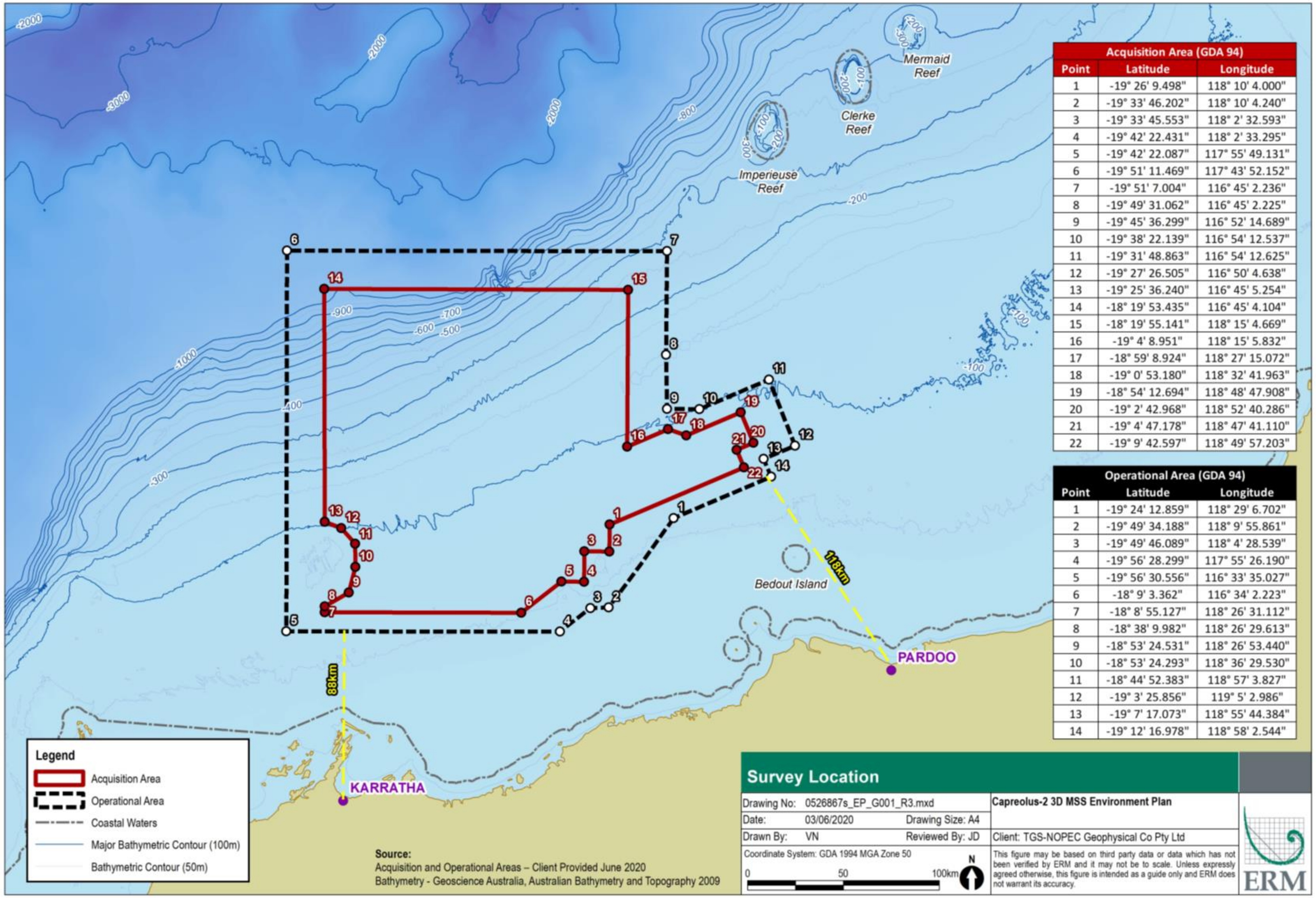
1.2 Scope

The scope of this EP addresses the petroleum activity—a marine seismic survey—and associated activities as described in Section 3.

In particular, the scope of this EP covers 3D seismic acquisition within the defined Acquisition Area (refer to Figure 1.1) and associated line turns, run-ins, run-outs, seismic testing and support activities within the defined Operational Area (Figure 1.1). The timeframe of this EP is from acceptance of the EP until 31 December 2024.

The petroleum activity is defined as commencing at the point when the seismic source is first deployed within the Operational Area, until the seismic vessel has retrieved the seismic source and departed from the Operational Area.

The scope of this EP does not include the periods when the seismic survey vessel and support vessels are not engaged in survey or associated activities, such as during cyclone avoidance, maintenance activities outside of the Operational Area, port calls, crew changes via helicopter/support vessel, or vessel mobilisation/demobilisation to/from the Operational Area. During these periods the seismic vessel and support vessels are deemed to be operating under the Commonwealth *Navigation Act 2012* (refer to Table 2-1) and not performing a petroleum activity.



Acquisition Area (GDA 94)		
Point	Latitude	Longitude
1	-19° 26' 9.498"	118° 10' 4.000"
2	-19° 33' 46.202"	118° 10' 4.240"
3	-19° 33' 45.553"	118° 2' 32.593"
4	-19° 42' 22.431"	118° 2' 33.295"
5	-19° 42' 22.087"	117° 55' 49.131"
6	-19° 51' 11.469"	117° 43' 52.152"
7	-19° 51' 7.004"	116° 45' 2.236"
8	-19° 49' 31.062"	116° 45' 2.225"
9	-19° 45' 36.299"	116° 52' 14.689"
10	-19° 38' 22.139"	116° 54' 12.537"
11	-19° 31' 48.863"	116° 54' 12.625"
12	-19° 27' 26.505"	116° 50' 4.638"
13	-19° 25' 36.240"	116° 45' 5.254"
14	-18° 19' 53.435"	116° 45' 4.104"
15	-18° 19' 55.141"	118° 15' 4.669"
16	-19° 4' 8.951"	118° 15' 5.832"
17	-18° 59' 8.924"	118° 27' 15.072"
18	-19° 0' 53.180"	118° 32' 41.963"
19	-18° 54' 12.694"	118° 48' 47.908"
20	-19° 2' 42.968"	118° 52' 40.286"
21	-19° 4' 47.178"	118° 47' 41.110"
22	-19° 9' 42.597"	118° 49' 57.203"

Operational Area (GDA 94)		
Point	Latitude	Longitude
1	-19° 24' 12.859"	118° 29' 6.702"
2	-19° 49' 34.188"	118° 9' 55.861"
3	-19° 49' 46.089"	118° 4' 28.539"
4	-19° 56' 28.299"	117° 55' 26.190"
5	-19° 56' 30.556"	116° 33' 35.027"
6	-18° 9' 3.362"	116° 34' 2.223"
7	-18° 8' 55.127"	118° 26' 31.112"
8	-18° 38' 9.982"	118° 26' 29.613"
9	-18° 53' 24.531"	118° 26' 53.440"
10	-18° 53' 24.293"	118° 36' 29.530"
11	-18° 44' 52.383"	118° 57' 3.827"
12	-19° 3' 25.856"	119° 5' 2.986"
13	-19° 7' 17.073"	118° 55' 44.384"
14	-19° 12' 16.978"	118° 58' 2.544"

Figure 1.1 Survey Location

1.3 Proponent Details

TGS-NOPEC Geophysical Company Pty Ltd (TGS) provides global subsurface data products and services to the energy industry through investments in multi-client data projects in frontier, emerging and mature markets worldwide. The company's extensive onshore and offshore libraries include seismic data, magnetic and gravity data, multibeam and coring data, digital well logs and production data from deep water offshore to conventional and unconventional onshore plays worldwide. TGS also offers advanced processing and imaging services, interpretation products and data integration solutions.

It is TGS' mission to provide the global energy industry with the right subsurface data, in the right place, at the right time, through investments in multi-client data projects in frontier, emerging and mature markets worldwide.

TGS employs approximately 550 employees and has its corporate headquarters in Asker, Norway and its operational headquarters in Houston, Texas, U.S.A. The company's other main offices are in Calgary, London and Perth, with further employees located in other cities around the globe.

Further information about TGS is available on their website at: https://www.tgs.com/.

1.3.1 Details of the Titleholder

The titleholder details are:

Company Name	TGS-NOPEC Geophysical Company Pty Ltd
Business Address	Ground Floor, 1110 Hay Street, West Perth WA, 6005 Australia
Phone	+61 (0) 8 9480 0000
Fax	+61 (0)8 9321 5312
Website	https://www.tgs.com/
ACN/ABN	48 077 150 424

The titleholder's nominated liaison person is:

Contact Name	Tanya Johnstone
Position	Business Manager Australia, PNG and NZ
Postal Address	Ground Floor, 1110 Hay Street, West Perth WA, 6005 Australia
Phone	+61 (0) 8 9480 0000
Email	Tanya.Johnstone@tgs.com

2. ENVIRONMENTAL MANAGEMENT FRAMEWORK

2.1 Legislation Requirements

2.1.1 OPGGS Act and Associated Regulations

The *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (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 2009 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. 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 scope of the OPGGS Act and OPGGS (E) Regulations and application to the Capreolus-2 3D MSS are described in Table 2-1.

2.1.2 EPBC Act

The Capreolus-2 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 the Department of the Environment and Energy) are detailed in Section 4.5.5.1 in the applicable sub-sections, as part of the description of the existing environment. The scope of the EPBC Act and application to the Capreolus-2 3D MSS are described in Table 2-1.

2.1.3 Other Applicable Legislation

Other applicable legislation relevant to the Capreolus-2 3D MSS is described in Table 2-1.

Table 2-1 Summary of Requirements Relevant to the Activity and its Environmental Management

Requirements	Scope (as Relevant to this EP)	Application to Capreolus-2 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 Sections 8.1, 8.2 and 8.3.	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

Requirements	Scope (as Relevant to this EP)	Application to Capreolus-2 3D MSS	Administering Authority
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. Assessment of impacts and risks to Matters of National Environmental Significance (MNES) from the survey are described in Section 7 and 8.	DAWE

Requirements	Scope (as Relevant to this EP)	Application to Capreolus-2 3D MSS	Administering Authority
Environment Protection and Biodiversity Conservation Regulations 2000	Provides additional regulations in regards to Matters of National Environmental Significance.	Part 8 of the Regulations details requirements for operating vessels and aircraft in relation to cetaceans. Sections 7 and 8 detail these requirements.	DAWE
if 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 8 details where the applicable requirements apply to this 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	NOPSEMA

Requirements	Scope (as Relevant to this EP)	Application to Capreolus-2 3D MSS	Administering Authority
		petroleum activity. This requirement must be met by the titleholder before NOPSEMA can accept the EP.	
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
Maritime Legislation Amendment (Prevention of Air Pollution from Ships) Act 2007	An Act to amend the Protection of the Sea (Prevention of Pollution from Ships) Act 1983, and for other purposes. This amended Act provides the protection of the sea from air pollution from ships.	Seismic survey vessel and support vessels hold an International Air Pollution Prevention Certificate (Section 7.7).	AMSA
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	AMSA

Requirements	Scope (as Relevant to this EP)	Application to Capreolus-2 3D MSS	Administering Authority
		▪ Marine Order 98: Marine pollution prevention – anti-fouling systems. Provides exemptions for the discharge of materials in response to marine pollution incidents. Requires ships greater than 400 gross tonnes to have pollution emergency plans. Section 7 and 8 details where the applicable requirements apply to this survey.	
Protection of the Sea (Harmful Antifouling Systems) Act 2006	It 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 8.8 details where the applicable requirements apply to the survey.	AMSA
Underwater Cultural Heritage Act 2018	This Act protects shipwrecks, sunken aircraft and other types of underwater heritage (including human remains) that have lain in territorial waters for 75 years or more. The Act replaced the Historic Shipwreck Act 1976 on 1 July 2019. It also increases penalties applicable to damaged sites.	A search for historic shipwrecks and sunken aircraft was undertaken for the Operational Area as detailed in Section 4.6.5.	DAWE

2.1.4 International Agreements

The principal international agreement (of which Australia is a signatory) affecting petroleum operations in Commonwealth waters is the United Nations Convention on the Law of the Sea, 1982 (UNCLOS), which became effective on 16 November 1994. UNCLOS enforces a comprehensive regime of law and order in global oceans and seas, establishing rules governing all uses of the oceans and their resources.

Australia is also a signatory to a number of other international conventions and agreements relevant to the Capreolus-2 3D MSS. Other relevant agreements are listed in Table 2-2.

Table 2-2 Summary of Relevant International Agreements

Legislation	Scope	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 the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	This Convention provides a global platform for conservation and the sustainable use of terrestrial, aquatic and avian migratory species throughout their range.	Control measures for the survey are described in Section 7 and 8 aim to ensure risks and impacts to migratory species or their habitat are reduced to levels that are ALARP and acceptable.
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 over 400 GRT will have a SOPEP in place (Section 8.4).
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).	Prevention of pollution in accordance with MARPOL requirements.
International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004	The Convention aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments.	Implemented through the *Biosecurity Act 2015* and Regulations 2016. Vessels will manage ballast in accordance with Australian Ballast Water Management Requirements (Section 8.8).

2.1.5 Management of Protected Areas

2.1.5.1 Commonwealth Protected Areas

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

Under the EPBC Act, the AMP Network, and any zones within AMPs, must be assigned to an International Union for Conservation of Nature (IUCN) Category. Several types of zones are represented in the AMP Network, with the zoning scheme administered by DAWE. The zones align to the IUCN categories as follows:

- Sanctuary Zone (IUCN Category Ia);
- National Park Zone (IUCN Category II);
- Recreational Use Zone (IUCN Category IV);
- Habitat Protection Zone (IUCN Category IV);
- Multiple Use Zone (IUCN Category VI);
- Special Purpose Zone (IUCN Category VI); and
- Special Purpose Zone (Trawl) (IUCN Category VI).

The Acquisition and Operational Areas do not overlap with any AMPs, however there are six AMPs located within the environment that may be affected (EMBA)[1] by the activity defined in this EP:

- Eighty Mile Beach Marine Park, Multiple Use Zone (30 km from the Operational Area);
- Argo-Rowley Terrace Marine Park, Multiple Use Zone and Special Purpose Zone (45 km and 75 km from the Operational Area, respectively);
- Montebello Marine Park, Multiple Use Zone (61 km from the Operational Area);
- Mermaid Reef Marine Park, National Park Zone (115 km from the Operational Area); and
- Gascoyne Marine Park, Multiple Use Zone (306 km from the Operational Area).

These marine parks are formally managed under the North-west Marine Region (NWMR) management framework. The NWMR is managed in accordance with the following values (DoNP 2017):

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

In making decisions regarding use in AMPs, the Director of National Parks (DoNP) will carefully consider the impacts and risks to these values for the relevant marine parks. Activities that have an EP accepted by NOPSEMA under the endorsed program may be conducted in accordance with the relevant petroleum title under the *OPGGS Act* and a class approval under this plan (DoNP 2017). Accordingly, activities covered by the endorsed NOPSEMA program do not require additional assessment by the

[1] Refer to Section 4 for further information on the EMBA.

DoNP because the endorsed program takes account of impacts and risks to marine park values in a manner that satisfies the DoNP.

The AMP values, zone objectives and management prescriptions relevant to the AMPs that overlap the EMBA for the Capreolus-2 3D MSS have been considered in the assessment of impacts and risks in this EP. A summary of the prescriptions relevant to this EP are provided in Table 2-3.

Table 2-3 Summary of Permitted Relevant Activities and Prescriptions in the AMP Zones

Zoning and IUCN Categories	Relevant AMPs	Purpose and Objectives	Relevant Activities Permitted in Zone	Relevant Management Prescriptions	Associated IUCN Management Principles (Schedule 8 of the EPBC Regulations 2000)
Multiple Use Zone IUCN Category VI	Eighty Mile Beach Mark Park (30 km from the Operational Area) Argo-Rowley Terrace Marine Park (45 km from the Operational Area) Montebello Marine Park (61 km from the Operational Area) Gascoyne Marine Park (306 km from the Operational Area)	Managed to allow ecological sustainable use while conserving ecosystems, habitats and native species.	Mining operations (including exploration). Vessel transiting. Anchoring. Ballast water discharge and exchange. Disposal of waste from vessels (compliant with MARPOL).	Authorisation required for mining operations (including exploration); this activity is allowable in accordance with a permit, class approval or commercial activity licence or lease issued by the DoNP. Mining operations must be conducted in accordance with an authorisation (however described) under the OPGGS Act or the *Offshore Minerals Act 1994* to the extent those laws apply to the operations and are capable of operating concurrently with this plan. Commercial ships may transit through the North-west Marine Park Network subject to compliance with the prescriptions in the associated Management Plan (General use and access) and relevant prescriptions relating to the activity in which shipping is involved. Ballast water may be discharged	**7.01** The reserve or zone should be managed mainly for the sustainable use of natural ecosystems based on these principles. **7.02** The biological diversity and other natural values of the reserve or zone should be protected and maintained in the long term. **7.03** Management practices should be applied to ensure ecologically sustainable use of the reserve or zone. **7.04** Management of the reserve or zone should contribute to regional and national development to the extent that this is consistent with these principles.

Zoning and IUCN Categories	Relevant AMPs	Purpose and Objectives	Relevant Activities Permitted in Zone	Relevant Management Prescriptions	Associated IUCN Management Principles (Schedule 8 of the EPBC Regulations 2000)
				or exchanged, subject to compliance with: a) the Australian ballast water management requirements and relevant state ballast water management arrangements; and b) relevant Commonwealth and state legislation or international agreements (if any) relating to ballast water management. Waste may be disposed of from vessels to which the International Convention for the Prevention of Pollution from Ships (MARPOL) (Schedule 1) applies, in accordance with the requirements of MARPOL.	
Special Purpose Zone **IUCN Category VI**	Argo-Rowley Terrace Marine Park (75 km from the Operational Area)	Managed to allow specific activities though special purpose management arrangements while conserving ecosystems, habitats and native	Mining operations (including exploration). Vessel transiting. Anchoring. Ballast waste discharge and exchange. Disposal of wastes from vessels	Refer to relevant management prescriptions as outlined above.	**7.01** The reserve or zone should be managed mainly for the sustainable use of natural ecosystems based on these principles. **7.02** The biological diversity and other natural values of the reserve or zone should be protected and maintained in the long term. **7.03** Management practices should be applied to ensure ecologically sustainable use of the reserve or zone. **7.04** Management of the reserve or zone should contribute to regional and national development to

Zoning and IUCN Categories	Relevant AMPs	Purpose and Objectives	Relevant Activities Permitted in Zone	Relevant Management Prescriptions	Associated IUCN Management Principles (Schedule 8 of the EPBC Regulations 2000)
		species. The zone allows or prohibits specific activities.	(compliant with MARPOL).		the extent that this is consistent with these principles.
National Park Zone **IUCN Category II**	Mermaid Reef Marine Park (115 km from the Operational Area)	Managed to protect and conserve ecosystems, habitats and native species in as natural a state as possible. The zone only allows non-extractive activities unless authorised for research and monitoring.	Ballast water discharge and exchange. Disposal of waste from vessels (compliant with MARPOL). Vessel transiting. Anchoring (only within permitted areas)	Refer to relevant management prescriptions as outlined above.	**3.01** The reserve or zone should be protected and managed to conserve its natural condition according to the following principles. **3.02** Natural and scenic areas of national and international significance should be protected for spiritual, scientific, educational, and recreational or tourist purposes. **3.03** Representative examples of physiographic regions, biotic communities, genetic resources, and native species should be perpetuated in as natural a state as possible to provide ecological stability and diversity. **3.04** Visitor use should be managed for inspirational, educational, cultural and recreational purposes at a level that will maintain the reserve or zone in a natural or near natural state. **3.05** Management should seek to ensure that exploitation or occupation inconsistent with these principles does not occur. **3.06** Respect should be maintained for the ecological, geomorphologic, sacred and aesthetic attributes for which the reserve or zone was

Zoning and IUCN Categories	Relevant AMPs	Purpose and Objectives	Relevant Activities Permitted in Zone	Relevant Management Prescriptions	Associated IUCN Management Principles (Schedule 8 of the EPBC Regulations 2000)
					assigned to this category. **3.07** The needs of indigenous people should be taken into account, including subsistence resource use, to the extent that they do not conflict with these principles. **3.08** The aspirations of traditional owners of land within the reserve or zone, their continuing land management practices, the protection and maintenance of cultural heritage and the benefit the traditional owners derive from enterprises, established in the reserve or zone, consistent with these principles should be recognised and taken into account.

2.1.5.2 State Protected Areas

State marine parks and reserves have been progressively established since 1987 and are managed by the Department of Biodiversity, Conservation and Attraction (DBCA). Parks are protected to conserve marine biodiversity and recreational uses. Accordingly, there are four types of management zones, each with different rules regarding the use and type of activities permitted within them. Management zones include

- Recreation zones: these zones provide for conservation and recreation including recreational fishing, subject to restrictions.
- General use zones: these zones are areas within marine parks where activities such as sustainable commercial fishing and aquaculture, pearling and petroleum production are permissible provided they do not compromise conservation values;
- No-take areas such as sanctuary zones: these zones are 'look but don't take' areas and are managed solely for nature conservation and low impact recreation and tourism. These zones are the highest level of protection for vulnerable or protected species and important habitat; and
- Special purpose zones: these zones are managed for a particular priority use or issue, for example, the protection of a habitat, a seasonal event such as wildlife breeding. Uses compatible with the priority use or seasonal event are allowed in these zones (DBCA, 2013).

The Operational Area does not overlap with any State Marine Parks, however the Rowley Shoals Marine Park and Montebello Islands Marine Park are located within the EMBA and discussed further in Section 4.6.2.

2.2 Conservation Advice and Recovery Plans

Species Recovery Plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened ecological communities (DoEE n.d.b). 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 newly listed species or ecological community (DoEE n.d.b).

The Capreolus-2 3D MSS will be conducted in a manner consistent with conservation advice and recovery plans for species with the potential to be present in the Operational Area. Section 4.5.5, describes the species that are listed as threatened and/or migratory under the EPBC Act, which have been identified to occur within the Operational Area and EMBA, and identifies the relevant conservation advices and recovery plans.

2.3 Applicable Policies, Industry Standards and Guidelines

In addition to legislation and international agreements, the government policies, industry standards and guidelines outlined in Table 2-4 apply to the conduct of marine seismic surveys in Australian waters and have been taken into account in the planning of the Capreolus-2 3D MSS and the evaluation and management of impacts and risks in Section 7 and 8.

Table 2-4 Summary of Applicable Policies, Industry Standards and Guidelines

Guideline	Description
Australian Standard AS/NZS ISO 31000:2009 Risk Management—Principles and Process	Provides principles, framework and a process for managing risk. The risk assessment method used for this EP is aligned with this standard.

Guideline	Description
EPBC Regulations 2000 Part 8 – Interacting with cetaceans and whale watching	These guidelines are set to minimise the impacts on cetaceans in relation to cetacean interactions, whale watching and the exporting and importing of cetaceans. Relevant to this survey, these guidelines provide guidance on how to act appropriately when cetaceans are in the vicinity of vessels.
EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines (DEWHA 2008e)	These guidelines encourage industry to minimise the likelihood of seismic activities causing injury or hearing impairment to whales, based on present scientific understanding.
Australian Ballast Water Management Requirements (Department of Agriculture and Water Resources 2017)	Provides guidance on how vessel operators should manage ballast water when operating within Australian seas in order to comply with the *Biosecurity Act 2015*, the aim of which is to manage the biosecurity risks posed by ballast water and sediments. They set out the obligations on vessel operators with regards to the management of ballast water and ballast tank sediment, including ballast water management systems, options for ballast water exchange, and vessel Ballast Water Management Plans.
National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds	In January 2020, the Department of Agriculture, Water and the Environment released Draft National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds (the Guidelines). The aim of the Guidelines is to manage artificial light so that wildlife is not disrupted, nor displaced from important habitat and is able to undertake critical behaviours such as foraging, reproduction and dispersal. It is noted that the Guidelines are in draft form and are yet to be finalised for implementation.
National Biofouling Management Guidance for the Petroleum Production and Exploration Industry, (Commonwealth of Australia 2009)	This guidance aims to provide assistance in regards to minimising the amount of biofouling accumulating on vessels, infrastructure and submersible equipment and thereby minimising the risk of spreading marine pests around the Australian coastline.
NOPSEMA Information Paper IP1411: Consultation Requirements Under the OPGGS Environment Regulations 2009, Rev 2 (NOPSEMA 2014a)	Information Paper outlines the consultation requirements of the Environment Regulations as they apply to EPs.
NOPSMEA Guidance Note GN0926: Notification and Reporting of Environmental Incidents, Rev 4 (NOPSEMA 2014b)	Outlines the requirements of notifying and reporting environmental incidents to NOPSEMA.
NOPSEMA Information Paper IPI765: Acoustic Impact Evaluation and Management (NOPSEMA 2018a)	The Information Paper provides good practice advice for the assessment and management of environmental impacts from acoustic emissions generated by seismic activities.
NOPSEMA Guidance Note GN1488: Oil Pollution Risk Management, Rev 2 (NOPSEMA 2018b)	Guidance note provides specific information on the content required in an OPEP and to articulate considerations that support the development of an acceptable EP submission in relation to oil pollution risks.
NOPSEMA Guidance Note GN1785: Petroleum Activities and Australian Marine Parks, Rev 0 (NOPSEMA 2018c)	The Guidance Note provides guidance on the key management arrangements and requirements that are relevant to petroleum and greenhouse gas activities that may affect AMPs.

Guideline	Description
NOPSEMA Guidance Note GN1344 Environment Plan Content Requirements, Rev 4 (NOPSEMA 2019a)	The purpose of this guidance note is to assist stakeholders in understanding the requirements for preparing and submitting an EP for assessment.
NOPSEMA Bulletin #1 Oil Spill Modelling (NOPSEMA 2019b)	The Bulletin provides advice on the application of stochastic modelling to support risk evaluations and application of deterministic modelling in response planning. The bulletin was released to promote good practice and ensure that the community is better informed about the purpose and interpretation of oil spill modelling and to ensure the outputs of oil spill modelling are meaningful.
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)	Provides guidance on the potential risks posed by seismic surveys on finfish and invertebrates in waters off Western Australia. The Report presents the outcomes of a workshop held by DPIRD. The risk assessment involved estimating the level of risk associated with seismic surveys, on the survival and/or the reproductive capacity of marine finfish and invertebrate individuals closest to the seismic source, for a period of 12 months directly following exposure.
International Association of Geophysical Contractors (IAGC) Environment Manual for Worldwide Geophysical Operations (IAGC 2013)	Provides the industry with useful information for conducting geophysical field operations in an environmentally sensitive manner.
IAGC Mitigation Measures For Cetaceans during Geophysical Operations (IAGC 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.
IOGP Recommended monitoring and mitigation measures for cetaceans during marine seismic survey geophysical operations (IOGP 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).
International Maritime Organisation (IMO) Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species (Biofouling Guidelines) (IMO 2011)	Provides a globally consistent approach to the management of biofouling. The approach was adopted by the Marine Environment Protection Committee (MEPC) in July 2011.

2.4 Titleholder's Environment Policy

TGS is committed to protecting the environment in which it lives and works, whilst also conducting operations in an environmentally sustainable and responsible manner. TGS strives to lead the industry in minimizing the impact of its operations on the environment and is dedicated to the continuous improvement of environmental programs and standards across all operations. TGS has a corporate Environment Policy (refer to Appendix A) that provides a public statement of the company's commitment to protecting the environment during offshore operations, including seismic surveys.

The Capreolus-2 3D MSS will be undertaken in a manner consistent with TGS' Environment Policy.

2.5 Titleholder's Health & Safety Policy

The TGS Health & Safety Policy aims to assist in providing a safe, healthy and sustainable workplace for employees, contractors, vendors and clients of TGS, while protecting the working environment. Accordingly, TGS outlines its commitment to the promotion and maintenance of the physical, psychological and social well-being of all employees.

TGS defines safe operating procedures in the HSE Management System that has been designed to meet or exceed all appropriate legal requirements and, in the absence of any defined standards, to meet or exceed generally-accepted best operating practices.

All levels of Management are responsible for the communication and implementation of TGS' Health and Safety Policies and Programs. Management are responsible for ensuring that employees are well equipped to meet health and safety requirements. These requirements are then reviewed on a regular basis to ensure ongoing sustainability and effectiveness.

A copy of TGS' Health & Safety Policy is provided in Appendix B.

3. DESCRIPTION OF THE ACTIVITY

3.1 Location

The Capreolus-2 3D MSS is located in Commonwealth waters in the Carnarvon Basin, offshore from north-west Australia.

The Acquisition Area comprises the area within which 3D seismic acquisition will be undertaken and covers approximately 26,897 km^2 (refer to Figure 1.1). The Acquisition Area is surrounded by a larger Operational Area (41,266 km^2) for the purpose of line turns, run-ins, run-outs, seismic testing and support activities.

The Operational Area is located approximately 88 km north of Karratha and approximately 118 km north-west of Pardoo (refer to Figure 1.1).

3.2 Schedule

The Capreolus-2 3D MSS may commence as early as October 2020 and will be completed before 31 December 2024.

Up to a maximum of 10,000 km^2 may be acquired per calendar year between 2020 and 2024 (up to a total of 26,897 km^2). It is estimated to take between approximately 95 - 140 days to acquire 10,000 km^2. To allow some contingency time for potential vessel or equipment down time and adverse weather conditions, it is assumed to take up to approximately 190 days to acquire 10,000 km^2 for the purposes of this EP. If TGS was to acquire the entire Acquisition Area, it would take a maximum of 510 days (including contingency time).

The precise timing of the survey is subject to NOPSEMA's acceptance of this EP, weather conditions, vessel availability and other operational considerations, and will take into account the seasonality of environmental sensitivities, where practicable. The exact start and end dates of the survey will be communicated to stakeholders, in accordance with the ongoing stakeholder consultation process described in Section 5.

The Operational Area has been divided into zones to avoid acquisition in seasonally sensitive areas for marine fauna. TGS will not acquire within the southern zone during the flatback turtle-nesting period (October – March) and during the peak humpback whale migration period (July – October). Similarly, TGS will not acquire within the northern zone during the pygmy blue whale migration (April – August and October – December). Figure 3.1, depicts the zoning of the Operational Area and the proposed timing of survey operations within these zones.

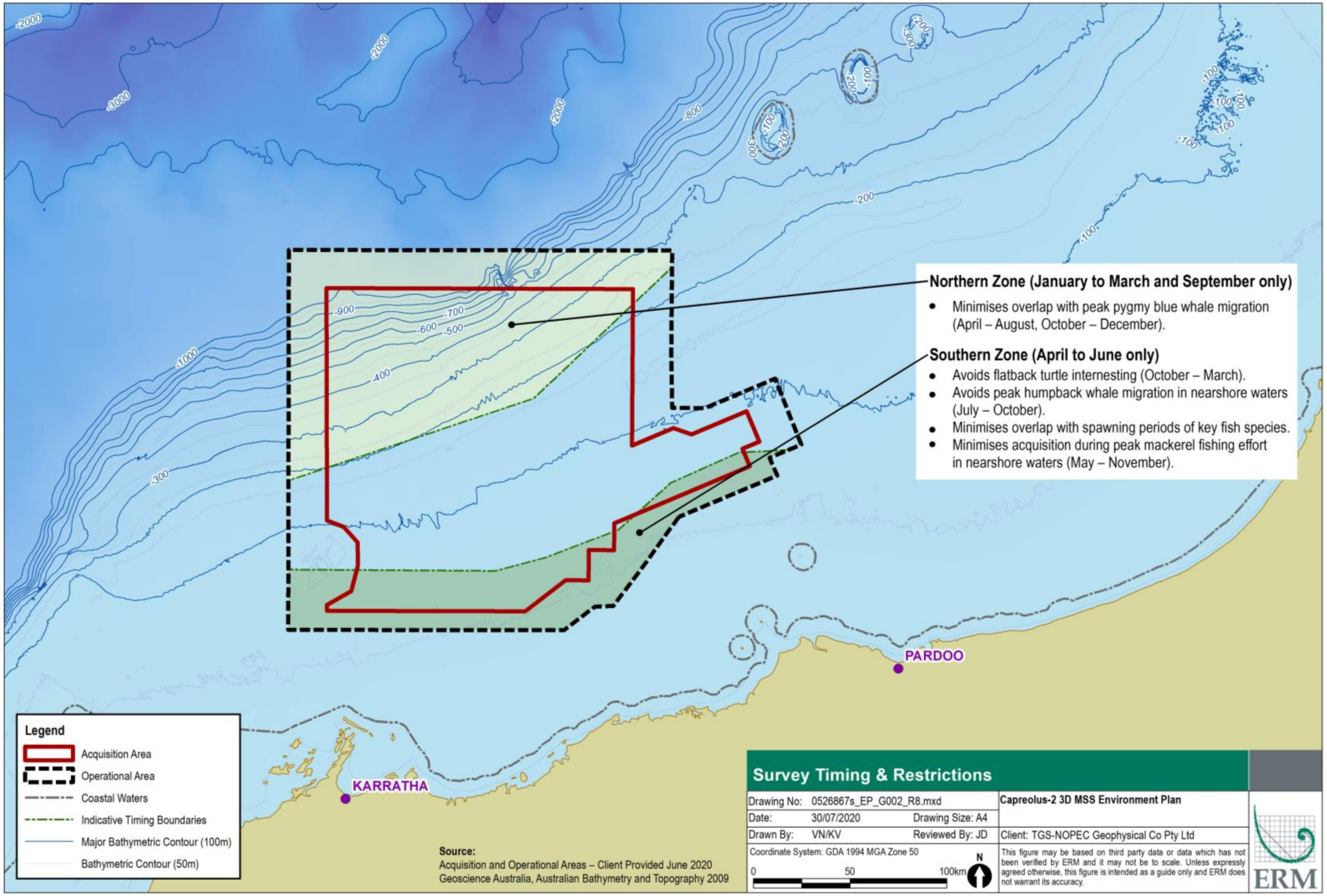


Figure 3.1 Operational Area and Proposed Survey Timing

3.3 Activity Details

The core activity that forms the basis of this EP is the undertaking of a marine seismic survey. Associated activities in support of undertaking the seismic survey include; refuelling and resupply, crew changes and use of support vessels in the Operational Area. Associated activities are described in this section, as appropriate, with a focus on those considered relevant to the assessment of environmental impacts and risks.

Key details of the Capreolus-2 3D MSS relevant to the purpose and objectives of this EP are summarised in Table 3-1.

The Capreolus-2 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 either be a 'dual source' (comprising two source sub-arrays discharged alternately) or a triple source (comprising three source sub-arrays discharged alternately). The seismic source will 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 formation. The data is later processed to provide information about the structure and composition of geological formations below the seabed.

The seismic vessel will tow the seismic source at 6 - 10 m beneath the sea surface, with a total discharge volume of up to 3,480 cubic inches (cui). 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 8 - 10 km behind the vessel and measure approximately 800 – 1,500 m across. The streamers will be towed at a depth of approximately 8 -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 3-1 Key Seismic Survey Details

Parameter	Details
Seismic Activity	
Survey earliest commencement date	1 October 2020
Survey latest completion date	31 December 2024
Distance between sail lines	450 m - 900 m
Seismic vessel sail line speed	4 - 5 knots
Seismic source discharge interval	Minimum of 12.5 m (approximately every 5.5 seconds)
Seismic Source	
Type	Dual or triple source
Size	Maximum of 3,480 cui
Pressure	2,000 pounds per square inch (psi) (nominal)
Source levels (at 0–2,000 Hz)	258 dB re 1 µPa m (PK) 231-234 dB re 1 $\mu Pa^2 m^2 s$ (SEL)
Sound source tow depth	6 – 10 m
Streamers	

Parameter	Details
Number	Up to 12
Streamer length	8 – 10 km
Streamer spread	800 – 1,500 m
Streamer tow depth	8 – 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*
Maximum fuel tank volume	1,062 m^3
Refuelling	Refuelling at sea will occur approximately every 2 - 6 weeks (*depending on the specific vessel and contractor*)
Crew changes	Via helicopter, support vessel or in Port every 4 - 6 weeks

3.3.1 Seismic Source Operation

The Capreolus-2 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.

When acquiring data, the seismic 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 a minimum of 12.5 m intervals (approximately every 5.5 seconds). Exact sail lines for the Capreolus-2 3D MSS have not yet been determined.

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 each line, the vessel will turn in a wide arc to position for another parallel line in the opposite direction. This pattern is repeated until the required coverage is completed. 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, run-ins, soft-starts, 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 – 5 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 – 5 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 elsewhere in the Operational Area in a controlled manner, for the purpose of source maintenance and testing. These activities are infrequent and typically involve intermittent controlled discharges of individual source elements (i.e. single gun/cluster or single source array) for durations in the order of a limited number of testing shots.

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 Vessels

3.3.2.1 Seismic Vessel

A purpose-built seismic survey vessel will be contracted for the Capreolus-2 3D MSS. The specific vessel has not yet been determined. The vessel may carry up to a maximum of 70 persons on board (POB). A small workboat will also be on board the seismic vessel, which may be launched to support equipment deployment, recovery and maintenance activities within the Operational Area.

The seismic survey vessel employed for the survey will use marine diesel oil (MDO) fuel.

3.3.2.2 Support Vessels

Two support vessels will be contracted for the Capreolus-2 3D MSS. These comprise:

- One support (or chase) vessel accompanying the seismic vessel to assist with managing potential interactions with other users of the area; and
- One supply vessel for resupply, refuelling, emergency towing and other support functions.

The supply vessel will be selected such that it is of a sufficient size and power to tow a seismic vessel in the unlikely event that the seismic vessel loses power.

4. DESCRIPTION OF THE ENVIRONMENT

4.1 Overview

This Section describes the environmental and socio-economic values and sensitivities within the existing environment of the Operational Area and the 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) from a seismic survey vessel.

The EMBA was derived from oil spill modelling for an instantaneous release of 1,062 m^3 within the Operational Area, as described in Section 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. 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.

Table 4-1 provides a summary of the values and sensitivities identified within the Operational Area and EMBA.

Table 4-1 Key Values and/or Sensitivities within the Operational Area and EMBA

Environmental Value and/or Sensitivity	Section	Description
Key Ecological Features (KEFs)	4.3	The Operational Area overlaps with two KEFs – the Ancient Coastline at 125 m Depth Contour and Glomar Shoals. The Glomar Shoals KEF is located solely within the Operational Area and outside of the Acquisition Area. An additional three KEFs are located in the EMBA: ■ Mermaid Reef and Commonwealth water surrounding Rowley Shoals ■ Continental Slope Demersal Fish Communities; and ■ Exmouth Plateau.
Bathymetry	4.4.3	Water depths in the Operational Area range from approximately 33 m to 1,684 m. Water depths in the Acquisition Area range between 50 m to 1,133 m.
Benthic Habitats	4.5.2	The soft sediments that cover the majority of the Operational Area support relatively little seabed structure or sessile epibenthos. They are sparsely covered by sessile filter-feeding organisms and mobile invertebrates. Glomar Shoals is located within the Operational Area and may present suitable habitat for benthic communities. The EMBA is expected to generally contain a similar benthic environment to the Operational Area, with the exception of habitats associated with hard-substrate KEFs, which may support hard corals.
Fish Assemblages	4.5.3	No protected species habitats were identified as occurring in the Operational Area. A range of fish species including reef fish may be present in the Operational Area with more abundance of species expected associated with the Glomar Shoals.

Environmental Value and/or Sensitivity	Section	Description
Sharks and Rays	4.5.6	The Operational Area overlaps with the Whale Shark foraging Biological Important Area (BIA). Accordingly, whale sharks may be present within the Operational Area and EMBA. No other BIAs for any threatened or migratory sharks and ray species overlaps with the Operational Area or EMBA. Shortfin and longfin mako sharks may transit through the area; however, no feeding, breeding or aggregation areas are located within the Operational Area or EMBA. Reef manta rays and giant manta rays may transit through the area; however, no feeding, breeding or aggregation areas are located within the Operational Area or EMBA.
Marine Reptiles	4.5.8	The Operational Area overlaps with the internesting BIA and Habitat Critical BIA for the flatback turtle. The EMBA also overlaps with the following: ■ Foraging BIA for the flatback turtle; ■ Internesting and foraging BIAs and a Habitat Critical for the green turtle; ■ Internesting and foraging BIAs for the loggerhead turtle; and ■ Internesting, foraging and breeding BIAs for the hawksbill turtle. No BIAs for the leatherback turtle occur within the Operational Area and EMBA, however this species may transit through the region.
Marine Birds	4.5.9	The Operational Area and EMBA overlap with the following: ■ Breeding BIA for the lesser frigatebird; ■ Breeding BIA for the white-tailed tropicbird; ■ Breeding BIA for the little tern; ■ Breeding BIA for the brown booby; ■ Breeding BIA for the fairy tern; ■ Breeding BIA for wedge-tailed shearwater; ■ Breeding BIA for roseate tern; and ■ Breeding BIA for the lesser crested tern. Other seabirds may be present within the Operational Area and EMBA, including threatened and migratory species.
Marine Mammals	4.5.7	The Operational Area overlaps with the migration and distribution BIA for pygmy blue whales. The Operational Area also overlaps with the migration BIA for humpback whales. No other migratory, resting, feeding or calving BIAs for marine mammals overlap with the EMBA. Sei, blue and Bryde's whales may transit through deeper waters in the norther part of the Operational Area and EMBA. Other marine mammal

Environmental Value and/or Sensitivity	Section	Description
		species (i.e. dolphins and dugongs) may be present within the Operational Area and EMBA as transitory individuals.
Commercial Fisheries	4.6.7	The following Commonwealth managed commercial fisheries management boundaries overlap with the Operational Area and EMBA: ■ North West Slope Trawl Fishery; ■ Western Tuna and Billfish Fishery; ■ Southern Bluefin Tuna; and ■ Skipjack Tuna Fishery. The following WA managed commercial fisheries management boundaries overlap the Operational Area and EMBA: ■ Abalone Managed Fishery; ■ Beche- de- Mer Managed Fishery; ■ Broome Prawn Managed Fishery; ■ Hermit Crab Fishery; ■ Kimberley Gillnet and Barramundi Managed Fishery; ■ Mackerel Managed Fishery (MMF) (Area 2); ■ Marine Aquarium Fish Managed Fishery; ■ Nickol Bay Prawn Managed Fishery; ■ Northern Demersal Scalefish Managed Fishery; ■ Onslow Prawn Managed Fishery; ■ Pearl Oyster Managed Fishery; ■ Pilbara Crab Managed Fishery; ■ Pilbara Line Managed Fishery; ■ Pilbara Trap Managed Fishery; ■ Pilbara Trawl Fish Trawl (Interim) Managed Fishery; ■ Specimen Shell Managed Fishery; and ■ West Coast Deep Sea Crustacean Managed Fishery.
Tourism / Recreation	4.6.8	The Operational Area and EMBA potentially support tourism and recreational activities, including recreational fishing, charter boat operations, scuba diving, snorkelling and other water sports.
Petroleum Activities	4.6.11	The Operational Area and EMBA currently supports other petroleum exploration and production activities.
Shipping	4.6.10	Heavy vessel traffic is expected throughout the Operational Area due to vessels heading in and out of Port Headland and Karratha. There are seven shipping fairways passing through the Operational Area.

Environmental Value and/or Sensitivity	Section	Description
Defence Activities	4.6.9	There are no designated Defence practice areas within the Operational Area.
Australian Marine Parks	4.6.1	The Operational Area does not overlap with any AMPs, however, the EMBA overlaps with the following AMPs: ■ Eighty Mile Beach Marine Park, Multiple Use Zone (30 km from the Operational Area); ■ Argo-Rowley Terrace Marine Park, Multiple Use Zone and Special Purpose Zone (45 km and 75 km from the Operational Area, respectively); ■ Montebello Marine Park, Multiple Use Zone (61 km from the Operational Area); ■ Mermaid Reef Marine Park, National Park Zone (160 km from the Operational Area); and ■ Gascoyne Marine Park, Multiple Use Zone (306 km from the Operational Area).
State / Territory Marine Parks	4.6.2	The Operational Area does not overlap with any State Marine Parks, however the EMBA overlaps with the following State Marine Parks: ■ Rowley Shoals Marine Park (70 km from the Operational Area); and ■ Montebello Islands Marine Park (110 km southwest of the Operational Area).

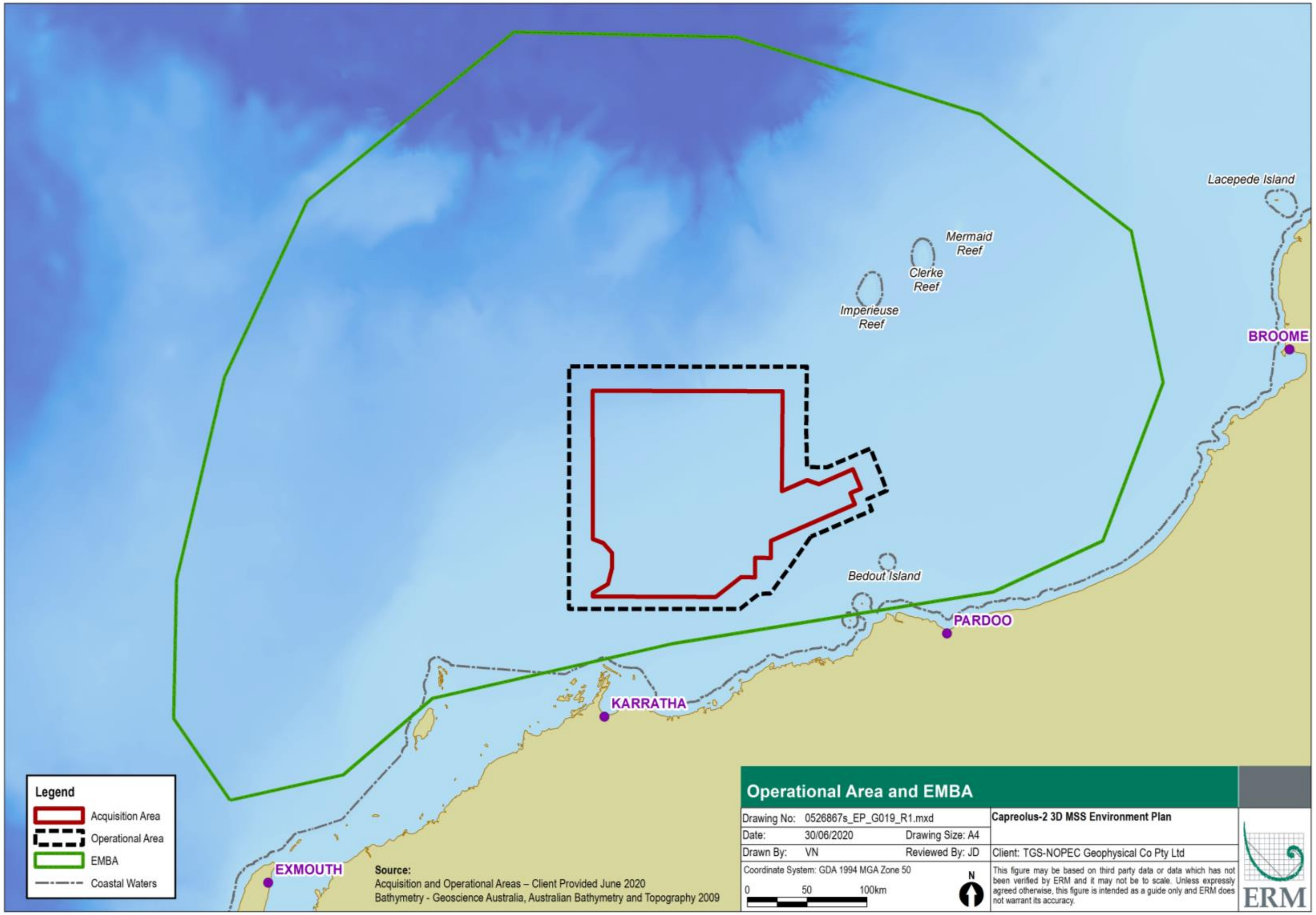


Figure 4.1 Operational Area and EMBA

4.1.1 Data Sources

The information provided in this section has been derived from desktop reviews. This includes peer reviewed journals, and government and industry reports. The key sources of information referred to in this section are from DAWE resources and published literature, including but not limited to:

- An EPBC Act Protected Matters Database search was conducted to identify listed threatened and migratory species, and Threatened Ecological Communities occurring in the Operational Area and wider EMBA.
- Species Profile and Threats (SPRAT) Database, which includes information about species and ecological communities protected under the EPBC Act, available at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.
- National Conservation Values Atlas, which includes information on Biologically Important Areas (BIAs) for protected species under the EPBC Act. These are areas that are particularly important for the conservation of protected species and where aggregations of individuals display biologically important behaviour such as breeding, foraging, resting or migration (DSEWPaC 2012a).

4.2 Regional Environment

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 (refer to 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.).

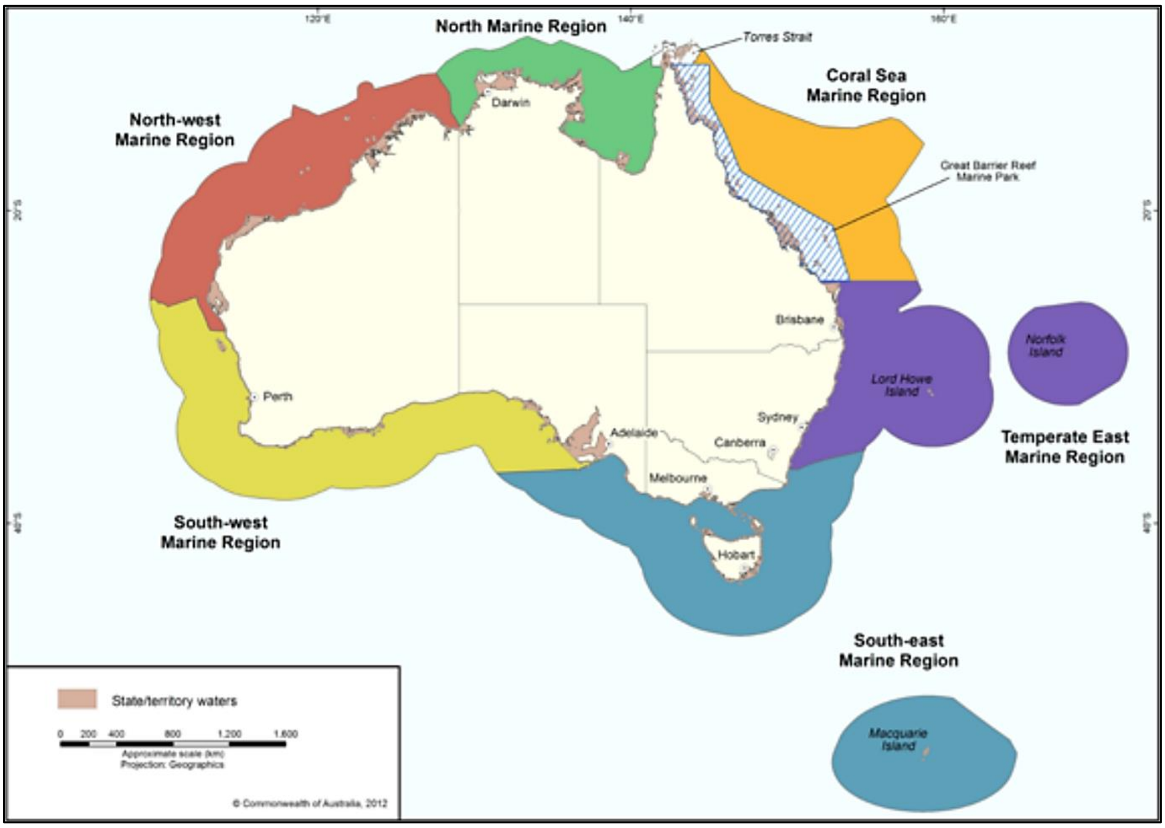
The Operational Area is located solely within the North-west Marine Region (NWMR).

4.2.1 North-west Marine Region

The NWMR comprises Commonwealth waters from 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 is 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; and
- 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 and EMBA is located within two bioregions, the Northwest Shelf Province, and the Northwest Transition (Figure 4.2). These two provincial bioregions are described below.



(Source: DSEWPaC 2012a)

Figure 4.2 Marine Bioregions of Australia

4.2.1.1 Northwest Shelf Province

The southern portion of the Operational Area and EMBA is located within the Northwest Shelf Province, a bioregion that covers 238,759 km^2 of water on the continental shelf in depths of up to 200 m. The Northwest 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. The region is commercially important to both the petroleum industry and commercial fishing industry.

4.2.1.2 Northwest Transition

The northern portion of the Operational Area is located within the Northwest Transition, a bioregion that covers 184,424 km^2 and includes the 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 Section 4.6.2.1). 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.

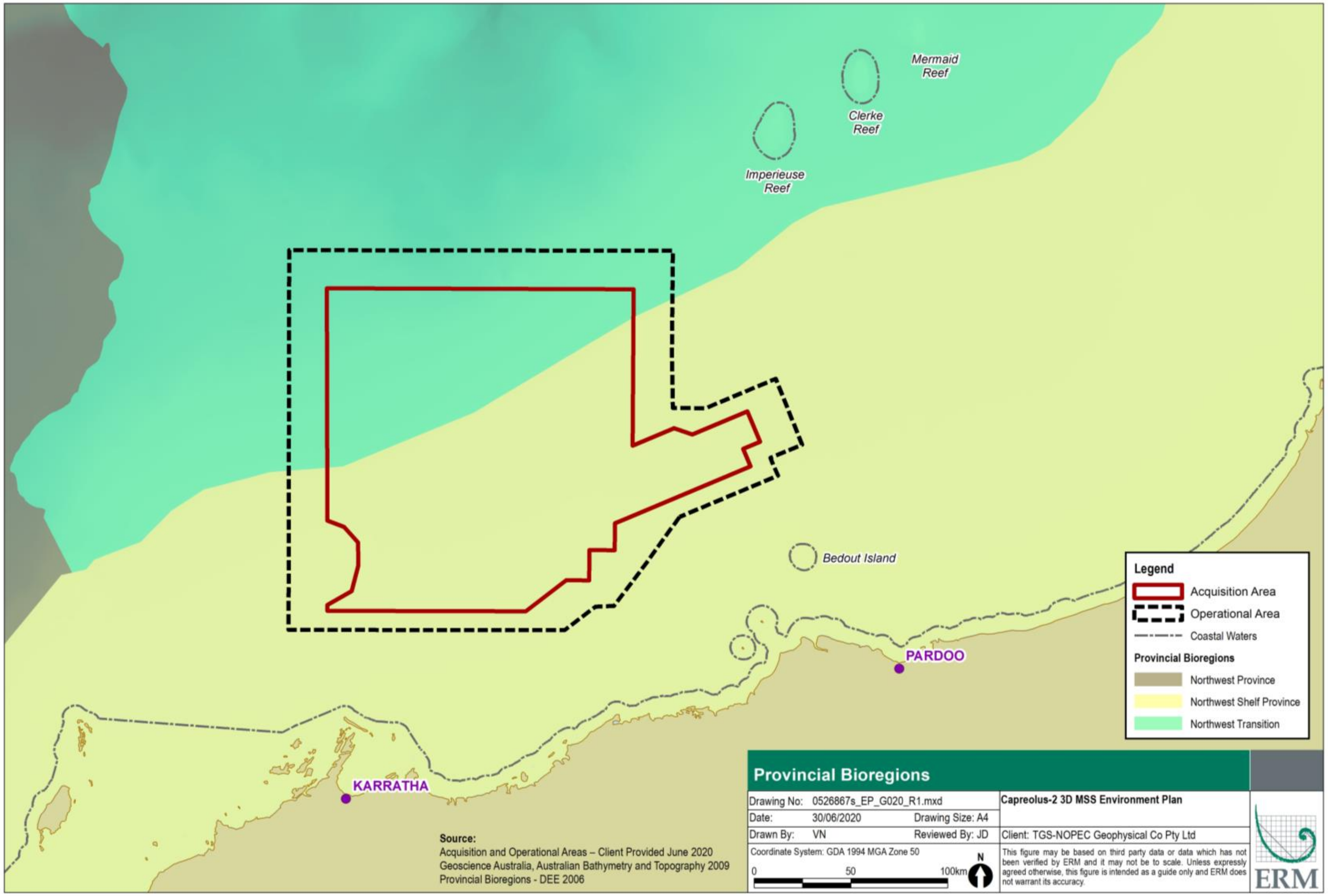


Figure 4.3 Provincial Bioregions

4.3 Key Ecological Features

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.c). KEFs have been identified by the Australian Government on the basis of advice from scientists about the ecological processes and characteristics of the area.

Two KEFs overlap with the Operational Area - the Ancient Coastline at 125 m Depth Contour and Glomar Shoals (refer to Figure 4.4). An additional three KEFs are located within the EMBA - the Mermaid Reef and Commonwealth Waters surrounding Rowley Shoals, the Continental Slope Demersal Fish Communities and the Exmouth Plateau. These KEFs are described in Table 4-2.

Table 4-2 Key Ecological Feature in the Operational Area and EMBA

KEF	Description	Values and / or Sensitivities	Relevant EP Section
Ancient Coastline at 125m Depth Contour	▪ This KEF consists of steps and terraces forming an escarpment along the NWS and Sahul Shelf at a water depth of 125 m. ▪ The KEF covers an area of approximately 16,190 km^2. ▪ The Operational Area overlaps with approximately 2,808 km^2 (17.3%) of the KEF.	▪ The KEF is a unique seafloor feature with ecological properties of regional significance. ▪ 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 2012a). ▪ 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. ▪ Migratory pelagic species (e.g. humpback whales and whale sharks) may use the KEF as a guide.	Refer to Section 4.5.2 for information on benthic habitats in relation to the KEF.
Glomar Shoals	▪ This KEF consists of submerged features situated at depths between 33 m to 77 m. ▪ The KEF consists of a high percentage of marine-derived sediments with high carbonate content and gravels of weathered coralline algae and shells. ▪ The KEF is located entirely within the Operational Area (outside of the Acquisition Area). ▪ The KEF is located approximately 5 km from the Acquisition Area boundary.	▪ The KEF is regionally important for their potentially high biological diversity and localised productivity. ▪ Biological communities found at the Glomar Shoals have not been comprehensively studied, however the shoals are known to be an important area for a number of commercial and recreational fish species.	Refer to Section 4.5.2 for information on benthic habitats in relation to the KEF.

KEF	Description	Values and / or Sensitivities	Relevant EP Section
Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	■ This KEF consists of the Rowley Shoals and surrounding waters. The Rowley Shoals are a collection of three atoll reefs - Clerke, Imperieuse and Mermaid. ■ The Operational Area is located approximately 160 km north-east of the KEF.	■ This KEF is considered regionally important in supporting high species richness and higher productivity and aggregations of marine life. ■ The reefs play an important role in supplying coral and fish larvae to other reefs located further south via the southward flowing ITF (DSEWPaC 2012a).	Refer to Section 4.5.2 for information on benthic habitats in relation to the KEF.
Continental Slope Demersal Fish Communities	■ This KEF is located along the Australian continental slope, between the North West Cape and the Montebello Trough. ■ The KEF is located approximately 114 km west from the Operational Area.	■ The KEF provides important habitat for demersal fish communities and is characterised by high endemism and species diversity.	Refer to Section 4.5.2 for information on fish assemblages in relation to the KEF.
Exmouth Plateau	■ The plateau ranges in water depths from 800 to 4,000 metres, whilst the surface of the plateau is rough and undulating at 800 to 1,000 metres. ■ The KEF covers an area of 49,310 km^2 and is located approximately 230 km west of the Operational Area.	■ This KEF is a unique seafloor feature with ecological properties of regional significance. ■ The KEF may serve an important ecological role by acting as a topographic obstacle that modifies the floor of deep water that generate internal tides, causing upwelling of deeper water and nutrients closer to the surface. ■ Fauna in the pelagic waters above the plateau are likely to include small pelagic species and nekton (DSEWPaC 2012a).	Refer to Section 4.5.2 for information on fish assemblages in relation to the KEF.

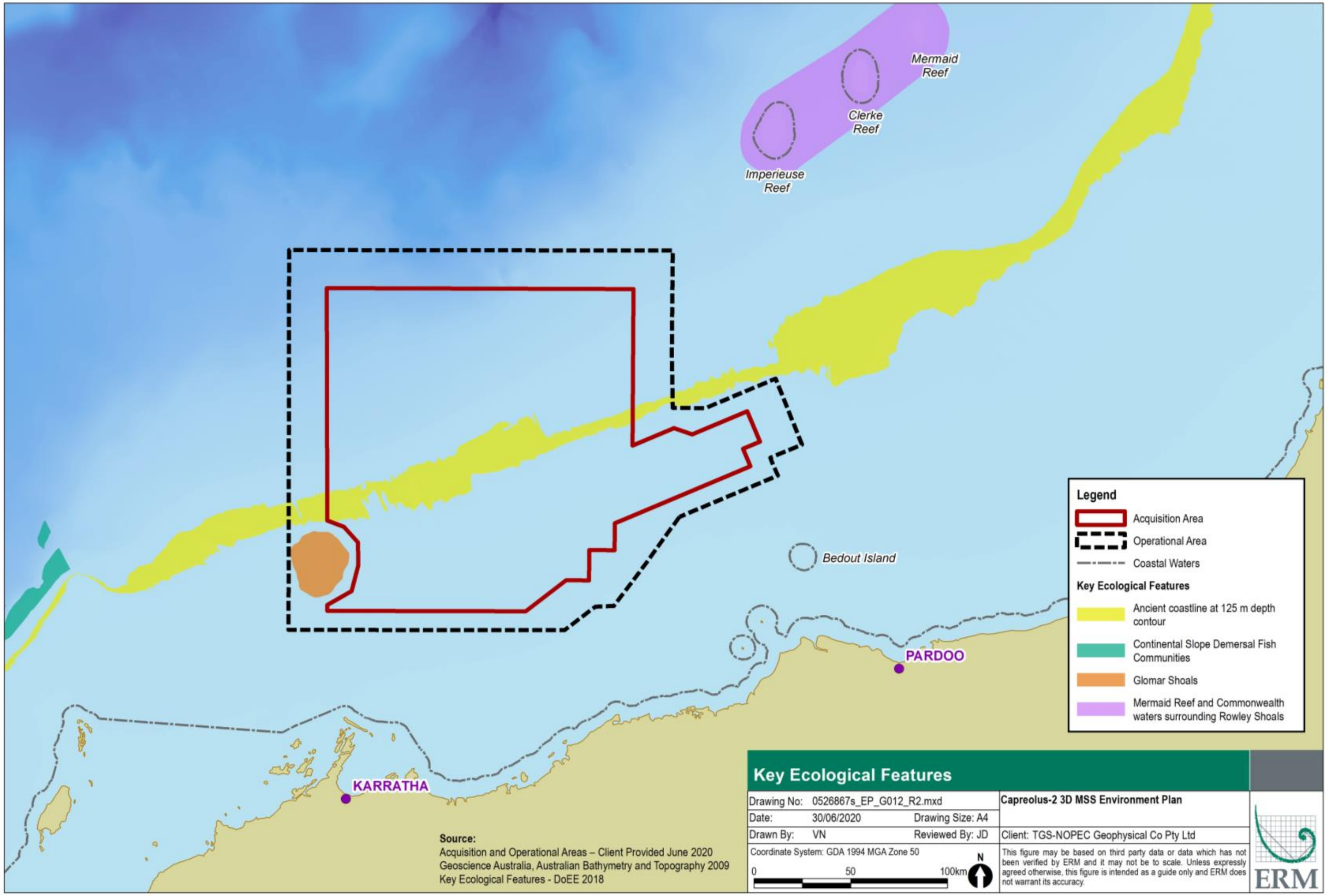


Figure 4.4 Key Ecological Features

4.4 Physical Environment

4.4.1 Climate

4.4.1.1 Seasonal Patterns

The climate of the NWMR is categorised as dry tropical, exhibiting a hot summer season from October to April and a milder winter season between May and September (BoM 2019a). 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).

4.4.1.2 Air Temperature and Rainfall

Air temperatures in the region, as measured at the Rowley Shoals weather station (approximately 70 km from the Operational Area); indicate maximum average temperatures during summer of 30.4ºC and minimum temperatures of 23.6ºC in winter (BoM 2019b).

The NWMR 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 typically occurs during the wet season (summer), with highest falls observed during late summer (BoM 2019c), and often associated with the passage of tropical low pressure systems and cyclones (Pearce et al. 2003). Rainfall outside this period is typically low.

4.4.1.3 Wind

Winds vary seasonally, with a tendency for winds from the south-west during summer and the south-east in winter. The summer west / 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 east / 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.

Wind data from 2013 to 2017 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. Table 4-3 shows the monthly average winds derived from a CFSR node closest to the Operational Area.

Table 4-3 Predicted Monthly Average and Maximum Winds for the Closest CFSR Node to the Operational Area

Month	Average Wind (knots)	Maximum Wind (knots)	General Direction (from)
January	6.2	18.3	West
February	5.5	24.7	West-southwest
March	4.9	16.8	West-southwest
April	5.3	18.2	East-southeast
May	5.6	15.9	East-southeast
June	7.8	17.2	East-southeast
July	6.6	14.3	East-southeast
August	5.7	15.1	East-southeast
September	5.1	13.5	Southwest
October	5.7	12.7	West-southwest

Month	Average Wind (knots)	Maximum Wind (knots)	General Direction (from)
November	5.9	13.3	West-southwest
December	6.0	25.6	West
Minimum	**4.9**	**12.7**	**-**
Maximum	**7.8**	**25.6**	**-**

4.4.1.4 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 2019d). 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 most severe weather has been experienced in April.

4.4.2 Oceanography

4.4.2.1 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 Northwest Shelf Province and Northwest Transition, 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.

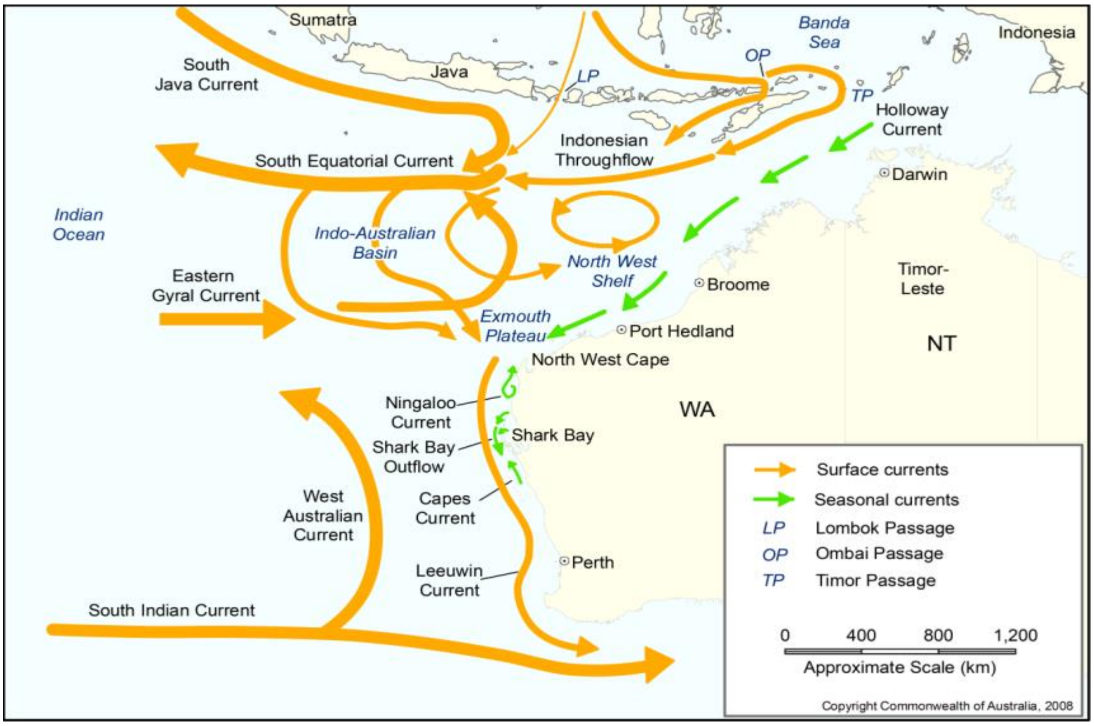
4.4.2.2 Waves

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 within the photic zone, and therefore producing biological productivity.

Furthermore, the region is known to have seasonal cyclonic events, which are key drivers in the bioregion (as described in Section 4.4.1.4).

4.4.2.3 Currents

The oceanography of this bioregion is generated by the movement of surface currents from the waters of the ITF (Figure 4.5). The ITF waters are circulated from the NWMR through the South Equatorial and Eastern Gyral Currents. Within the Northwest Shelf Province and Northwest Transition water circulation is highly seasonal. During winter, the ITF's southern flow is at its strongest and tends to dominate the water column. During summer, the ITF is weaker and strong winds from the southwest cause intermittent reversal of the currents, which generates upwellings of colder and deeper water.



Source: DEWHA (2008)

Figure 4.5 Surface Currents in Western Australian Waters

4.4.2.4 Temperature

The offshore oceanic seawater 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 ITF and the Leeuwin Current, with temperatures reaching 30ºC in summer and dropping to 22ºC in winter (Pearce et al. 2003). This is reflected in location-specific data available from NOAA, where the average annual surface temperature water in the Operational Area is approximately 26°C (NOAA 2019).

4.4.2.5 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 publically available data from NOAA (NOAA, 2019b), where annual surface salinity levels are approximately 35 PSU.

4.4.2.6 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 on 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 runoff, 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).

4.4.3 Bathymetry and Geomorphology

Water depths in the Operational Area range from approximately 33 m (located in the south-west of the Operational Area nearby to Glomar Shoals) to 1,684 m (located in the north of the Operational Area). Water depths in the Acquisition Area range between 50 m to 1,133 m (refer to Figure 4.6). The bathymetry of the Operational Area is predominately characterised by relatively flat seabed, which gradually increases in depth in the north of the Operational Area.

As described in Section 4.3, the Operational Area overlaps with the Glomar Shoals KEF. Glomar Shoals is located solely within the Operational Area and outside of the Acquisition Area. Water depths within the Glomar Shoals KEF range between 33 m – 77 m. In addition, the Ancient Coastline at the 125 m Depth Contour KEF is located within the Acquisition Area and Operational Area.

The Northwest Shelf 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. Table 4-4 and Figure 4.7 describe the geomorphic features located within the Operational Area (based on Baker et al. 2008).

Table 4-4 Geomorphic Features located within the Operational Area

Geomorphic Features	Definition
Terrace	■ Relatively flat horizontal or gently inclined surface, sometimes long and narrow, which is bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side.
Ridge	■ Long, narrow elevation with steep sides. ■ Long, narrow elevation often separating ocean basins. ■ Linked major mid-oceanic mountain systems of global extent.
Shelf	■ Area of Shelf Geomorphic Province in which no other geomorphic features have been identified.

The province includes a number of seafloor 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). Note, these features are not present within the Operational Area.

The Northwest Transition encompasses the shelf break, the continental slope and the majority of the Argo Abyssal Plain. The sediments of the continental slope are dominated by sands, whereas the sediments of the abyssal plain/deep ocean floor are dominated by muds. Water depths within the bioregion range from 200 m (the shelf break) to 1,000 m (the continental shelf) and reaching over 5,000 m within the Agro Abyssal Plain. Other topographic features within the bioregion include areas of rise, ridges, canyons, apron/fans and reefs.

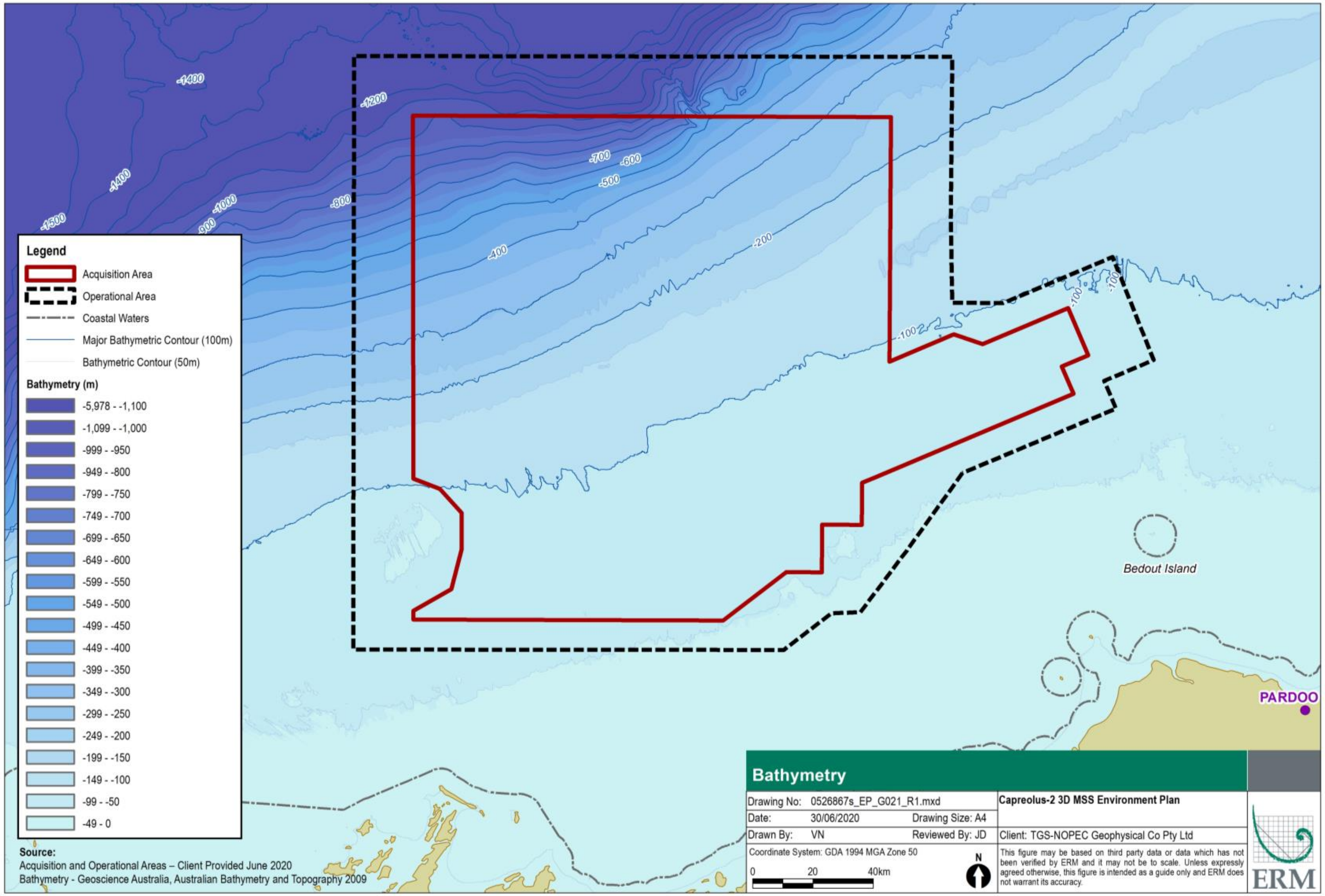


Figure 4.6 Bathymetry within the Operational Area

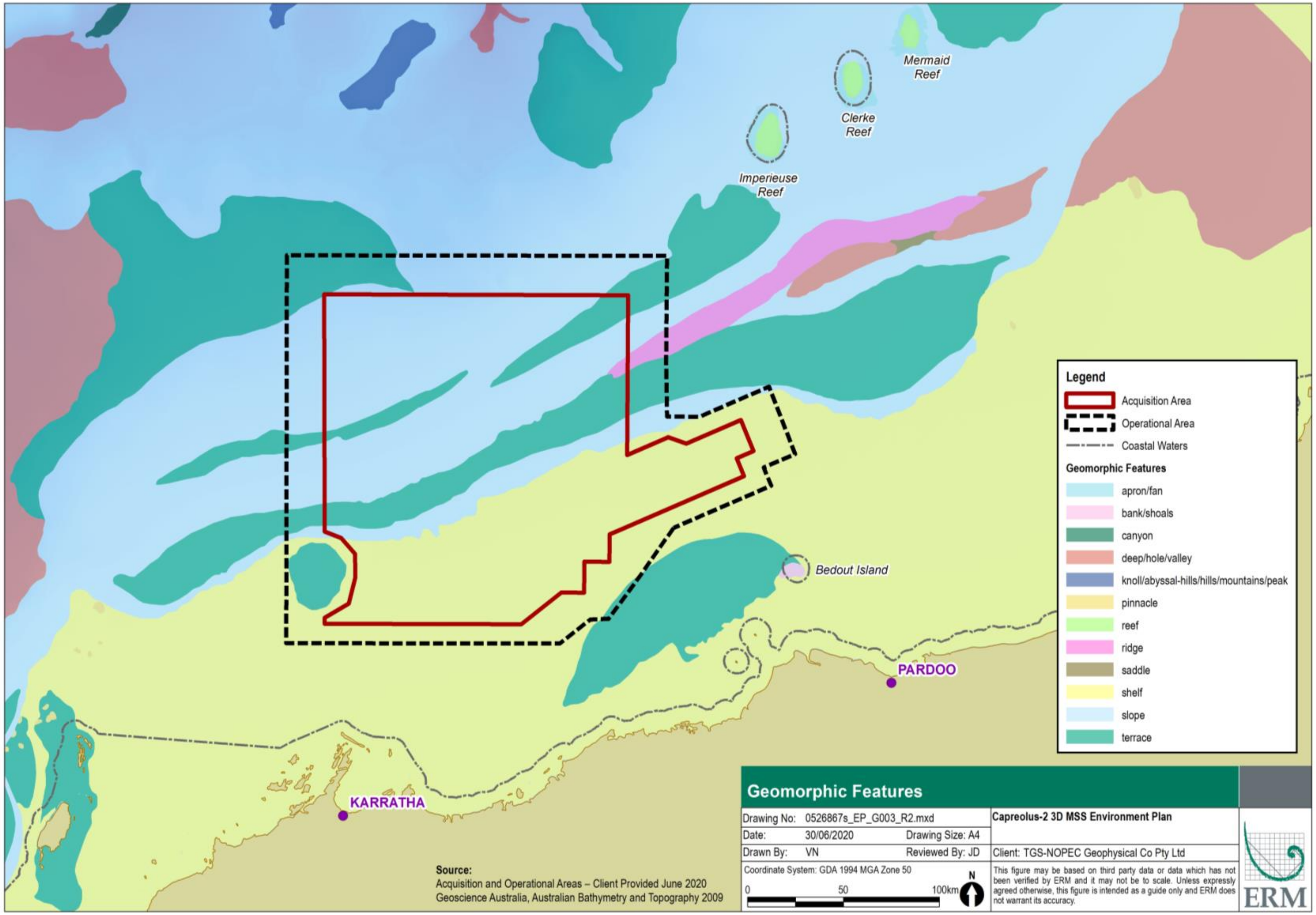


Figure 4.7 Geomorphic Features within the Operational Area

4.4.4 Sedimentology

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). Sediments within the Operational Area are expected to be relatively homogenous and dominated by sand (DEWHA 2008a; CSIRO 2015). There are also expected to be regions of calcareous gravel, shell, boulders and mud (Baker et al. 2008).

4.5 Biological Environment

4.5.1 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. Sporadic/short-lived and potentially localised episodes of nutrient upwelling can occur as a result of internal waves (the rising and sinking of seawater 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.

Sampling by the UWA Oceans Institute in 2015 (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 approximately 260 km east of the Operational Area (Thomson 2015).

4.5.2 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 (refer to Section 4.4.4). 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 2019, Santos Limited (Santos) commissioned a study to investigate the potential presence of silver-lipped pearl oysters, *Pinctada maxima*, and pearl oyster habitat targeted at 40 to 60 m water depths (measured from lowest astronomical tide [LAT]) within the Keraudren 3D MSS Operational Area using towed video imagery. The Capreolus-2 3D MSS Operational Area partially overlaps with the towed video target area, and the depth range and seabed morphology are comparable. Therefore, the findings of the study are considered to be representative of the potential presence of pearl oysters and pearl oyster habitat in the Capreolus-2 3D MSS Operational Area.

The key findings of the study as presented within the Santos Keraudren Extension 3D Marine Seismic Survey Environment Plan (Santos 2020) were 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 mesophotic gorgonian forest with high densities of large epibiota on relatively flat emergent bedrock with sand/gravel veneer. Gorgonians were estimated at between 1 to 1.8 m high, with shorter colonies also present; and
- Only two pearl oysters were identified from a total of 21.9 km of seabed surveyed. Both individuals were observed growing in water depths of 50-54 m (LAT). This indicated that although potential pearl habitat was likely to occur in the depth range surveyed, the habitat did not support a high density of pearl oysters (only a few individuals).

Based on the findings of the study, the shallowest areas of the Capreolus-2 3D MSS Operational Area are likely to support only sub-optimal pearl oyster habitat and low densities of pearl oysters (limited to a few individuals). These findings are consistent with the preliminary results from the North West Shoals to Shore research program.

It is expected that the Capreolus-2 3D MSS Operational Area would support similar epibenthos as those found in the Santos study due to shared bioregions and comparable benthic habitat, sediments, and geomorphic features. The Acquisition Area is unlikely to support diverse benthic assemblages, such as hard and soft corals, gorgonians, encrusting sponges, seagrass and macroalgae. Potential habitats within the Operational Area are likely to exist in the southern regions and at Glomar Shoals.

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

4.5.2.1 Glomar Shoals and Rankin Bank

Glomar Shoal is defined as a KEF for its high productivity and aggregation of marine life (refer to Section 4.3). The submerged feature rises gently on the south-west side from 80 m depth to a single plateau at 40 m depth. The north-eastern side of the reef rises steeply from 70 to a minimum depth of approximately 33 m.

Glomar Shoal consists of a high percentage of marine-derived sediments with high carbonate content and gravels of weathered coralline algae and shells. The shoals consists of high concentrations of coarse material compared to surrounding areas, indicative of a high energy environment subject to strong seafloor currents (DSEWPaC 2012a). Biological communities found at Glomar Shoal have not been comprehensively studied, however the shoals are known to be an important area for a number of commercial and recreational fish species such as rankin cod, brown striped snapper, red emperor, crimson snapper, bream and yellow-spotted triggerfish (DoEE 2019a).

Rankin Bank which is located within the EMBA, is approximately 125 km west of Glomar Shoal and 100 km west of the Operational Area. Rankin Bank is not formally designated as a KEF. It is a smaller submerged feature than Glomar Shoal, but rises to shallower water depths. The minimum water depth at Rankin Bank is approximately 20 m.

The benthic communities and fish assemblages at Glomar Shoal were surveyed during a study of Glomar Shoals and Rankin Bank conducted by AIMS. The benthos was characterised for four different depth ranges - <40 m, 40–<60 m, 60–<80 m and >80 m. The results are described in AIMS (2014) and more recently published in Abdul Wahab (2018).

Epibenthic cover at Glomar Shoal was 21.1%, 9.3%, 2.3% and 0.1% for the four depth categories (Abdul Wahab 2018). Across all depth ranges, macro-benthic organisms represent just 9.5% of the total cover; macroalgae (4.8%), sponges (1.8%), soft corals (1.3%), hard corals (0.4%) and other organisms (1.1%). The remaining cover comprised abiotic substrates. Total cover of hard corals, soft coral, sponges and other organisms (including ascidians bryozoans and hydrozoans) was highest at <40 m and decreased with depth (Abdul Wahab 2018). The habitat map developed by AIMS for Glomar Shoal, as available online via the North West Atlas, is presented in Figure 4.8.

Rankin Bank had a higher (more than double) coverage of benthic taxa than Glomar Shoal, with 43.5%, 35.5%, 21.3% and 6.1% cover of biota reported for the four depth categories, including higher coverage of corals than at Glomar Shoal (Abdul Wahab 2018).

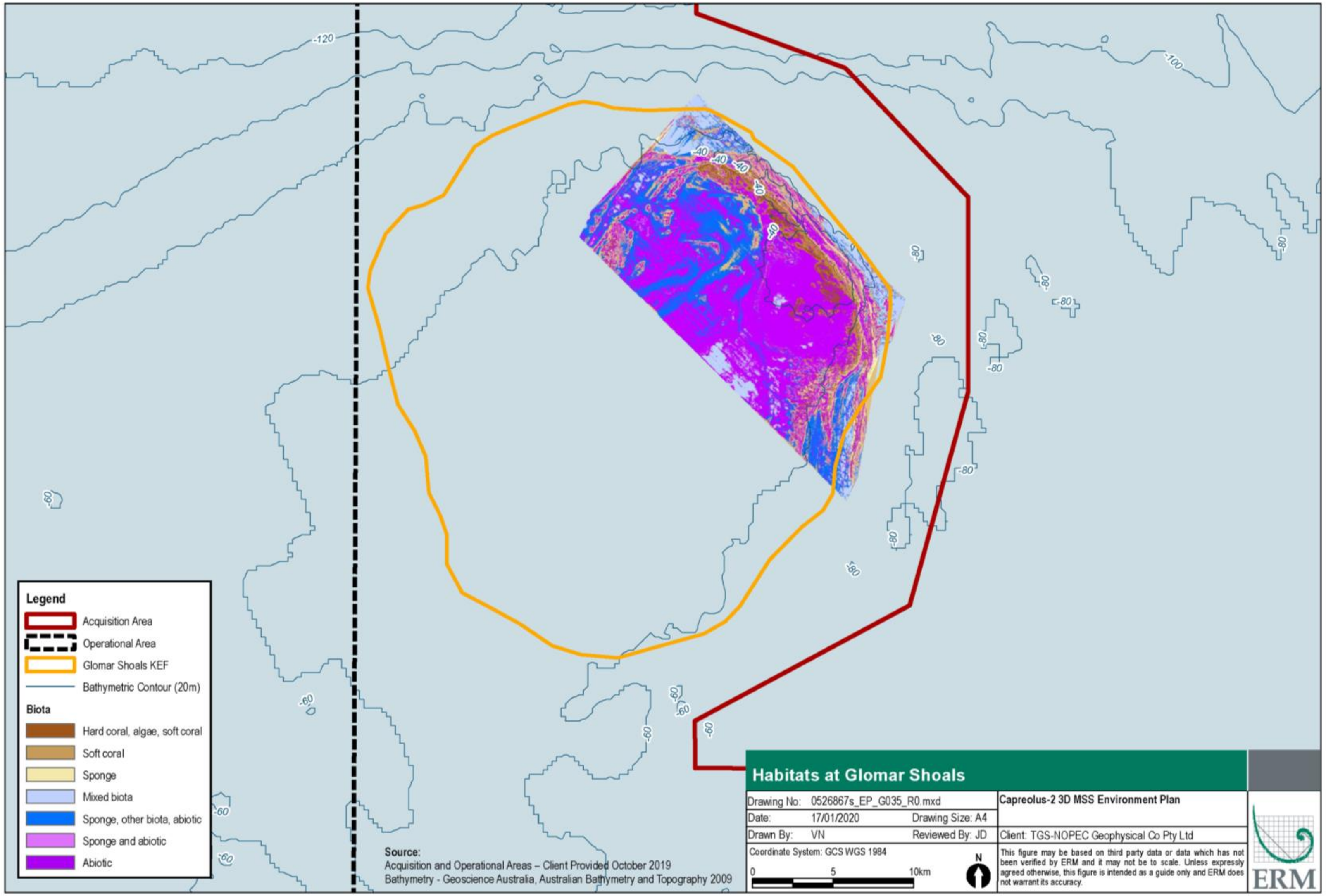


Figure 4.8 Glomar Shoals Benthic Habitat Map (Abdul Wahab 2018)

4.5.2.2 Ancient Coastline at 125 m Depth Contour

The Ancient Coastline at 125 m Depth Contour KEF is a series of several steps and terraces that form an escarpment along the NWS (refer to Section 4.3). The KEF is thought to provide areas of hard substrate that may contribute to higher diversity and enhanced species richness relative to the surrounding soft sediment habitat, and may include sponges, crinoids, molluscs, echinoderms and other benthic invertebrates (DSEWPaC 2012a). The topographic complexity of these escarpments may also provide a relatively nutrient-rich environment for sessile communities (DSEWPaC 2012a).

Preliminary data from the AIMS North West Shoals to Shore research program, which includes multibeam and towed video surveys of some areas of the Ancient Coastline at the 125 m Depth Contour KEF, has found that these depth contours are dominated by sandy habitats with limited areas of hard substrate filter feeder communities.

4.5.2.3 Rowley Shoals

The Rowley Shoals are located within the EMBA and comprise a collection of three atoll reefs - Clerke, Imperieuse and Mermaid. These reefs provide a distinctive biophysical environment in the NWMR, with steep and distinct reef slopes, which attract a range of migratory pelagic species and associated fish communities. 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). 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).

Sparse seagrass is found within the subtidal coral reef communities, but is not a major habitat type at the Rowley Shoals (Berry 1986; Walker & 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).

4.5.3 Fish Assemblages

The Protected Matters Database search identified 29 pipefish species, six seahorse species, five pipehorse species and one seadragon that may potentially occur in the EMBA. 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.

It is likely that the principal habitat within the Operational Area that may support significant assemblages of site-attached fish is at Glomar Shoal. The fish community structure at Glomar Shoal shows a strong relationship with habitat type, with a distinct difference in structure (species richness, abundance) in water depths <36.7 m (Abdul Wahab 2018), as shown in Figure 4.9. Benthic cover and morphological composition of hard corals is likely to be a key influencing factor in fish community composition, with coral reef associated and herbivorous fish species associated with occurrences of corals. More mobile species of emperor, snapper, and other deep water commercial species occupied a mixture of deep rugose sponge habitat and bare ground at Glomar Shoal, including on the plateau feature at 40 m depth on the south-west side of the shoal (Abdul Wahab 2018).

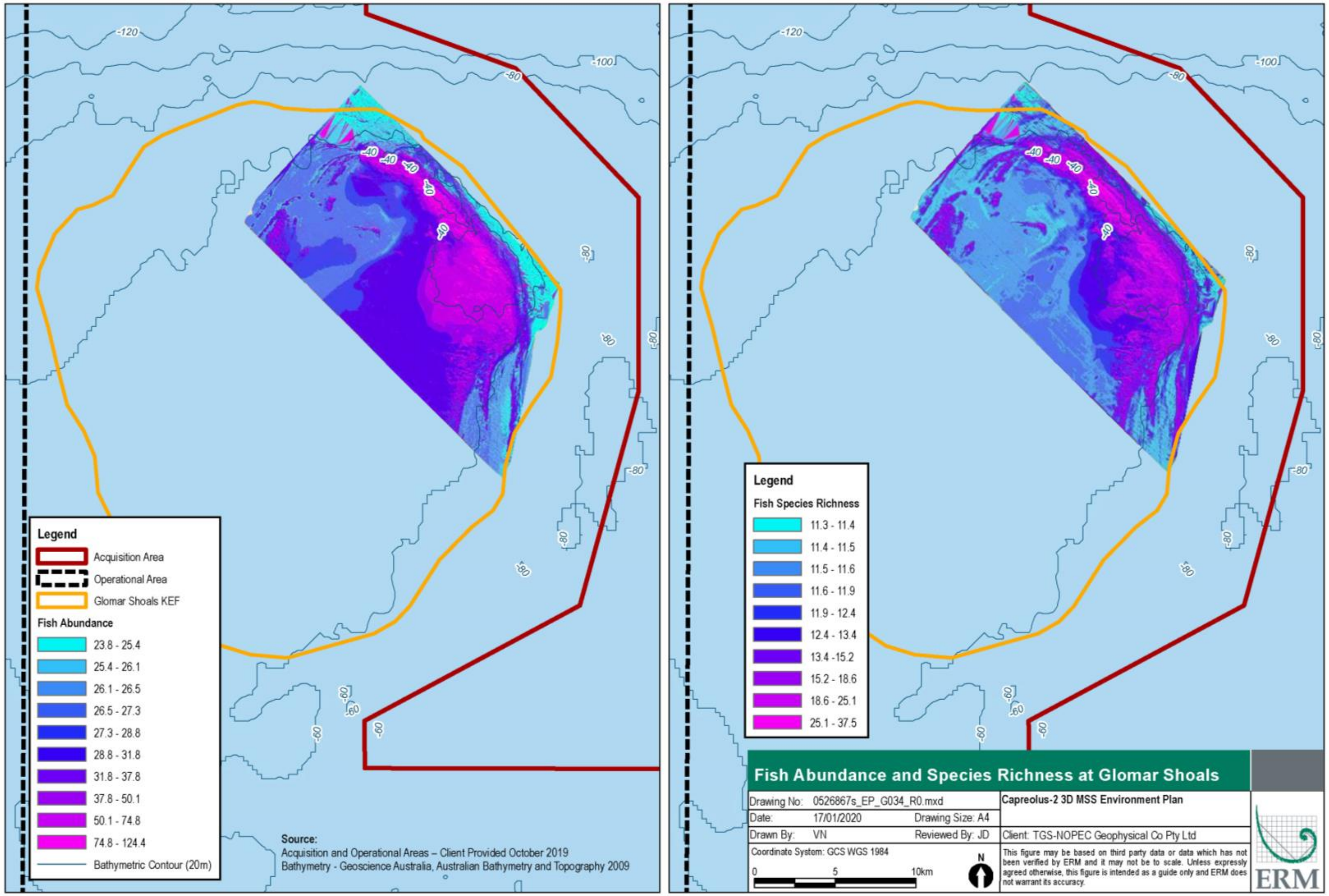


Figure 4.9 Fish Community Structure at Glomar Shoal (Abdul Wahab 2018)

4.5.4 Commercially Targeted Fish Stocks

The NWMR provides fishing grounds for several commercial fisheries, which target a variety of demersal and pelagic fish species. During the consultation process, the Department of Primary Industries and Regional Development (DPIRD Fisheries) 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 the Capreolus-2 3D MSS does not overlap with) 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).

Table 4-5 summarises the indicator fish species that are relevant to the Operational Area, the spatial extent of their biological stocks, and their reproductive biology, based on information provided by DPIRD (2019c) and other published literature on the fisheries and fish species.

Note that fish stocks may also be considered in terms of smaller more discrete fisheries 'management units', which are adopted by fisheries management authorities for the purposes of fisheries management and monitoring. The management units consider the genetic stock and larval settlement, but also take into account the smaller ranges and localised movements of adult and juvenile fish, as well as the extent of the fisheries that target the stocks. Consequently, the fisheries management units are typically smaller than the extent of the genetic stocks. Application of management units provides a more conservative approach to managing the resource (Gaughan et al. 2018). The North Coast Fisheries Bioregion of WA defined by DPIRD is divided into two management units, the Pilbara and the Kimberley management units (Figure 4.10), which also inform the FRDC (2019) stock assessments. The Operational Area is located within the Pilbara management unit.

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).

Both the biological stock ranges and the fishery management units are discussed in the impact and risk assessments in Section 7.1 and Section 7.2.

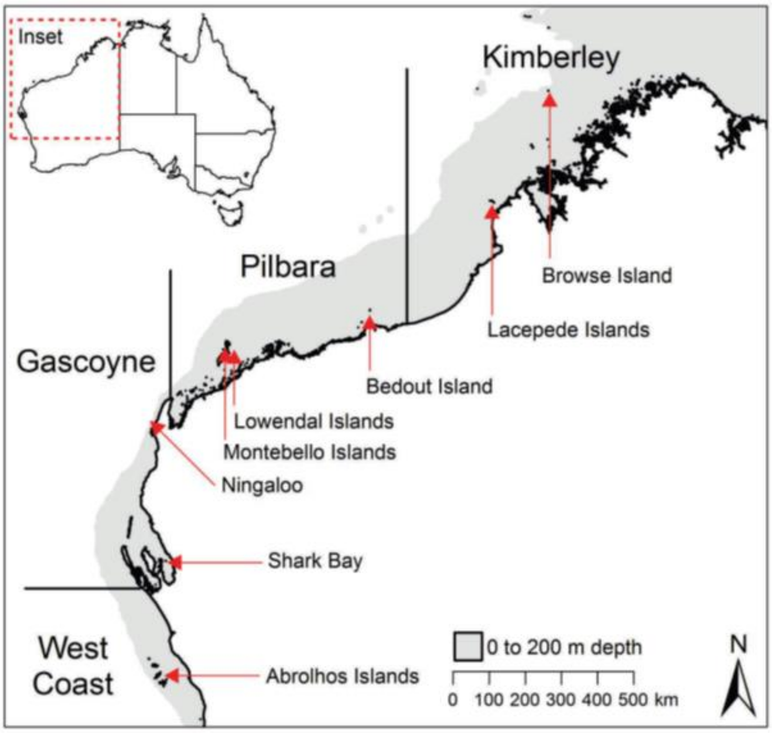


Figure 4.10 Management Units for the Scalefish Resources in Northern WA (Gaughan et al. 2018)

Table 4-5 Key Indicator Fish Species Relevant to the TGS Capreolus-2 3D MSS

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
Demersal Species							
Goldband snapper (Pilbara stock) (*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. 2018a).	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. 2018a).	50-200 m (DPIRD 2019).	Goldband snapper are highly fecund, serial, broadcast spawners and they can produce several million eggs per season (Newman et al. 2008). They spawn throughout their range (DPIRD 2019). Goldband snapper can spawn approximately every three days / every week during the spawning period (Santos 2020). Juveniles remain in offshore waters with the adult spawning biomass, but are found in association with different habitat (Newman et al. 2008). Fish are estimated to reach maturity after approximately 4.6 years (Saunders et al. 2018a).	**Sustainable (Newman et al. 2019).**	October – May (extended peak spawning period) (DPIRD 2019).	Given the known distribution and habitat depths, goldband snapper are likely to occur and may spawn within the Acquisition Area. Spawning will be limited to water depths in less than 200 m.
Rankin cod (*Epinephelus multinotatus*)	Rankin cod are a demersal species distributed along the North-west Western Australia from the Abrolhos Islands to Cape Leveque in depths ranging from 5 – 150 m. 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.	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 2019).	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 2019). 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. 2018a).	**Sustainable (Newman et al. 2019)**	The species spawns for 8-10 months of the year in the Pilbara region (Gaughan et al. 2018). DPIRD (2019) 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 Acquisition Area. Spawning will be limited to water depths between 5 – 150 m.
Red emperor (*Lutjanus sebae*)	Red emperor occur from the central west coast of WA to southern Queensland (Newman et al. 2018a). 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 2019).	Red emperor are highly fecund, serial, broadcast spawners. Females release numerous batches of eggs over an extended spawning period. (Newman et al. 2008; Gaughan et al 2018). They spawn throughout their range (DPIRD 2019). Juvenile fish are more common in nearshore waters and move offshore and recruit to the stock as they mature (Newman et al. 2008; van Herwerden et al. 2009). Fish are estimated to reach maturity after approximately 4 – 6 years (Newman et al. 2018a).	**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 (2019) advise that the main spawning season is September – June (with bimodal peaks September – November and January – March).	Given the known distribution and habitat depths, red emperor are likely to occur and may spawn within the Acquisition Area. Spawning will be limited to water depths between 10 – 180 m.
Blue-spotted emperor (*Lethrinus punctulatus*)	The blue-spotted emperor is distributed primarily from around Geraldton and the Abrolhos Islands in WA to Darwin in the NT (Newman et al. 2018a). Greatest	There is extensive connectivity among populations of bluespotted emperor over large distances, and there is considered to be a single biological	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).	**Sustainable (Newman et al. 2019).**	The species spawns for 11 months of the year (Gaughan et al. 2018).	Given the known distribution and habitat depths, blue-spotted emperor are likely to occur

Species	Distribution and Habitat	Biological Stock Range	Principal Depth Range	Reproduction and Recruitment	Stock Status	Spawning Season	Relevance to EP
	abundances are noted in the western Pilbara region (Newman et al. 2018a; Gaughan et al. 2018). The species is often found in association with shallow reef, sand and mud areas (Newman et al. 2008).	stock in WA and potentially as far as the Northern Territory (Newman et al. 2018a).		They spawn throughout their range (DPIRD 2019c). Fish are estimated to reach maturity after approximately 18 months (Newman et al. 2018; Guaghan et al. 2018).		DPIRD (2019c) advise that the main spawning season is July – March (extended peak spawning period)	and may spawn within the Acquisition Area. Spawning will be limited to water depths between 5 – 110 m.
Giant ruby snapper (*Etelis carbunculus*)	Ruby snapper occurs across the Indo-West pacific region. In Australia, ruby snapper is 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 2019).	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).	**Sustainable (Newman et al. 2019).**	December-April (peak spawning period January-March)	Given the known distribution and habitat depths, ruby snapper are likely to occur and may spawn within the Acquisition Area (in depths between 150 m – 480 m).
Other demersal species (non-indicator species)	Variable (DPIRD 2019).	Variable (DPIRD 2019).	Variable (DPIRD 2019).	Spawn throughout their range (DPIRD 2019).	**Sustainable (Newman et al. 2019).**	Most likely to exhibit a peak spawning period from Oct-May (DPIRD 2019).	Other demersal fish species may spawn in the Operational Area.
Pelagic Species							
Spanish mackerel (Pilbara stock) (*Scomberomorus commerson*)	Spanish mackerel are a pelagic species that are widely distributed throughout In do-West Pacific waters. In Australia, Spanish mackerel are found from approximately Geraldton in WA to Northern NSW (Langstreth et al. 2018). Adult movements in Australian waters occur over ranges of 100 – 300 km (Mackie et al. 2010.	Spanish mackerel in northern Australia form three distinct genetic stocks: an east coast stock, a Torres Strait stock, and a single stock across the north and west coasts of Australia (Northern Territory and WA) (Langstreth et al. 2018). Consequently, the whole of the WA Mackerel Managed Fishery (spanning the Kimberley, Pilbara and Gascoyne regions) is defined as a single stock (Langstreth et al. 2018).	1 – 50 m (DPIRD 2019).	Form spawning schools around inshore reefs in north coast bioregion (Mackie et al. 2010; Lewis and Jones 2018). Spanish mackerel spawning occurs in coastal waters. They are serial spawners and alongshore dispersal of eggs maintains genetic homogeneity (Mackie et al. 2010). Females are capable of producing a batch of hundreds of thousands of eggs every 1-3 days during the spawning season, though a spawning frequency of 1.9 to 5.9 days has also been reported (McPherson 1993; Mackie et al. 2010). Larvae are commonly associated with reef lagoonal areas, before juveniles move to estuary and foreshore nursery and feeding grounds where they tend to remain for the first year of life (McPherson 1993; Begg et al. 2006; Mackie et al. 2010). Fish are estimated to reach maturity after approximately 2 years (Langstreth et al. 2018).	**Sustainable (Lewis and Brand-Gardner 2019).**	September – December (peak spawning) (DPIRD 2019).	Given the known distribution and habitat depths, spanish mackerel may occur in the Acquisition Area but is unlikely to spawn in the Acquisition Area due to the species preferred water depth ranges. Spawning is limited to water depths in less than 50 m. The minimum water depth in the Acquisition Area is 50 m.

4.5.5 Threatened and Migratory Species

A search of the EPBC Act Protected Matters Database was undertaken to identify listed marine species under the EPBC Act that may occur within the Operational Area and EMBA. 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.

The results of the EPBC Protected Matters Search are provided in Table 4-6. The search identified 72 listed species as potentially occurring within the Operational Area, of which 30 are considered threatened and 37 considered migratory. No threatened ecological communities (TECs) were identified.

The full list of species identified from the Protected Matters Search Tool (PMST) is provided in the EPBC Act Protected Matters Search Report (Appendix C).

Table 4-6 Environmental Values and Sensitivities Protected under the EPBC Act

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Protected Species: Fish, Sharks and Rays						
Grey Nurse Shark	*Carcharias taurus*	Vulnerable	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.
Great White Shark	*Carcharodon carcharias*	Vulnerable, Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat may occur within area.
Dwarf Sawfish	*Pristis clavata*	Vulnerable, Migratory	✓	Habitat preference for shallow estuarine waters and therefore presence is not expected.	✓	Breeding known to occur within area.
Green Sawfish	*Pristis zijsron*	Vulnerable, Migratory	✓	Habitat preferences a restricted to a few square kilometres within the coastal fringe.	✓	Breeding known to occur within area.
Whale Shark	*Phincodon typus*	Vulnerable, Migratory	✓	Foraging, feeding or related behaviour known to occur within area.	✓	Foraging, feeding or related behaviour known to occur within area.
Narrow Sawfish	*Anoxypristis cuspidate*	Migratory	✓	Species or species habitat known to occur within area.	✓	Species or species habitat known to occur within area.
Shortfin Mako	*Isurus oxyrinchus*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Longfin Mako	*Isurus paucus*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.
Reef Manta Ray	*Manta alfredi*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat known to occur within area.
Giant Manta Ray	*Manta birostris*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.
Freshwater Sawfish	*Pristis*	Vulnerable, Migratory	x	N/A	✓	Species or species habitat known to occur within area.
Protected Species: Marine Mammals						
Sei Whale	*Balaenoptera borealis*	Vulnerable, Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.
Blue Whale	*Balaenoptera musculus*	Endangered, Migratory	✓	Migration route known to occur within area.	✓	Migration route known to occur within area.
Fin Whale	*Balaenoptera physalus*	Vulnerable, Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.
Humpback Whale	*Megaptera novaeangliae*	Vulnerable, Migratory	✓	Species or species habitat known to occur.	✓	Species or species habitat known to occur within area.
Bryde’s Whale	*Balaenoptera edeni*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Killer Whale	*Orcinus orca*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat may occur within area.
Sperm Whale	*Physeter microcephalus*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat may occur within area.
Spotted Bottlenose Dolphin	*Tursiops aduncus*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Species or species habitat likely to occur within area.
Indo-Pacific Humpback Dolphin	*Sousa chinensis*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat likely to occur within area.
Dugong	*Dugong dugon*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.
Southern Right Whale	*Eubalaena australis*	Endangered, Migratory	x	N/A	✓	Species or species habitat may occur within area.
Antarctic Minke Whale	*Balaenoptera bonaerensis*	Migratory	x	N/A	✓	Species or species habitat likely to occur within area.
Protected Species: Marine Reptiles						
Short-nosed Seasnake	*Aipysurus apraefrontalis*	Critically Endangered	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.
Loggerhead Turtle	*Caretta*	Endangered, Migratory	✓	Species or species habitat likely to occur within area.	✓	Foraging, feeding or related behaviour known to occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Green Turtle	*Chelonia mydas*	Vulnerable, Migratory	✓	Species or species habitat likely to occur within area.	✓	Foraging, feeding or related behaviour known to occur within area.
Leatherback Turtle	*Dermochelys coriacea*	E, M	✓	Species or species habitat likely to occur within area.	✓	Foraging, feeding or related behaviour likely to occur within area.
Hawksbill Turtle	*Eretmochelys imbricate*	Vulnerable, Migratory	✓	Species or species habitat likely to occur within area.	✓	Foraging, feeding or related behaviour known to occur within area.
Flatback Turtle	*Natator depressus*	Vulnerable, Migratory	✓	Congregation or aggregation known to occur within area.	✓	Foraging, feeding or related behaviour known to occur within area.
Protected Species and Communities: Birds (Seabirds)						
Common Noddy	*Anous stolidus*	Migratory	✓	Species or species habitat may occur in the area.	✓	Species or species habitat likely to occur within the area.
Streaked Shearwater	*Calonectris leucomelas*	Migratory	✓	Species or species habitat likely to occur within the area.	✓	Species or species habitat likely to occur within the area.
Lesser Frigatebird	*Fregata ariel*	Migratory	✓	Species or species habitat likely to occur within area.	✓	Breeding known to occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Great Frigatebird	*Fregata minor*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat may occur within area.
White-tailed Tropicbird	*Phaethon Lepturus*	Migratory	✓	Foraging, feeding or related behaviour likely to occur within area.	✓	Breeding likely to occur within area.
Roseate Tern	*Sterna dougallii*	Migratory	✓	Foraging, feeding or related behaviour likely to occur within area.	✓	Breeding known to occur within area.
Brown Booby	*Sula leucogaster*	Migratory	✓	Breeding known to occur within area.	✓	Breeding known to occur within area.
Abbott's Booby	*Papasula abbotti*	Endangered	✓	Species or species habitat may occur within area.	✓	Species or species habitat may occur within area.
Australian Fairy Tern	*Sternula nereis*	Vulnerable	✓	Species or species habitat may occur within area.	✓	Breeding known to occur within area.
Roseate Tern	*Sterna dougallii*	Migratory	x	Foraging, feeding or related behaviour likely to occur within area.	✓	Breeding known to occur within area.
Caspian Tern	*Hydroprogne caspia*	Migratory	x	N/A	✓	Breeding known to occur within area.
Little Tern	*Sternula albifrons*	Migratory	x	N/A	✓	Breeding known to occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Red-tailed Tropicbird	*Phaethon rubricauda*	Migratory	x	N/A	✓	Breeding known to occur within area.
Bridled Tern	*Onychoprion anaethetus*	Migratory	x	N/A	✓	Breeding known to occur within area.
Masked Booby	*Sula dactylatra*	Migratory	x	N/A	✓	Breeding known to occur within area.
Wedge-tailed Shearwater	*Ardenna carneipes*	Migratory	x	N/A	✓	Breeding known to occur within area.
Flesh-footed Shearwater	*Ardenna carneipes*	Migratory	x	N/A	✓	Species or species habitat may occur within area.
Southern Giant-Petrel	*Macronectes giganteus*	Endangered, Migratory	x	N/A	✓	Species or species habitat may occur within area.
Soft-plumaged Petrel	*Pterodroma mollis*	Vulnerable	x	N/A	✓	Species or species habitat may occur within area.
Fork-tailed Swift	*Apus pacificus*	Migratory	x	N/A	✓	Breeding likely to occur within area.
Protected Species: Birds (Shorebirds)						
Red knot	*Calidris canutus*	Endangered, Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Curlew Sandpiper	*Calidris ferruginea*	Critically Endangered, Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.
Eastern Curlew	*Numenius madagascariensis*	Critically Endangered, Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.
Common Sandpiper	*Actitis hypoleucos*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat known to occur within area.
Sharp-tailed Sandpiper	*Calidris acuminate*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat likely to occur within the area.
Pectoral Sandpiper	*Calidris melanotos*	Migratory	✓	Species or species habitat may occur within area.	✓	Species or species habitat likely to occur within the area
Osprey	*Pandion haliaetus*	Migratory	✓	Species or species habitat may occur within area.	✓	Breeding known to occur within area.
Western Alaskan Bar-tailed Godwit	*Limosa lapponica baueri*	Vulnerable	x	N/A	✓	Species or species habitat likely to occur within the area.
Bar-tailed Godwit	*Limosa lapponica*	Migratory	x	N/A	✓	Species or species habitat known to occur within area.
Oriental Plover	*Charadrius veredus*	Migratory	x	N/A	✓	Species or species habitat may occur within area.

Common Name	Scientific Name	EPBC Act Status	Operational Area	Assessment of Values or Sensitivities within the Operational Area	EMBA	Assessment of Values or Sensitivities within the EMBA
Oriental Pratincole	*Glareola maldivarum*	Migratory	x	N/A	✓	Species or species habitat may occur within area.
Crested Tern	*Thalasseus bergii*	Migratory	x	N/A	✓	Breeding known to occur within area.
Common Greenshank	*Tringa nebularia*	Migratory	x	N/A	✓	Species or species habitat likely to occur within the area.
Northern Siberian Bar-tailed Godwit	*Limosa lapponica menzbieri*	Critically Endangered	x	N/A	✓	Species or species habitat likely to occur within the area.
Australian Painted Snipe	*Rostratula australis*	Endangered	x	N/A	✓	Species or species habitat may occur within area.

4.5.5.1 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 ecological communities (DoEE n.d.b). 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 newly listed species or ecological community (DoEE n.d.b).

Table 4-7 lists the applicable recovery plans and/or conservation advice for EPBC Act-listed species within the Operational Area and EMBA, as identified in the PMST Report.

Table 4-7 Recovery Plans and Conservation Advice for EPBC Act-Listed Species Occurring within the Operational Area and EMBA

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
Sharks and Rays				
Great white shark	Recovery plan for the White Shark (*Carcharodon carcharias*) (2013)	Ecosystem effects as a result of habitat modification and climate change	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Dwarf sawfish	Sawfish and River Sharks Multispecies Recovery Plan (2015)	Habitat degradation and modification	■ Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life. ■ Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	Refer to Section 7 and 8.
Green sawfish	Commonwealth Conservation Advice on *Pristis zijsron* (green sawfish). Sawfish and River Sharks Multispecies Recovery Plan (2015)	Habitat degradation and modification	■ Reduce and, where possible, eliminate any adverse impacts of marine debris on sawfish and river shark species noting the linkages with the Threat Abatement Plan for the Impact of Marine Debris on Vertebrate Marine Life. ■ Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	Refer to Section 7 and 8.
Whale shark	Approved Conservation Advice for *Rhincodon typus* (whale shark) (2015)	Boat strike from large vessels	■ Minimise transit time of large vessels in areas close to marine features likely to correlate with whale shark aggregations (Ningaloo Reef,	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
			Christmas Island and the Coral Sea) and along the northward migration route.	
		Habitat disruption from mineral exploration, production and transportation	■ Implement measures to reduce adverse impacts of habitat disruption.	Refer to Section 7 and 8.
		Marine debris	■ Reduce and, where possible, eliminate any adverse impacts of marine debris on whale sharks. ■ Take into account and protect BIAs for whale sharks when assessing the impact of proposed activities in the marine environment.	Refer to Section 7 and 8.
Freshwater sawfish / Largetooth sawfish	Approved Conservation Advice for *Pristis* (largetooth sawfish) (2014).	Habitat degradation/ modification	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification. ■ Take into account and protect BIAs for sawfish and river sharks when assessing the impact of proposed activities in the marine environment.	Refer to Section 7 and 8.
Marine Mammals				
Sei whale	Approved Conservation Advice for *Balaenoptera borealis* (sei whale) (2015)	Pollution (persistent toxic pollutants)	■ Implement measures to manage and reduce, where possible, waste generation.	Refer to Section 7 and 8.
		Vessel strike	■ Ensure all vessel strike incidents are reported in the National Vessel Strike Database.	Refer to Section 7 and 8.
		Anthropogenic noise and acoustic disturbance	■ All seismic surveys must be undertaken consistent with Part A of the EPBC Act Policy	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
			Statement 2.1 – Interaction between offshore seismic exploration and whales.	
		Habitat degradation including pollution (increasing port expansion and coastal development)	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Blue whale	Blue Whale Conservation Management Plan 2015 - 2025 (2015)	Noise interference	■ Anthropogenic noise in biologically important areas will be managed such that any blue whale continues to utilise the area without injury, and is not displaced from a foraging area. ■ EPBC Act Policy Statement 2.1—Interaction between offshore seismic exploration and whales is applied to all seismic surveys.	Refer to Section 7 and 8.
		Habitat modification	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
		Vessel disturbance	■ Ensure all vessel strike incidents are reported in the National Ship Strike Database. ■ Ensure the risk of vessel strikes on blue whales is considered when assessing actions that increase vessel traffic in areas where blue whales occur and, if required, implement appropriate mitigation measures.	Refer to Section 7 and 8.
Fin whale	Approved Conservation Advice for *Balaenoptera physalus* (fin whale) (2015)	Pollution (persistent toxic pollutants)	■ Implement measures to manage and reduce, where possible waste generation.	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
			■ Reduce and, where possible, eliminate any adverse impacts of marine debris.	
		Vessel strike	■ Ensure all vessel strike incidents are reported in the National Vessel Strike Database.	Refer to Section 7 and 8.
		Anthropogenic noise and acoustic disturbance	■ All seismic surveys must be undertaken consistent with Part A of the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales.	Refer to Section 7 and 8.
		Habitat degradation	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Humpback whale	Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (2015)	Noise Interference	■ For actions involving acoustic impacts on humpback whale calving, resting, feeding areas, or confined migratory pathways site specific acoustic modelling should be undertaken (including cumulative noise impacts). ■ All seismic surveys must be undertaken consistent with Part A of the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales. ■ Should a survey be undertaken in or near a calving, resting, foraging area, or a confined migratory pathway then Part B (Additional Management Procedures) must also be applied.	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
		Habitat degradation	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
		Entanglement (marine debris)	■ Reduce and, where possible, eliminate any adverse impacts of marine debris.	Refer to Section 7 and 8.
		Vessel Strike	■ Ensure the risk of vessel strike on humpback whales is considered and, if required appropriate mitigation measures are implemented to reduce the risk of vessel strike. ■ All collisions with whales in Commonwealth waters are reported via the National Ship Strike Database.	Refer to Section 7 and 8.
Marine Reptiles				
Loggerhead turtle, Green turtle, Hawksbill turtle, Flatback turtle and Leatherback turtle	Recovery plan for marine turtles in Australia 2017 – 2027 (2017)	Deteriorating water quality	■ Implement measures to manage and reduce, where possible waste generation.	Refer to Section 7 and 8.
		Marine debris	■ Reduce and, where possible, eliminate any adverse impacts of marine debris on marine turtles.	Refer to Section 7 and 8.
		Light pollution	■ Manage artificial light from onshore and offshore sources to ensure biologically important behaviours of nesting adults and emerging/dispersing hatchlings can continue.	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
		Vessel disturbance	■ Manage activities to ensure marine turtles are not displaced from identified Habitat Critical to the survival and biological important areas.	Refer to Section 7 and 8.
		Noise interference	■ A precautionary approach should be applied to seismic work, such that surveys planned to occur inside important internesting habitat should be scheduled outside the nesting season. ■ Seismic surveys must undertake soft starts during surveys irrespective of location and time of year to protect marine turtles.	Refer to Section 7 and 8.
Short-nosed Seasnake	Commonwealth Conservation Advice on *Aipysurus apraefrontalis* (short-nosed seasnake) (2011)	Degradation of reef habitat	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Marine Birds				
Red Knot	Approved Conservation Advice for *Calidris canutus* (Red knot) (2016)	Pollution/contamination impacts	■ Implement measures to manage and reduce, where possible, waste generation.	Refer to Section 7 and 8.
		Disturbance	■ Manage disturbance at important sites when red knots are present.	Refer to Section 7 and 8.
		Habitat loss and degradation	■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Curlew Sandpiper	Approved Conservation Advice for *Calidris ferruginea* (Curlew Sandpiper) (2015)	Habitat loss and degradation from pollution	■ Manage disturbance at important sites when curlew sandpipers are present.	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
			■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	
Eastern Curlew	Approved Conservation Advice for *Numenius madagascariensis* (Eastern Curlew) (2015)	Habitat loss and degradation from pollution	■ Manage disturbance at important sites when eastern curlews are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Abbott's Booby	Conservation advice *Papasula abbotti* Abbott's booby (northern Siberian) (2015)	Modification and destruction of breeding habitat	■ Manage disturbance at important sites when Abbott's booby are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Australian Fairy Tern	Approved Conservation Advice for *Sternula nereis* (Australian fairy tern) (2011)	Habitat loss, disturbance and modification from pollution	■ Manage disturbance at important sites when Australian fairy terns are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Soft-plumaged Petrel	Conservation advice *Pterodroma Mollis*	Habitat loss, disturbance and modification from pollution	■ Manage disturbance at important sites when Soft-plumaged petrel are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
Bar-tailed Godwit (Western Alaskan)	Approved Conservation Advice for *Limosa lapponica baueri* (bar-tailed godwit western Alaskan) (2016)	Habitat loss and degradation from pollution	■ Manage disturbance at important sites when bar-tailed godwits are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Bar-tailed Godwit (Northern Siberian)	Approved Conservation Advice for *Limosa lapponica menzbieri* (bar-tailed godwit northern Siberian) (2016)	Habitat loss and degradation from pollution	■ Manage disturbance at important sites when northern Siberian bar-tailed godwits are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Australian Painted Snipe	Approved Conservation Advice for *Rostratula australis* (Australian painted snipe) (2013)	Habitat loss, disturbance and modification	■ Manage disturbance at important sites when Australian painted snipes are present. ■ Implement measures to reduce adverse impacts of habitat degradation and/or modification.	Refer to Section 7 and 8.
Migratory Seabirds	Draft Wildlife Conservation Plan for Seabirds (DoEE 2019)	Habitat modification and anthropogenic disturbance	■ Manage anthropogenic disturbance to seabird breeding and roosting areas.	Refer to Section 7 and 8.
		Invasive species	■ Ensure seabirds are protected from the adverse effects of invasive species.	
Other				
Other threatened and migratory species	All other threatened and migratory species identified by the EPBC Protected Matters Search as potentially occurring within the Operational Area and EMBA, have	N/A	N/A	N/A

Common Name	Recovery Plan / Conservation Advice	Threats identified as relevant to the Activity	Requirements relevant to the Capreolus-2 3D MSS	Addressed in EP Section
	no conservation advices and/or recovery plans.			

4.5.5.2 Summary of Relevant 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.c). BIAs have no legal status, however they provide information to help inform regulatory and management decisions.

Table 4-8 identifies the BIAs associated with threatened and/or migratory species potentially occurring within the Operational Area and EMBA. Further information on these BIAs is provided in the individual species descriptions below where relevant.

Table 4-8 Threatened and Migratory Species' BIAs within the Operational Area and EMBA

Class	Species	BIA	Location	Distance from the Operational Area (km)
Sharks and Rays	Whale Shark	Foraging	NWS 200 m isobath	N/A - Overlaps
Mammals	Humpback Whale	Migration	North-west WA coast	N/A - Overlaps
	Pygmy Blue Whale	Distribution	South and west Australia waters	N/A - Overlaps
		Migration	WA waters	N/A - Overlaps
Reptiles	Flatback Turtle	Internesting	North Turtle Island	N/A - Overlaps
			Cape Thouin / Mundabullangana / Cowrie Beach	N/A - Overlaps
			Dampier Archipelago	N/A - Overlaps
			Legendre Island and Huay Island	N/A - Overlaps
			Delambre Island	N/A - Overlaps
			West of Cape Lambert	N/A - Overlaps
			Dixon Island	N/A - Overlaps
			Port Hedland, Paradise Beach, Cemetery Beach, Pretty Pool	N/A - Overlaps

Class	Species	BIA	Location	Distance from the Operational Area (km)
			Intercourse Island	0.5 km
			Eighty Mile Beach	45 km
			Montebello Island	100 km
			Thevernard Island	134 km
			Lowendal Island Group	110 km
		Nesting	North Turtle Island	62 km
			Montebello Islands	115 km
		Foraging	De Grey River	27 km
			Montebello Islands	115 km
		Mating	Montebello Islands	115 km
		Habitat Critical[2]	Eighty Mile Beach	N/A - Overlaps
	Green Turtle	Internesting	Dampier Archipelago	29 km
			Legendre Island, Huay Island	30 km
			Delambre Island	34 km
			Montebello Islands	100 km
			Middle Is. West Coast Barrow Island West Coast and North Coast	118 km
		Nesting	Montebello Islands	109 km
		Mating	Montebello Islands	109 km
		Foraging	De Grey River	27 km
			North Turtle Island	62 km

[2] Habitat critical to the survival of a marine turtle species (DoEE 2017).

Class	Species	BIA	Location	Distance from the Operational Area (km)
			Montebello Islands	109 km
		Aggregation	Montebello Islands	126 km
		Habitat Critical[2]	Karratha	30 km
	Loggerhead Turtle	Internesting	Cohen Island	26 km
			Reosemary Island	36 km
			Montebello Islands	100 km
			Lowenthal Island	110 km
		Nesting	Montebello Islands	118 km
		Foraging	De Grey River	27 km
	Hawksbill Turtle	Internesting	Delambre Island	26 km
			Dampier Archipelago	29 km
			Reosemary Island	36 km
			Montebello Islands, Trimoulle and NW Islands	92 km
			Ah chong and South East Island	95 km
			Varanus Island	112 km
			Barrow Island	118 km
		Foraging	De Grey River	27 km
			Montebello Islands	115 km
		Nesting	Montebello Islands	115 km
		Mating	Montebello Islands	115 km
Marine Birds	Lesser Frigatebird	Breeding	Bedout Island	N/A - Overlaps

Class	Species	BIA	Location	Distance from the Operational Area (km)
	White-tailed Tropicbird	Breeding	Rowley Shoals	N/A - Overlaps
	Little Tern	Resting	Rowley Shoals	70 km
		Breeding	Pilbara coast (multiple sites)	N/A - Overlaps
		Foraging	Pilbara coast	118 km
	Brown Booby	Breeding	Pilbara coast (multiple sites)	N/A - Overlaps
	Fairy Tern	Breeding	Pilbara coast	55 km
	Wedge-tailed Shearwater	Breeding	Pilbara coast	N/A - Overlaps
	Roseate Tern	Breeding	Pilbara coast (multiple sites)	N/A - Overlaps
		Foraging	Pilbara coast	34 km
	Lesser Crested Tern	Breeding	Pilbara coast (multiple sites)	N/A - Overlaps

4.5.6 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 2008a).

One threatened, five threatened and migratory, and five migratory shark and ray species were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the EMBA (Appendix C).

A description of the identified threatened and/or migratory sharks, sawfish and rays is provided in Table 4-9 including their distribution, migratory movements, preferred habitat and likely presence within the Operational Area and EMBA.

One BIA for the shark and ray species has been identified within the Operational Area, as follows:

- The whale shark foraging BIA extends northwards from Ningaloo along the 200 m isobath. The Operational Area overlaps with the BIA (Figure 4.11).

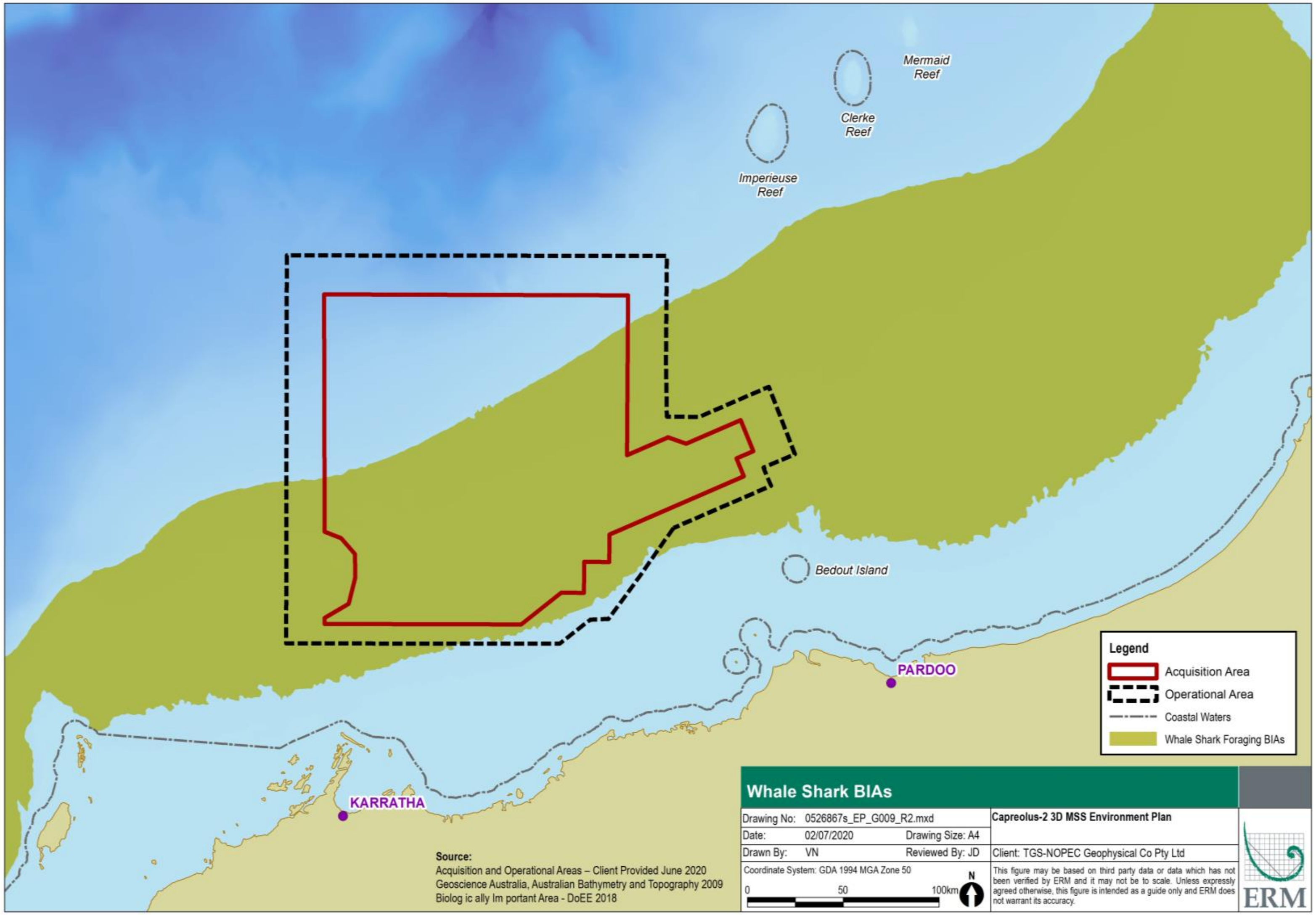


Figure 4.11 Whale Shark BIA

Table 4-9 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, NTand QLD, 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 1,480 km away) between December and January and at Ningaloo Reef (approximately 520 km away) between March and July to feed on krill and baitfish associated with coral spawning events (DoEE 2019a). 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 4.11), which extends northwards from Ningaloo along the 200 m isobath. The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in Spring (September to November).	Whale sharks are regarded as highly migratory - although these 'migration patterns' are poorly understood. The whale shark migration between Christmas Island and Ningaloo Reef is expected to occur between January and March (Colman 1997; Wilson et al. 2006; DoEE 2019a). The northern migration route is considered to follow the northern WA coastline along the 200 m isobath consistent with the extent of the whale shark foraging BIA.	Given the recorded migratory routes in the region, the cosmopolitan distribution of the species and overlap with the foraging BIA, whale sharks may be encountered in the Operational Area and EMBA in low numbers, particularly during seasonal migrations.
Great White Shark	The species has been recorded from central Queensland around the south coast to north-west WA, with movements occurring between the mainland coast and the 100 m depth contour (DoEE 2019a). 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 2019a).	Great white sharks area known to undertake migrations along the WA coast, with some individuals travelling as far north as North West Cape during spring, before returning south for summer (DoEE 2019a).	Given the species known distribution and habitat, great while sharks may occur within the Operational Area and EMBA.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
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 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.	There is insufficient data to prescribe distribution behaviours, migration times and routes and seasonal patterns.	Given the species distribution in deep offshore waters, the presence of the species within the Operational Area and 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 extended from Indo-Australian Archipelago to Japan and South Korea. The species 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 shallow waters of the 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 2019a). This species is often resident in or along productive near-shore environments, such as island groups, atolls or continental coastlines. This species tends to inhabit warm tropical or sub-tropical waters. 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 (Marshall et al. 2018).	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 shallow waters of the 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, giant manta rays may occur within the Operational Area. The species may be present in higher numbers around Rowley Shoals and in shallow waters of the EMBA.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Grey Nurse Shark	The grey nurse shark has a broad inshore distribution, primarily in sub-tropical to cool temperate waters. The species is predominantly found in the south-west coastal waters of WA and has been recorded as far as the North West Shelf. Grey nurse sharks are observed hovering motionless just above the seabed, in or near deep sandy bottomed gutters or rocky caves and in the vicinity of inshore reefs and islands. The species has been recorded at varying depths but is generally found between 15 – 40 m (DoEE 2019a).	The species generally occurs as solitary individuals or in small schools. Research suggests that the species may be migratory and not confined to particular localities or habitats (DoEE 2019a).	Given the species distribution further south and tendency for shallower waters, numbers in the Operational Area and EMBA are expected to be low.
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). The closest foraging and breeding BIA is located 110 km from the Operational Area.	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 shallow waters of 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, but are rarely encountered. Longfin mako usually occur to depths of 760 m, but has been reported to 1,752 m (Rigby et al. 2019).In Australian waters, the species is found from Geraldton, in WA, and north to Port Stephens in New South Wales (Last and Stevens 2009).	There is insufficient data to prescribe distribution behaviours, migration times and routes and seasonal patterns.	Given the species wide-distribution and preference for deeper waters, the presence of the species within the Operational Area is expected to be low. The species may be present in the deeper waters of the Operational Area and EMBA.
Dwarf Sawfish	The dwarf sawfish is found in Australian coastal waters extending north from Cairns around the Cape York Peninsula in QLD to the Pilbara coast (DoEE 2019a).	Dwarf sawfish may move into marine waters after the wet season and during	Given the species distribution and nearby pupping, nursing and foraging BIAs, the presence of the

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	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 the species, with immature juveniles remaining in these areas up until three years of age. 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 110 km from the Operational Area.	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.	species in the EMBA is expected to be low.
Sharks And Rays Potentially Occurring within the 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, WA, to the western side of Cape York Peninsula, QLD (DoEE 2019a). It is a marine/estuarine species that spends its first three–four years in freshwater (DoEE 2019a). 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. The Fitzroy River has been identified as a likely important nursery site for the largetooth sawfish (located 525 km from the Operational Area and outside the EMBA) (Whitty et al. 2008). The freshwater sawfish pupping and foraging BIAs are located at Eighty Mile Beach and Roebuck Bay. Pupping is known to occur from the months of January to May at Eighty Mile Beach.	A study on the movement patterns of other sawfish species, *P. clavata* 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 species may be present in the shallow waters of the EMBA.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	The closest foraging BIA is located 110 km from the Operational Area		

4.5.7 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 sixteen whale species and at least eleven species of dolphin (DEWHA 2008a).

Five threatened and migratory, and seven 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 whales and humpback whales, 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 high dugong populations, due to the open ocean location and relatively deep water depths.

A description of the identified threatened and/or migratory marine mammals is provided in Table 4-10 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 EMBA, as follows:

- The humpback whale migration, breeding and calving BIAs extend along the length of the coast of Western Australia, to its northernmost extent offshore of the Kimberley region. The migration BIA overlaps the southern portion of the Operational Area. The breeding, nursing and calving BIA is located approximately 415 km east of the Operational Area. Refer to Figure 4.12.
- The pygmy blue whale migration BIA passes along the continental shelf edge at depths between 500 m and 1,000 m. The Operational Area overlaps with both the distribution and migration BIAs. Refer to Figure 4.12.

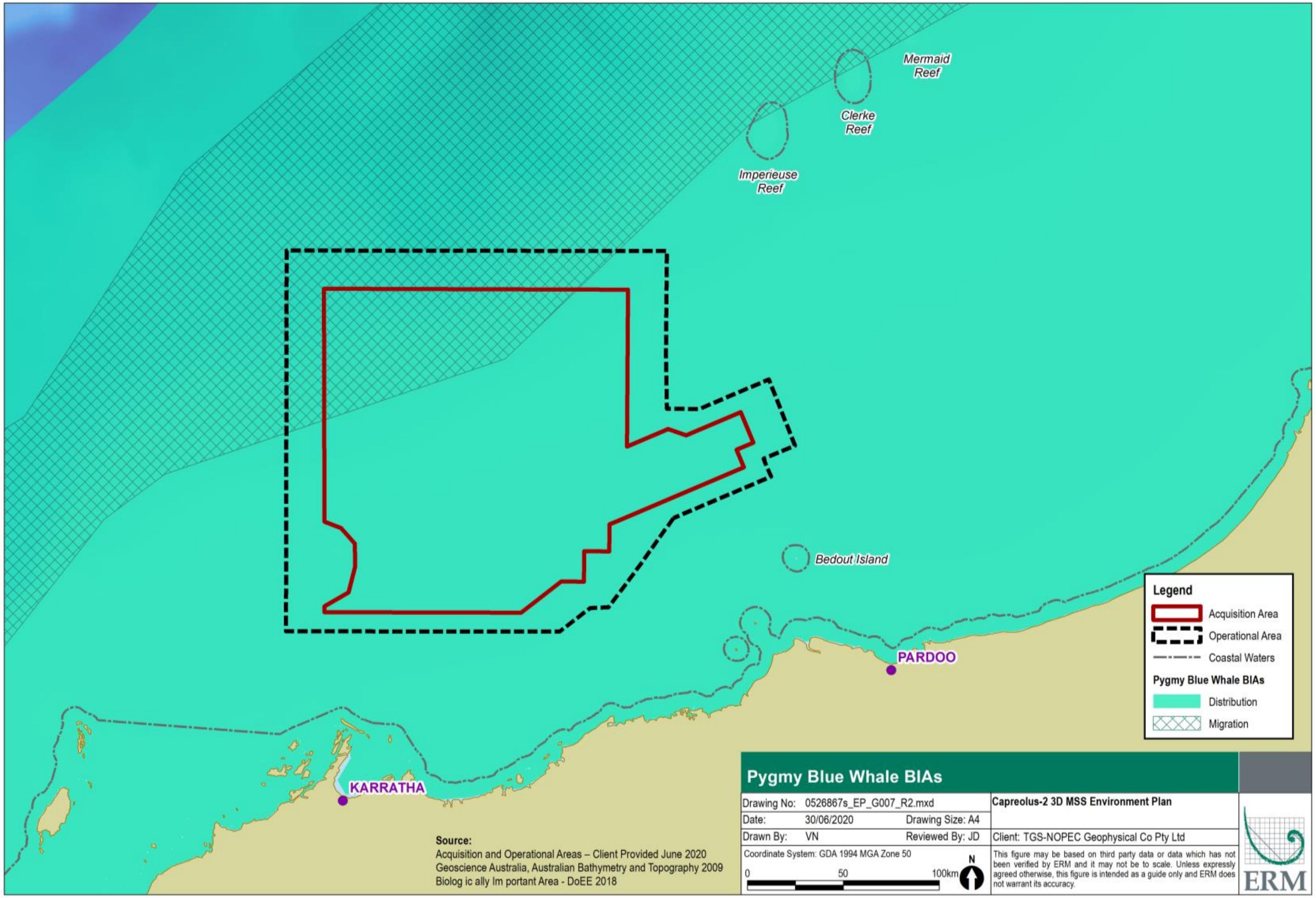


Figure 4.12 Pygmy Blue Whale BIAs

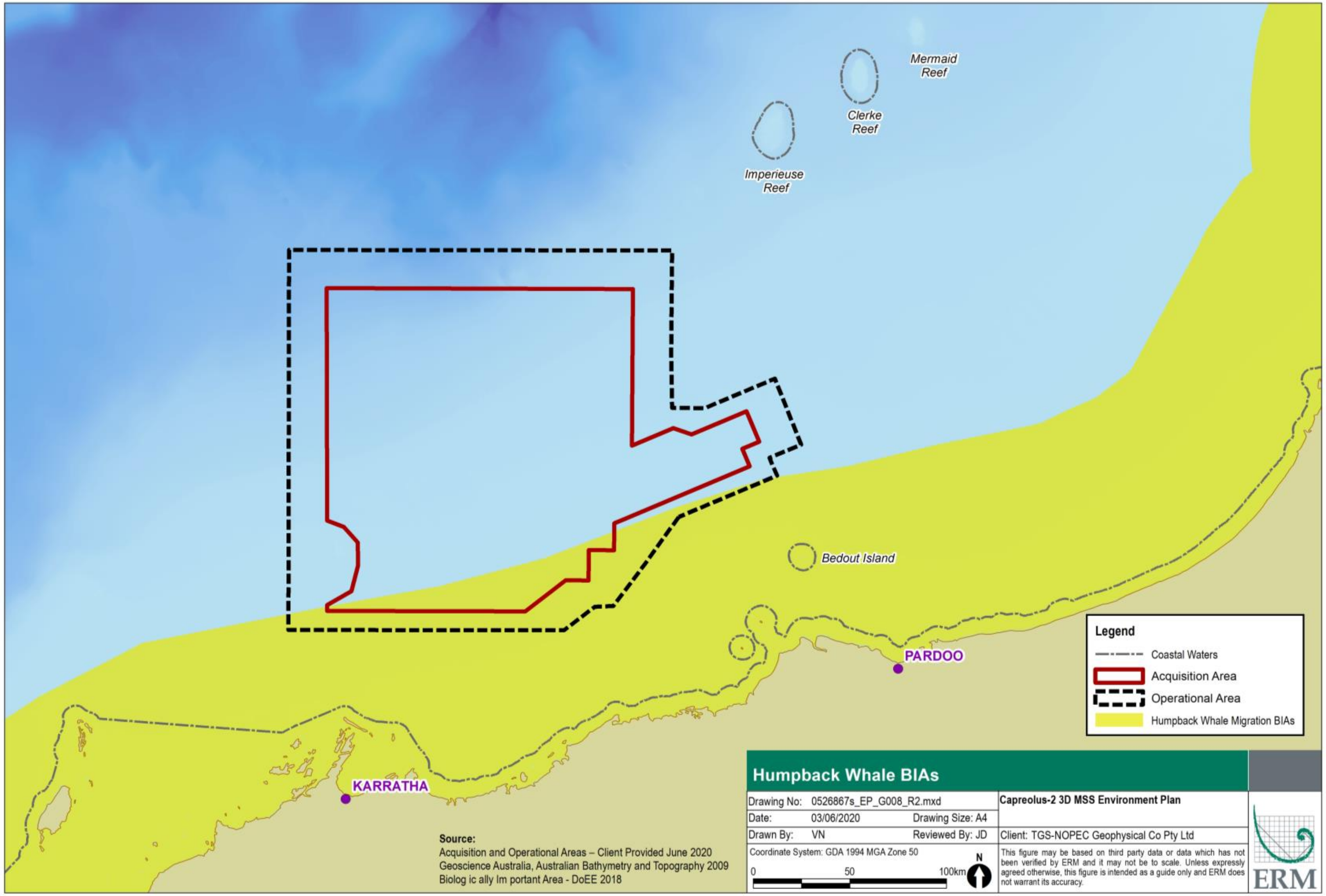


Figure 4.13 Humpback Whale BIA

Table 4-10 Threatened and Migratory Marine 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 60^{0}S, while pygmy blue whales are usually found north of 55^{0}S (DoEE 2019a). 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 and migration BIAs (refer to Figure 4.12. Satellite tacking of pygmy blue whales undergoing their northern migration indicate 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 & Jenner 2010; McCauley & Duncan 2011; Double et al. 2012; Double et al. 2014).	The Operational Area is located within the pygmy blue whale distribution and migration BIA. However, due to the absence of known foraging, resting and calving habitat, presence within the Operational Area and EMBA, the presence of the species is likely to be infrequent and consist of transitory individuals. Individuals may be present in greater abundance in the northern region of the Operational Area during seasonal migrations. Acquisition will not occur within the migration BIA during the northern (April – August) and southern (October – December) migration periods.
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 2019a). There are two genetically distinct populations of humpback whales in Australia (i.e. west coast and east coast) (DoEE 2019a). 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 2019a); estimates conducted suggest that in 2008 the population	Humpback whales undergo an annual migration from the summer feeding grounds in Antarctica to the breeding and calving grounds in Camden Sound (approximately 730 km from the Operational Area) occurs between June and October (DoEE 2019a). During migration, individuals travel alone or in temporary aggregations of generally non-related individuals. The northern migration across the North West Shelf towards resting and calving grounds in the Kimberley region may occur from as early as June through to August and the southward migration from September to October, though actual timing of annual migration may vary by	The Operational Area overlaps with the migration BIA for the species. Given, seismic acquisition will not occur within the migration BIA during the peak migration period (July to October), the presence of the species in the remainder of the Operational Area is likely to be infrequent and consist of transitory individuals. Individuals are likely to be present in greater abundance in the southern region of the Operational Area and EMBA during seasonal migrations.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	migrating up the WA coast was at 21,750 individuals (Hedley et al. 2011). Humpback whale songs change in composition among years, but most energy is consistently between 200 – 500 Hz (Salgado Kent et al. 2012). The Operational Area overlaps with the migration BIA for the species (refer to Figure 4.13). The humpback whale migration corridor is not an identified aggregation area or critical habitat, whales are in transit, and are migrating from their southern polar ‘summer’ feeding grounds to their northern tropical ‘winter’ calving / breeding grounds. During the northbound migration, the data presented in Jenner et al. (2001) indicates the whales appear to remain within the 200 m isobath near the Montebello Island before moving closer to shore as they head further north to the calving grounds in the Kimberley. A recent study as part of the Kimberley Marine Research Project (Thums et al. 2018) analysed three decades of satellite, aerial, boat-based sightings and determined that abundance was greatest in nearshore waters in water depths of approximately 35 m (Thums et al. 2018). Of all 42 humpback whale sightings during the Santos Keraudren 3D MSS (which partially overlaps with the Capreolus-2 3D MSS) between May and July 2019, 38 were made at longitudes greater than 19˚S and water depths less than 90 m. The other four sightings were made in water depths of approximately 150 m or greater (Santos 2020). These sightings are broadly consistent with the data presented in Jenner et al. (2001) and Thums et al. (2018), where the majority of the migrating humpback population pass through these waters within approximately 100 km of the coast, with relatively small number of animals passing further offshore.	as much as 3 weeks from year to year due to food availability in the Antarctic (Jenner et al. 2001; Thums et al. 2018). Peak northward migration across the North West Shelf is identified from late July to early August, and peak southward migration from late August to early September. Data collected between 1995 and 1997 by the Centre for Whale Research indicates that the period for peak northern migration into the calving grounds in the Kimberley is mid to late July and the peak for southern migration from the Kimberley is in the first half of September. Marine fauna sightings data collected during the Santos Keraudren 3D MSS (which partially overlaps with the Capreolus-2 3D MSS) between May and July 2019 included 42 confirmed sightings of humpback whales. The first sighting ooccurred on 8 June 2019. Occasional sightings of humpback whales were subsequently made every few days throughout June, becoming more frequent in late June and through to mid-July (Santos 2020).	
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 2019a). 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)	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	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 480 km away), the presence of the species within the Operational Area

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	and breeds and calves over several months during winter (Best et al. 1984; Kato 2002). The nearest known area of aggregation is Ningaloo Reef (740 km from the Operational Area) (DoEE 2019a). Aerial surveys carried out in 2009, between mainland Australia and Scott Reef (approximately 570 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.	migrate seasonal 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.	and EMBA is likely to be infrequent and limited to transitory individuals.
Fin Whale	Fin whales occur from polar to tropical waters, but rarely in inshore waters (DoEE 2019a). Fin whales are widely distributed in both hemispheres between latitudes 20–75° S (Mackintosh 1965). This species is 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 2019a). 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 2019a).	Given the wide ranging nature of this species, lack of nearby important habitat and a preference for deeper offshore waters, the presence of the species within the Operational Area and EMBA is likely to be infrequent and limited to transitory individuals.
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	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 and lack of nearby important habitat, the presence of the species within the Operational Area and EMBA is likely to be infrequent and limited to transitory individuals.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	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).		
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 SA and Victoria (DoEE 2019a). 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 2019a).	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 EMBA is also likely to be infrequent and limited to transitory individuals
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 2019a). 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 2019a). 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	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 EMBA is likely to be infrequent and limited to transitory individuals

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	Shelf, suggesting that they occasionally occur in the deep, oceanic waters of the region (RPS 2010).		
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 2019a). 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 340 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 shallow waters of the Operational Area and EMBA.
Dugong	Dugongs are also known to occur along the coast throughout the Kimberley to the WA–NT border; however, population estimates for these areas are not available (DSEWPaC 2012c). Dugongs inhabit protected shallow coastal areas, such as wide shallow bays and mangrove channels. 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 2012c). 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 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 diffusely seasonal breeders and the seasonality of breeding is more marked in the sub-tropics (mostly spring, early summer calving) than in the tropics.	Due to the species' foraging BIA being located approximately 480 km from the Operational Area and preference for shallow waters, presence of the species within the Operational Area and EMBA is likely to limited to transitory individuals.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	The closest foraging BIA is located south of the Operational Area, along the Dampier Peninsula (approximately 480 km from the Operational Area).		
Indo-Pacific Humpback Dolphin	Indo-Pacific humpback dolphins are found in tropical/subtropical waters of the Sahul Shelf from northern Australia to the southern waters of the island of New Guinea. Along the Australian coast, humpback dolphins are most likely found in relatively shallow and protected coastal habitats such as inlets, estuaries, major tidal rivers, shallow bays, inshore reefs and coastal archipelagos rather than in open stretches of coastline. Few animals have been observed in water up to 30 to 50 m deep. Similarly, humpback dolphins have been observed feeding in a wide range of inshore-estuarine coastal habitats including rivers and creeks, exposed banks, shallow flats, rock and coral reefs as well as over submerged reefs in waters at least up to 40m deep.	Humpback dolphins do not appear to undergo large-scale seasonal migrations, although seasonal shifts in abundance have been observed. They are usually found within 20 km of the coastline (DoEE 2019a).	Due to the distribution of the species (within 20km of the coastline), the presence of the species within the Operational Area and EMBA is likely to be limited.
Mammals Potentially Occurring Within the EMBA			
Antarctic Minke Whale	The Antarctic minke whale has been recorded off all States of Australia but not in the NT. The distribution up the west coast of Australia is currently unknown. The whales appear to occupy primarily offshore and pelagic habitats within cold temperate to Antarctic waters between 21 and 65 degrees south (DoEE 2019a).	The species undergoes an extensive migration between the summer Antarctic feeding grounds and winter sub-tropical to tropical breeding grounds (DoEE 2019a).	Given the species distribution and preference for subtropical waters, it is unlikely that the species will occur within the EMBA.
Southern Right Whale	The southern right whale is seasonally present along the Australian coast between late April and early November. The species is principally found around the southern coastline off southern WA and far west SA. Based on sightings, most feeding areas are thought to be in deeper offshore waters ranging from sub-Antarctic areas to locations south of 60 degrees south (DoEE 2019a).	In Australia, the southern right whale migrates between higher latitudes and mid latitudes. They are regularly present on the Australian coast from about mid-May to mid-November (DoEE 2019a).	Given the preferences for cooler waters, it is unlikely that the species will occur within the EMBA.

4.5.8 Marine Reptiles

4.5.8.1 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.

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

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

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

The Operational Area overlaps with an internesting BIA for flatback turtles and a habitat critical to the survival of flatback turtles. Refer to Figure 4.14 and Figure 4.15. 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 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 4-11.

There are several BIAs for turtle species in the region, including along the coastline and offshore islands adjacent to the Operational Area (refer to Figure 4.14 and Figure 4.15). These include:

- multiple internesting BIAs and an habitat critical to the survival of flatback turtles overlapping the southern portion of the Operational Area. Additionally, there is a foraging BIA approximately 27 km south of the Operational Area.
- multiple internesting BIAs for green turtles located along the Pilbara cost. A habitat critical to the survival of green turtles is located approximately 30 km south-west of the Operational Area. Additionally, there is a foraging BIA located approximately 27 km south of the Operational Area.
- multiple internesting BIAs for loggerhead turtles located along the Pilbara cost. Additionally, there is a foraging BIA located approximately 27 km south of the Operational Area.
- multiple internesting BIAs for hawksbill turtles located along the Pilbara coast. Additionally, there is a foraging BIA located approximately 27 km south of the Operational Area.

4.5.8.2 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.

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 seasnake) 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 4-11. Due to water depths and the existing habitat within the Operational Area, sea snakes are expected to occur in low numbers.

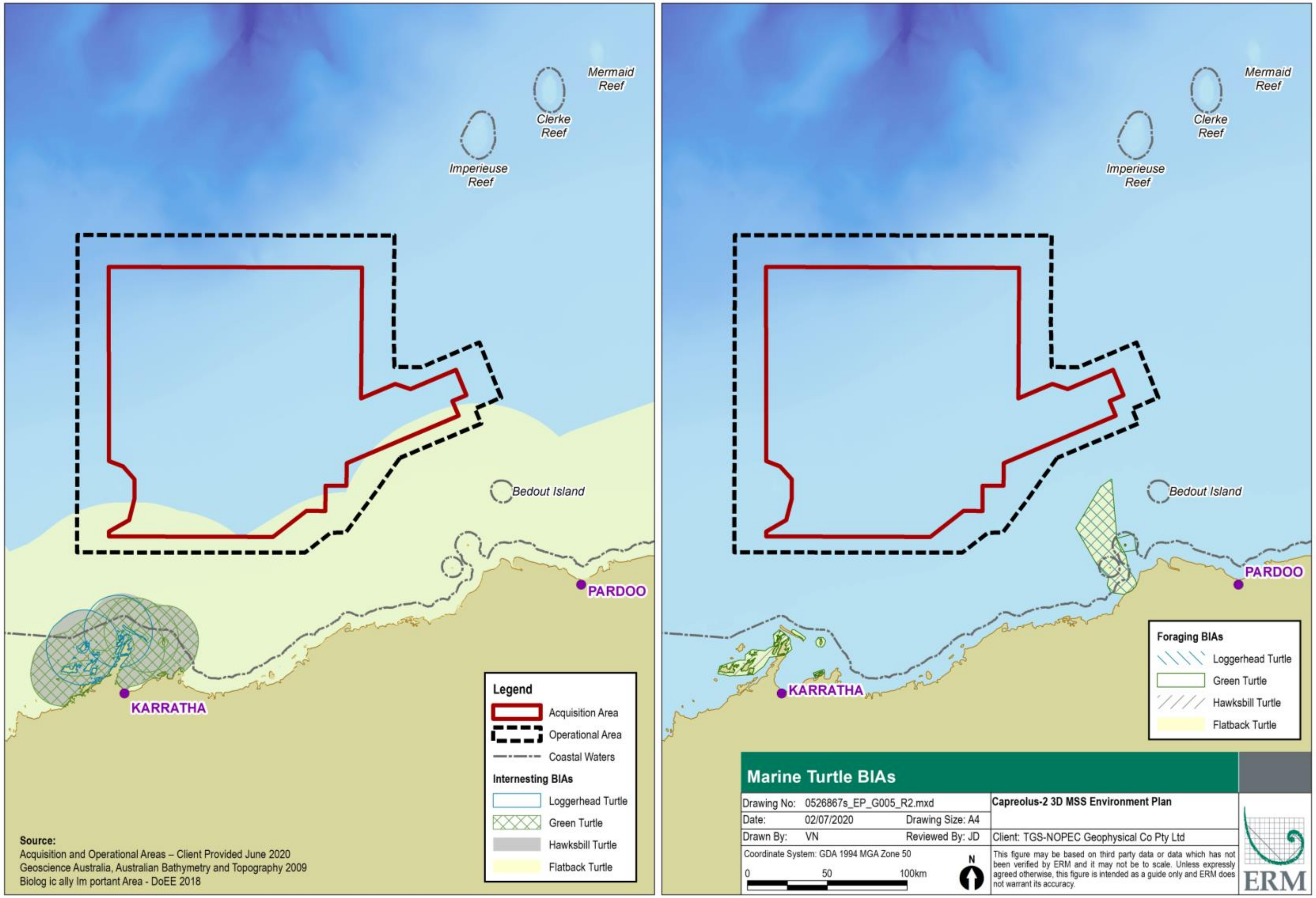


Figure 4.14 Marine Turtle BIAs

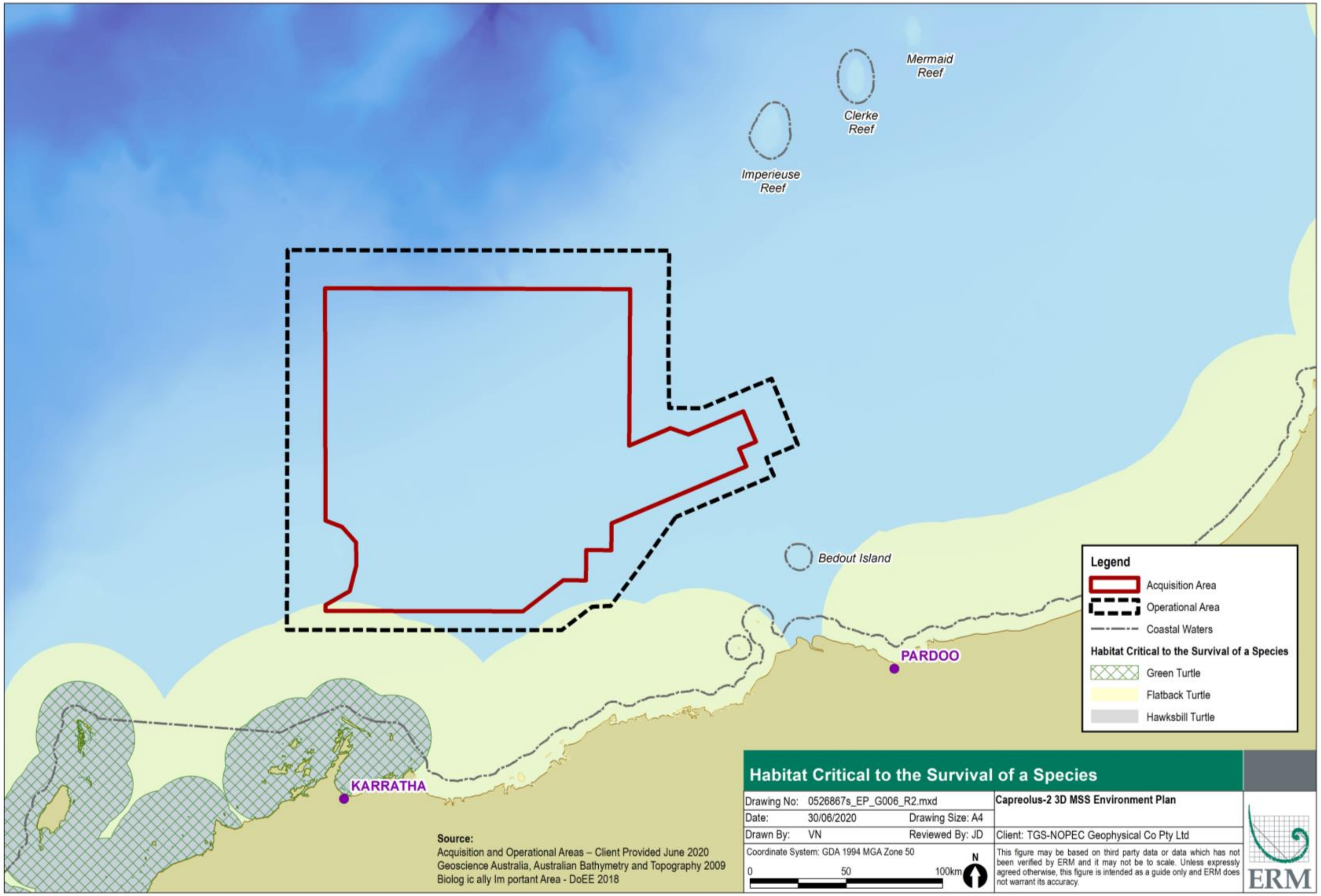


Figure 4.15 Habitat Critical to the Survival of Marine Turtles

Table 4-11 Threatened and Migratory Marine Reptiles Potentially Occurring Within the Operational Area and EMBA

Common Name	Habitat and Distribution	Seasonality	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 2019a). The species are known to forage nearshore, in water depths up to approximately 50-60 m (DoEE 2019a). In WA, the species nests on the Muiron Islands (approximately 306 km away) and on the beaches of North West Cape (approximately 320 km away) (DoEE 2019a; Guinea 1995). The species are known to nest between October and February, with a peak in December (DoEE 2019a). 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 2019a). There is an internesting BIA and foraging BIA for the loggerhead turtle located approximately 26 km south-west and 27 km south of the Operational Area respectively.	Nesting occurs between October and February, with a peak in December (DoEE 2019a).	There are no known loggerhead turtle BIAs located within the Operational Area or EMBA. Loggerhead turtles may occur within the Operational Area in low numbers as transitory individuals. Foraging habitat occurs in the shallow waters of the 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 415 km away), Barrow Island (approximately 152 km away), the Montebello Islands (approximately 122 km away), North West Cape (approximately 320 km away) and the Muiron Islands (306 km away) (DoEE 2017). Smaller rookeries in the region include Ashmore Reef and Cartier Island (approximately 807 km away), Browse Island (approximately 700 km away), Cassini Island (approximately 900 km away), Maret Island (approximately 818 km away) and Sandy Islet at Scott Reef (approximately 570 km away) (DoEE 2017). The species primarily forages in shallow benthic habitats (<10 m) such as tropical tidal and subtidal coral and rocky reef habitat or	Nesting occurs between November and March (DoEE 2019a). 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 (DoEE 2017).	There are no known green turtle BIAs located within the Operational Area or EMBA. Green turtles may occur within the Operational Area is low numbers as transitory individuals. Foraging habitat potentially occurs in the shallow waters of the EMBA where individuals may occur in higher numbers.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	inshore seagrass beds, feeding on seagrass beds or algae mats (Hazel et al. 2009). The nearest internesting BIA is located off the coast of Karratha (approximately 29 km from the Operational Area). Females are known to stay within approximately 20 km from nesting beaches (DoEE 2017). The green turtle 'habitat critical to the survival of marine turtles' BIA is located at Dampier Archipelago, approximately 30 km to the south of the Operational Area. A foraging BIA is also located approximately 27 km south of the Operational Area (De Grey River).		
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 2019a).	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 2019a)	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, 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 2019a). A foraging BIA is also located approximately 1 km south of the Operational Area (De Grey River). The nearest internesting BIA is located at the Dampier Archipelago (i.e. islands to the west of the Burrup Peninsula), 29 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 (approximately 70 km south of the Operational Area, not within the EMBA).	Hawksbill turtles nest year round, with a peak between October and December (DEWHA 2008a). Internesting females are known to stay within approximately 20 km of nesting beaches. The north-east subpopulation breeds throughout the year with a peak nesting period during July to October (DSEWPaC 2012b), 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 2019a).	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 EMBA.

Common Name	Habitat and Distribution	Seasonality	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 (320 km from the Operational Area) to the Lacepede Islands (415 km from the Operational Area) and along the Kimberley coast and islands. There are significant rookeries on Barrow Island, Thevenard Island, Montebello Islands and Lowendal Islands (DoEE 2017). Nesting occurs between November and March Lacepede Islands peaking in January (DoEE 2017). The nearest internesting BIA overlaps with the Operational Area. A 'habitat critical to the survival of marine species' also overlaps with the Operational Area. Refer to Figure 4.14. Nesting occurs between October and March (DoEE 2019a). The 60 km internesting buffer for flatback turtles in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017) is based primarily on the movements of tagged internesting flatback turtles along the NWS reported by Whittock et al. (2014), which found that flatback turtles may demonstrate internesting displacement distances up to 62 km from nesting beaches. However, these movements were confined to longshore movements in nearshore coastal waters or travel between island rookeries and the adjacent mainland (Whittock et al., 2014). There is no evidence to date to indicate flatback turtles swim out into deep offshore waters during the internesting period. Flatback turtle hatchlings do not have an offshore pelagic phase. Instead, hatchlings grow to maturity in shallow coastal waters thought to be close to their natal beaches (DoEE 2017). Flatback turtle hatchlings do not undertake oceanic migrations like the juveniles of other turtle species do, but spend their juvenile life phase within continental shelf waters (Limpus 2009). Flatback turtle internesting habitat suitability in the North West Shelf was recently mapped in Whittock et al. 2016a. The habitat suitability map was developed using several environmental variables and satellite tracks of 47 nesting female flatback turtles from five rookeries (Barrow Island (n = 26), Thevenard Island (n = 6), Ashburton Island (n = 4), Mundabullangana (n = 2), and at Cemetery beach in Port Hedland (n = 9) tracked over 1,289 days. The study defined suitable interesting habitat as water 0–16 m deep and within 5–10 km of the	In the Kimberley and Pilbara regions of WA, from approximately the Lacepede Islands to Exmouth, there is a mid-summer peak nesting season. Nesting occurs between November and March on the NWS (DoEE 2019a).	Transient turtles are expected to be present within the Operational Area, given the Operational Area overlaps with an internesting BIA for the species. Flatback turtles migrating from nearby nesting beaches may occur in the Operational Area, in water depths of approximately 60 m. Foraging habitat potentially occurs in the EMBA, where individuals may occur in higher numbers.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	coastline. Unsuitable internesting flatback habitat was defined as waters > 25 m deep and > 27 km from the coastline. Although turtles remain close to nesting beaches during the internesting period, there is evidence that flatback turtles undertake long-distance migrations between breeding and feeding grounds. A survey carried out in the region between 2005 and 2012 identified the distances 73 female flatback turtles travelled to their foraging grounds; 11 remained within 100 km of their rookeries, four migrated an average of 400 km and 58 migrated between 1,000 and 1,500 km (Pendoley et al., 2014). More recent tagging studies further identified waters utilised by flatback turtles during post-nesting migration and foraging (Whittock et al. 2016a, 2016b; Thums et al. 2017). The studies found that turtles from the Pilbara region migrated north-east along the inner continental shelf, foraging in waters around Broome and James Price Point, Quondong Point, the Lacepede Islands, Lynher Bank, and at the Holothuria Banks in the Timor Sea (Whittock et al. 2016a, 2016b). Foraging areas were typically located in less than 50 m water depth (36.5 m mean depth) and 66 km from shore. Thums et al. (2017) studied flatback turtles during their post-nesting migration from the Lacepede Islands and during foraging. The study found that flatback turtles migrated along the coast in water depths of 63 ± 5 m, passing near Adele Island on the way to foraging grounds on the Sahul Shelf in the Timor Sea. Flatback turtles are known to feed on gastropod molluscs, squid, soft corals, hydroids and jellyfish (DoEE 2019a). A foraging BIA is located approximately 27 km south of the Operational Area (De Grey River).		
Short-nosed Seasnake	The short-nosed sea snake is endemic to WA and has been recorded from Exmouth Gulf to the reefs of the Sahul Shelf (DoEE 2017). 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. 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 2019a).	Seasnakes are long-lived and slow-growing with small broods and high juvenile mortality. Little is known of the age at which seasnakes reach sexual maturity. Seasnakes have a gestational period of 6-7 months, indicating that females are unlikely to breed every year.	Although the PMST identified the species within the Operational Area, it is expected to be restricted to shallow waters and may occur in the shallow coastal waters of the EMBA.

4.5.9 Marine Birds

Many seabird and migratory shorebird species (including those frequenting offshore islands) are known to occur in the NWMR. Migratory shorebirds 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.

Five threatened, four threatened and migratory, and 25 migratory bird species relevant to this EP were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the EMBA.

There are eight BIAs for marine bird species overlapping either the Operational Area or EMBA, as follows (refer to Figure 4.16):

- Lesser frigatebird breeding BIA overlaps with the southern portion of the Operational Area.
- White-tailed tropicbird breeding BIA overlaps the northern portion of the Operational Area.
- Little tern breeding BIA is located approximately 2 km south of the Operational Area. A resting BIA is also located approximately 70 km north-east of the Operational Area.
- Brown booby breeding BIA overlaps the southern portion of the Operational Area.
- Fairy tern breeding BIA is located approximately 55 km south-west of the Operational Area.
- Wedge-tailed shearwater breeding BIA overlaps the south-west portion of the Operational Area.
- Roseate tern breeding BIA overlaps the south-east corner of the Operational Area.
- Lesser crested Tern breeding BIA overlaps the southern portion of the Operational Area.

A description of the distribution, migration movements, and preferred habitat and life stages of the identified marine bird species is provided in Table 4-12 including commentary on their likely presence in the Operational Area and EMBA.

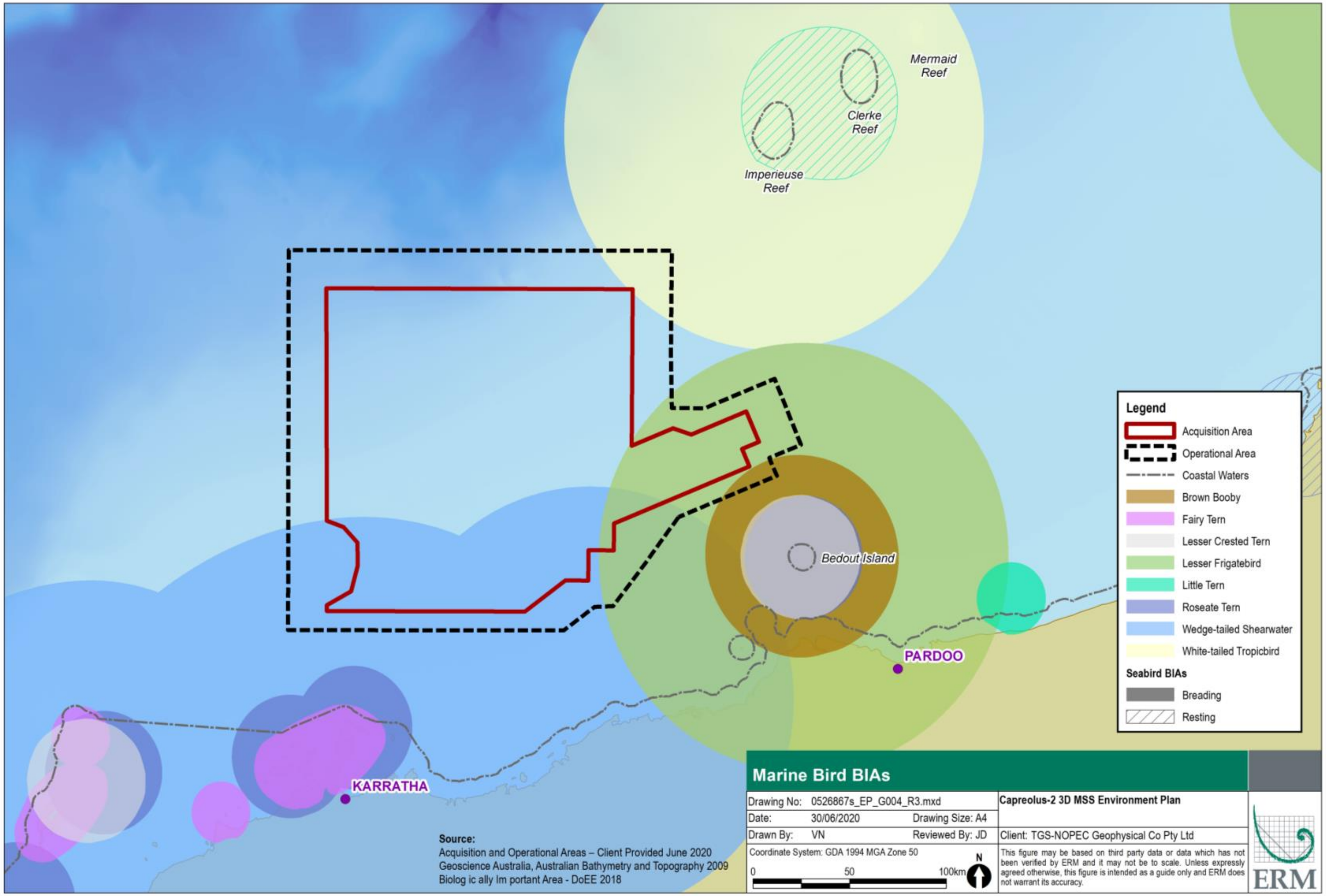


Figure 4.16 Marine Bird BIAs

Table 4-12 Threatened and Migratory Marine Birds Potentially Occurring Within the Operational Area and EMBA

Common Name	Habitat and Distribution	Seasonality	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, WA, through the Kimberley and along the NT, QLD, and NSW coasts and the islands of Torres Strait (DoEE 2019a). During the non-breeding season in Australia, the eastern curlew is most commonly associated with sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons, with large intertidal mudflats or sandflats, often with beds of seagrass (Zosteraceae) (DoEE 2019a).	This species does not breed in Australia, rather in the Northern Hemisphere summer, between early May and late June (DoEE 2019a). They start to departure 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 EMBA.
Red Knot	The red knot is common in all the main suitable habitats around the coast of Australia with large numbers regularly recorded in northern Australia. In Australasia, the red knot mainly inhabit intertidal mudflats, sandflats and sandy beaches of sheltered coasts or shallows pools on exposed wave-cut rock platforms or coral reefs. The red knot usually forages in soft substrate near the edge of water on intertidal mudflats or sandflats exposed by low tide. At high tide they may feed at nearby lakes, sewage ponds or floodwaters. They have also been observed foraging on thick algal mats in shallow water and in shallow pools on crests of coral reefs. The red knot is diurnal and nocturnal. In non-breeding areas, feeding activity is regulated by tide; they feed less just before and after high tide. The red knot is omnivorous and eats mostly worms, bivalves, gastropods, crustaceans and echinoderms (DoEE 2019a)..	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 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 & Higgins 1990).	The species travels large distances to feeding grounds during breeding season. It appears that some adults leave Christmas islands 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 Operation Area and EMBA in low numbers or isolated individuals/groups.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
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 WA is Roebuck Bay (approximately 360 km away from the Operational Area). Generally, the species forages in shallow water and on bare soft mud at the edges of wetlands. The species may 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 species 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 Operation Area in low numbers or isolated individuals/groups. Higher population density may be encountered in the nearshore waters of the EMBA.
Common Noddy	In Australia, the common noddy occurs mainly in the ocean off the QLD coast, but the species also occurs off the north-west and central WA coast. During the breeding season, the common noddy usually occurs on or near islands, on rocky islets and stacks with precipitous cliffs, or on shoals or cays of coral or sand. When not at the nest, individuals will remain close to the nest, foraging in the surrounding waters. During the non-breeding period, the species occurs in groups throughout the pelagic zone. Birds may nest in bushes, saltbush, or other low vegetation. The species 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. In WA, they are widely distributed from Cape Arid to Carnarvon, around coastal plains of the Pilbara Region to south-west and east Kimberly Division. In Australasia, the Sharp-tailed Sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emerged grass or low vegetation. The species forages on seeds, worms, molluscs, crustaceans and insects. Eighty Mile Beach (approximately 110 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 EMBA.
Pectoral Sandpiper	In Australasia, the pectoral sandpiper prefers shallow fresh to saline wetlands. The species is found at coastal lagoons, estuaries, bays,	The pectoral sandpiper breeds in the northern hemisphere during the boreal summer, before undertaking long	Given the wide distribution of this species and the migratory pattern, it is likely the

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	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.	distance migrations to feeding grounds in the southern hemisphere. The species occurs throughout mainland Australia between spring and autumn.	presence of this species will be encountered in low numbers or isolated individuals within the Operational Area. Higher population density may be encountered in the nearshore waters of the 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 2019a)	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	Lesser Frigatebird is usually seen in tropical or warmer waters off northern WA, NT, QLD and northern NSW. 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 & Higgins 1990). The species breeds in mangroves or bushes, and even on bare ground. It feeds mainly on fish (especially flying-fish) and squid, but also on seabird eggs and chicks, carrion and fish scraps (Birdlife 2019b). In Australia, egg laying occurs mostly at mid-year. A breeding BIA overlaps the Operational Area.	The species 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 WA to Lake Macquarie in NSW. Ospreys occur in littoral and coastal habitats and terrestrial wetlands of tropical and temperate Australia and offshore islands. Ospreys mainly feed on fish, especially mullet where available, and rarely take molluscs, crustaceans, insects, reptiles, birds and mammals.	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.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	The species usually forage diurnally, but have also been observed hunting prey at night.		
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 and foraging 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	The great frigatebird is found in tropical waters globally. It breeds on small, remote tropical and sub-tropical islands, in mangroves or bushes and occasionally on bare ground The species feeds on fish, squid and chicks of other bird species.	Breeding is known to occur between May to June and in August (DoEE 2019a).	Given the distribution of the species and nearby breeding habitat, this species may be present in the Operational Area and EMBA.
Curlew Sandpiper	The curlew sandpipers breeding areas are mainly restricted to the Arctic of northern Siberia (DoEE 2019a). This species does not breed in Australia. Within Australia, the species occur around the coasts while also being widespread inland, though in smaller numbers (DoEE 2019a). This species forages mainly on invertebrates, including worms, molluscs, crustaceans, and insects, as well as seeds. Outside Australia, they also forage on shrimp, crabs and small fish. It usually forages in water, near the shore or on bare wet mud at the edge of wetlands (DoEE 2019a).	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 2019a).	Given the distribution of the species and nearby breeding habitat, this species may be present in the Operational Area and EMBA.
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 2019a). The species nests on rugged rocky terrain such as cliffs and steep slopes, on larger islands, beaches, coral rubble and guano flats on cays (DoEE 2019a). The species is known to be resident and partly nomadic (i.e. birds dispersing widely between breeding seasons). Breeding occurs in and	The species typically leaves breeding islands when not breeding, in search of better foraging grounds (DoEE 2019a). Breeding times are unknown.	Given the distribution of the species and habitat, this species is likely to be present in the Operational Area and nearshore waters of the EMBA.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
	adjacent to region, including on Ashmore Reef, Adele Island, White Island, Lacepede Islands and Bedout Island. A breeding BIA overlaps the Operational Area.		
Australian Fairy Tern	Within Australia, the fairy tern occurs along the coasts of Victoria, South Australia (SA) and WA, occurring as far north as the Dampier Archipelago near Karratha. In Western Australia, there are less than 1600 pairs, but the population appears to be stable. The species nests on sheltered sandy beaches, spits and banks above the high tide line and below vegetation (DoEE 2019a) The closest breeding BIA is located off the shores of Karratha approximately 55 km southwest of the Operational Area.	The species breeds in October to February in colonies on coral shingle on continental islands or coral cays, on sandy beaches inside estuaries and on open sandy beaches (DoEE 2019a).	Given the distribution of the species and habitat, this species is likely to be present in the Operational Area and nearshore waters of the EMBA.
Roseate Tern	In WA, the subspecies is regularly recorded north from Mandurah to around Eighty Mile Beach, in the Pilbara Region. Around the Kimberley coastline, the subspecies occurs at scattered sites, north to the Bonaparte Archipelago and possibly further. The roseate tern occurs in coastal and marine areas in subtropical and tropical seas. The species inhabits rocky and sandy beaches, coral reefs, sand cays and offshore habitats. Breeding in WA occurs from Second Rock, near Penguin Island, to Lacepede Island (approximately 437 km from the Operational Area) (DoEE 2019a). A breeding BIA overlaps with the south eastern portion of the Operational Area.	Breeding in WA occurs in two quite distinct periods, within peak months for laying April to November. At the same sites, breeding occurs during both late spring-summer and late autumn-winter.	Given the distribution of the species and habitat, this species is likely to be present in the Operational Area and nearshore waters of the EMBA.
Wedge-tailed Shearwater	The wedge-tailed shearwater is a pelagic, marine bird known to occur in tropical and sub-tropical waters. In Australia, the bird breeds in the east and west coasts of Australia on off-shore islands (DoEE 2019a). The species breeds colonially and is rarely seen alone. The species usually excavates burrows on flat areas with dense grassy vegetation (DoEE 2019a). A breeding BIA overlaps the southwest portion of the Operational Area.	Breeding on the NWS of Australia occurs between late October to early November (DoEE 2019a).	Given the species preferred habitat, known distribution and breeding areas, it is likely that the species will be present in the Operational Area and EMBA.
Lesser Crested Tern (not a	The Lesser Crested Tern is found along estuaries and beaches in the northern half of Australia. Specific to Western Australia, the species is	This species is known to be sedentary in Australia.	The species not listed as migratory or threatened

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
threatened or migratory species)	found in the Kimberley, Pilbara, Gascoyne coasts and islands including Ashmore Reef. A breeding BIA overlaps the southern portion of the Operational Area.		pursuant to the EPBC Act. As a breeding BIA overlaps the Operational Area, the species may be present during the survey.
Marine Birds Potentially Occurring within 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 2019a). The little tern is a coastal seabird which usually forages in very shallow water, more often in brackish lagoons and saltmarsh creeks (DoEE 2019a). The little tern usually forages close to breeding colonies. 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 70 km from the Operational Area. In addition, a breeding BIA is located approximately 2 km south of the Operational Area.	Migration about this species is 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.
Bar-tailed Godwit (Western Alaskan)	The bar-tailed godwit has been recorded in the coastal areas of all Australian states. It is widespread in the Torres Strait and along the east	The bar-tailed godwit breeds in the Northern Hemisphere and moves south	Given the preferred coastal habitat, it is likely that the

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Bar-tailed Godwit (Northern Siberian) Bar-tailed Godwit	and south-east coasts of QLD, NSW and Victoria, including the offshore islands. The Bar-tailed Godwit and sub-species is found mainly in coastal habitats such as large intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays. The species typically roosts on sandy beaches, sandbars, spits and also in near-coastal saltmarsh. Roebuck Bay (375 km from the Operational Area) and Eighty Mile Beach (110 km from the Operational Area) are internationally important sites for the species, supporting over 50,000 individuals (DoEE 2019a).	for the Northern Hemisphere winter, including non-breeding areas from south-east Asia to Australia and New Zealand (DoEE 2019a).	species and sub-species will occur along the coastline of the EMBA.
Oriental Plover	The oriental plover is a non-breeding visitor to Australia, where the species occurs in both coastal and inland areas, mostly in northern Australia. The species usually forage among short grass or on hard stony bare ground, but also on mudflats or among beachcast seaweed on beaches. In Australia, the species typically inhabits coastal habitats such as estuarine mudflats and sandbanks, on sandy or rocky ocean beaches or nearby reefs, or in near-coastal grasslands (DoEE 2019a).	The species is a migratory species, breeding in the Northern Hemisphere and flying south for the boreal winter. Internationally important sites in Australia includes Roebuck Bay, approximately 375 km northeast of the Operational Area (DoEE, 2019a).	Given the preferred coastal habitat and movement pattern, it is possible that the species will occur within the EMBA along the coastline during summer months. It is unlikely that the species will be present in the Operational Area.
Oriental Pratincole	Within Australia, the species is widespread in northern areas, especially along the coasts of the Pilbara Region and the Kimberley Division in WA, the top end of the NT, and parts of the Gulf of Carpentaria. In non-breeding grounds in Australia, the species usually inhabits open plains, floodplains or short grassland (including farmland or airstrips), often with extensive bare areas. The species does not breed in Australia (DoEE, 2019a).	The species is partly migratory with most of the population breeding in the Northern Hemisphere and flying south for the boreal winter.	Given the preferred coastal habitat and movement pattern, it is possible that the species will occur within the EMBA along the coastline during summer months. It is unlikely that the species will be present in the Operational Area.
Crested Tern	The crested tern inhabits most of the Australian coastline. The species is found on exposed ocean beaches or sheltered embayments, such as bays, harbours, inlets, estuaries and lagoons. The species breeds in large groups on islands, cays and banks of sand, shell, coral or rock. Breeding takes place between October and December (DoEE 2019a).	Many populations remain sedentary in their breeding areas or disperse locally although some are migratory.	Given the species preferred habitat, known distribution and breeding areas, it is likely that the species will be present in the EMBA, along the coastline.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Common Greenshank	The species is found in a wide variety of inland wetlands as well as sheltered coastal habitats, typically with large mudflats and saltmarshes, mangroves and seagrass (DoEE 2019a). This species does not breed in Australia.	The species is a migratory species, breeding in the Palaearctic and flying south, along coasts to non-breeding areas for boreal winter.	Given the preferred habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the EMBA, along the coastline.
Australian Painted Snipe	The species has been recorded at wetlands in all states of Australia, however has been recorded less frequently at a smaller number of more scattered locations farther west in SA, NT and WA. The species generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and clay pans. The species may breed in response to wetland conditions rather than during a particular season (DoEE, 2019a)	Migratory patterns for this species are poorly known.	Given the preferred habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the EMBA, along the coastline.
Caspian Tern	The species is widespread in coastal regions, from the Great Australian Bight to the Dampier Peninsula. The species is mostly found in sheltered coastal embayment (harbours, lagoon, inlets, bays, estuaries and river deltas) and those with sandy or muddy margins are preferred (DoEE, 2019a).	In Australia, the species is a resident and present throughout the year at sites where breeding is protracted (e.g. Darwin and WA).	Given the preferred habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the EMBA, along the coastline.
Bridled Tern	In Australia, the species is widespread, breeding on offshore islands in western, northern and north-eastern Australia. The species forages in offshore, continental shelf waters and is only rarely recorded along mainland coasts. The species occupy tropical and subtropical seas, breeding islands, including vegetated coral cays, rocky continental islands and rock stacks (DoEE 2019a).	The species is migratory. In WA, almost all birds return to breeding colonies between late September and early October and leave from early to mid-April (DoEE 2019a).	The species is not identified within the Operational Area or surrounding region pursuant to the known distribution of the species. Accordingly, the species is unlikely to occur however may exist in the EMBA.
Masked Booby	In Australia, the masked booby ranges from Dampier Archipelago in WA, along the north coast. Individuals have been recorded at Barrow Island in WA. The species is a pelagic marine bird using tropical and subtropical waters. The species breeds in tropical oceanic islands, atolls and cays, usually far from mainland areas (DoEE 2019a).	Migratory patterns for this species are poorly understood.	Given that the species is known to breed on Barrow Island, it is likely that the species will occur within the EMBA.

Common Name	Habitat and Distribution	Seasonality	Relevance to EP
Wedge-tailed Shearwater	The wedge-tailed shearwater breeds on the east and west coasts of Australia and on off-shore islands. The marine bird is known to occupy tropical and sub-tropical waters. The species breeds throughout its known range, mainly on vegetated islands, atolls and cays (DoEE 2019a)	Movement patterns are poorly known but populations at the northern and southern extremities are migratory, departing nests in early April to early May and spending the non-breeding season in the tropics.	Given that the species is known to breed in the area, it is likely that the species will occur within the EMBA.
Flesh-footed Shearwater	This species is a common visitor to waters of the continental shelf and continental slope off southern Australia. The species occurs mainly in subtropics over continental shelves and slopes and occasionally inshore waters (DoEE 2019a).	Migratory patterns for this species are poorly understood.	Given the distribution of the species further south, the species is unlikely to occur within the EMBA.
Southern Giant-Petrel	The species breeds on subantarctic and Antarctic islands in Australian territory. The species is a marine bird that occurs in Antarctic to subtropical waters. In summer, the species predominantly occurs in subantarctic to Antarctic waters. Some adults are sedentary, remaining close to their breeding islands throughout the year (DoEE 2019a).	Migratory patterns for this species are poorly understood.	Given the distribution of the species further south, the species is unlikely to occur within the EMBA.
Soft-plumaged Petrel	This species is generally found over temperate and subantarctic waters. The species regularly visits southern Australian seas, but is more common in the west. The species is a marine, oceanic species. Breeding usually occurs on islands off Tasmania, New Zealand and Indian and South Atlantic Oceans (DoEE 2019a).	This species are dispersive or migratory from breeding islands but their movements in the non-breeding season are poorly documented (DoEE 2019a).	Given the species known distribution further south it is unlikely that the species will occur in the EMBA.
Fork-tailed Swift	In WA, the fork-tailed swift is scattered along the coast from south-west Pilbara to the north and east Kimberley region, near Wyndham. The species is almost exclusively aerial, flying from less than 1 m to at least 300 m above ground. The species does not breed in Australia (DoEE, 2019a).	The species usually arrives in Australia around October. Flocks have been recorded near Broome on southward passage across the continent.	Given the preferred habitat, the species is unlikely to be present in the Operational Area. Higher population densities may be encountered in the EMBA, along the coastline.

4.5.10 Timing of Key Biological Sensitivities

A number of biological sensitivities related to the seasonality of the marine fauna discussed in Sections 4.5.3 to 4.5.9 are expected to occur within the Operational Area and EMBA.

Table 4-13 identifies the timing of key biological sensitivities relevant to the Capreolus-2 3D MSS.

Table 4-13 Timing of Key Biological Sensitivities Relevant to the Operational Area and EMBA

Sensitivity	January	February	March	April	May	June	July	August	September	October	November	December
Mammals												
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[1]												
Fish Spawning												
Goldband snapper spawning (Pilbara stock)[3]												
Rankin cod spawning[3]												
Red emperor spawning[3]												
Blue-spotted emperor spawning[3]												
Giant ruby snapper spawning[3]												
Spanish mackerel spawning (Pilbara stock)[3]												
Other demersal fish species spawning[3]												
Seabirds												
White-tailed tropicbird foraging[1]												
Lesser frigatebird foraging[1]												

Sensitivity	January	February	March	April	May	June	July	August	September	October	November	December
Reptiles												
Flatback turtle nesting[4]												
Green turtle nesting[4]												
Hawksbill turtle nesting[4]												
Peak period												
Extended peak period												

[1] (Source: DoEE 2019a)

[2] (Source: DoE 2015a, Double *et al*. 2012, 2014)

[3] (Source: DPIRD 2019)

[4] (Source: DoEE 2017)

4.6 Socio-Economic Environment

4.6.1 Commonwealth Protected Areas

The Australian Marine Park (AMP) Network has been established around Australia as part of a National Representative System of Marine Protected Areas (NRSMPA), the primary goal of which is to establish and effectively manage a comprehensive, adequate and representative system of marine parks to contribute to the long-term conservation of marine ecosystems and protect marine biodiversity. Refer to Section 2.1.5 for further information on the management of the AMPs.

The Acquisition and Operational Areas do not overlap with any AMPs, however there are six AMPs located within the EMBA:

- Eighty Mile Beach Marine Park, Multiple Use Zone (30 km from the Operational Area);
- Argo-Rowley Terrace Marine Park, Multiple Use Zone and Special Purpose Zone (45 km and 75 km from the Operational Area, respectively);
- Montebello Marine Park, Multiple Use Zone (61 km from the Operational Area);
- Mermaid Reef Marine Park, National Park Zone (160 km from the Operational Area); and
- Gascoyne Marine Park, Multiple Use Zone (306 km from the Operational Area).

Further information on these AMPs is provided below.

4.6.1.1 Argo-Rowley Terrace Marine Park

The Argo-Rowley Terrace AMP is located approximately 45 km north of the Operational Area, within the EMBA (Figure 4.17). The Argo-Rowley Terrace AMP covers an area of 146,003 km^2 in 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 AMP includes an 83,379 km^2 Marine National Park Zone (IUCN II), a 62,720 km^2 Multiple Use Zone (IUCN VI), and an 1140 km^2 Special Purpose Zone (Trawl). The Argo-Rowley Terrace AMP boundary is contiguous with the Rowley Shoals State Marine Park (Section 4.6.2.1) and Mermaid Reef Australian Marine Park (Section 4.6.1.3), 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 seafloor features such as canyons on the slope between the Argo Abyssal Plain. These geomorphic features are thought to contribute to small, periodic upwellings that results 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 whale. 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.d).

The AMP contains two KEFS: the Canyons Linking the Argo Abyssal Plain with the Scott Plateau (outside the EMBA) and the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals (overlaps the EMBA). The Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF is valued for enhanced productivity, aggregations of marine life and high species richness (DoEE n.d.e). This KEF is further described in Section 4.3.

4.6.1.2 Eighty Mile Beach Australian Marine Park

Eighty Mile Beach AMP is located directly adjacent to the Operational Area, approximately 30 km south. The AMP is located approximately 74 km north-east of Port Hedland and adjacent to the WA State Eighty Mile Beach Marine Park. The Marine Park covers an area of 10,785 km² and a 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 AMP consists of shallow shelf habitats, including terrace, banks and shoals. The Marine Park supports a range of species including threatened, migratory and marine species. Biologically important areas within the AMP 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 (refer to Section 4.6.4).

The AMP also has a range of cultural values for the community. Sea country (of the Nyangumarta, Karajarri and Ngarla) is valued for Indigenous cultural identity, health and wellbeing (Director of National Parks 2018).

4.6.1.3 Mermaid Reef Australian Marine Park

Mermaid Reef Australian Marine Park is located approximately 160 km from the Operational Area, within the EMBA. The AMP covers an area of approximately 540 km² 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, one of the three reef systems forming the Rowley Shoals (refer to 4.6.2.1). Mermaid Reef is totally submerged at high tide and falls under Australian Government jurisdiction.

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 NWS, and are thought to provide ecological stepping stones for reef species originating in Indonesian/Western Pacific waters (Director of National Parks 2018) (refer to Section 4.5.2.3).

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.e) (refer to Section 4.3).

4.6.1.4 Montebello Australian Marine Park

The Montebello AMP is located 61 km south west of the Operational Area, within the EMBA. It is located offshore of Barrow Island and 80 km west of Dampier extending from the WA state water boundary and is adjacent to the Barrow Island and Montebello Island Marine Parks. The AMP protects the following values:

- Foraging areas for migratory seabirds;
- Areas used by vulnerable and migratory whale sharks for foraging;
- Foraging areas marine turtles which are adjacent to important nesting sites;
- Section of the north and south bound migratory pathway of the humpback whale;
- Shallow shelf environments with depths ranging from 15-150 m which provides protection for shelf and slope habitats, as well as pinnacle and terrace seafloor features;
- Seafloor habitats and communities of the Northwest Shelf Province provincial bioregions; and

- One key ecological feature for the region: the ancient coastline at the 125-m depth contour (Director of National Parks, 2018).

4.6.1.5 Gascoyne Australian Marine Park

The Gascoyne AMP is located 306 km south west of the Operational Area, within the EMBA. The AMP covers approximately 81,766 km^2 and protects the following conservation values:

- Important foraging areas for migratory seabirds threatened and migratory hawksbill and flatback turtles and vulnerable and migratory whale shark;
- A continuous connectivity corridor from shallow depths around 15 m out to deep offshore waters on the abyssal plain at over 5,000 m;
- Seafloor features including canyon, terrace, ridge, knolls, deep hole/valley and continental rise. It also provides protection for sponge gardens in the south of the reserve adjacent to WA coastal waters;
- Ecosystem examples from the surrounding provinces;
    - Four key ecological features: Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula, Commonwealth waters adjacent to Ningaloo Reef, Continental slope demersal fish communities (overlaps with the EMBA) and Exmouth Plateau (overlaps with the EMBA);
    - The canyons in the reserve are believed to be associated with the movement of nutrients from deep water over the Cuvier Abyssal Plain onto the slope where mixing with overlying water layers occurs at canyon heads; and
    - The reserve therefore provides connectivity between the inshore waters of the existing Ningaloo Commonwealth Marine Park and the deeper waters of the area (Director of National Parks, 2018).

4.6.2 State Protected Areas

4.6.2.1 Rowley Shoals Marine Park

The Rowley Shoals Marine Park is located approximately 70 km from the Operational Area within the EMBA. The Marine Park consists of three different protective zones; general use, sanctuary and recreation. Rowley Shoals is covered by the 'Rowley Shoals Marine Park Management Plan 2007-2017', which is still in effect. Refer to Section 4.6.2.1, for further information on the management of the Marine Park.

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 - 700m (DoEE n.d.e).

The marine environments within the shoal are typically 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 WA (DoEE n.d.e).

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 noted in Section 4.6.1.3, 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.e). Furthermore, Rowley Shoals provides important habitat, feeding, resting and breeding grounds a number of migratory birds, including the red-tailed tropicbird, white-tailed tropicbird and little tern.

4.6.2.2 Montebello Islands Marine Park

The Montebello Islands Marine Park (MP) is located approximately 110 km southwest of the Operational Area. It is located approximately 20 km north of Barrow Island and 120 kilometres west of Dampier. The Marine Park (overlapping the EMBA) consists of three different protective zones; general use, sanctuary and special purpose (benthic habitats).

The Park protects more than 58,000 hectares of ocean surrounding more than 250 low-lying islands. The complex system of reefs, lagoons and channels support a large range of habitats, and marine flora and fauna. The area supports a minimum of 150 species of hard coral, 450 species of fish, 630 species of molluscs and 170 species of sea stars, urchins and other echinoderms.

Socio-economic values include hydrocarbon exploration and production, pearling, nature-based tourism, commercial and recreational fishing (DEC, 2009).

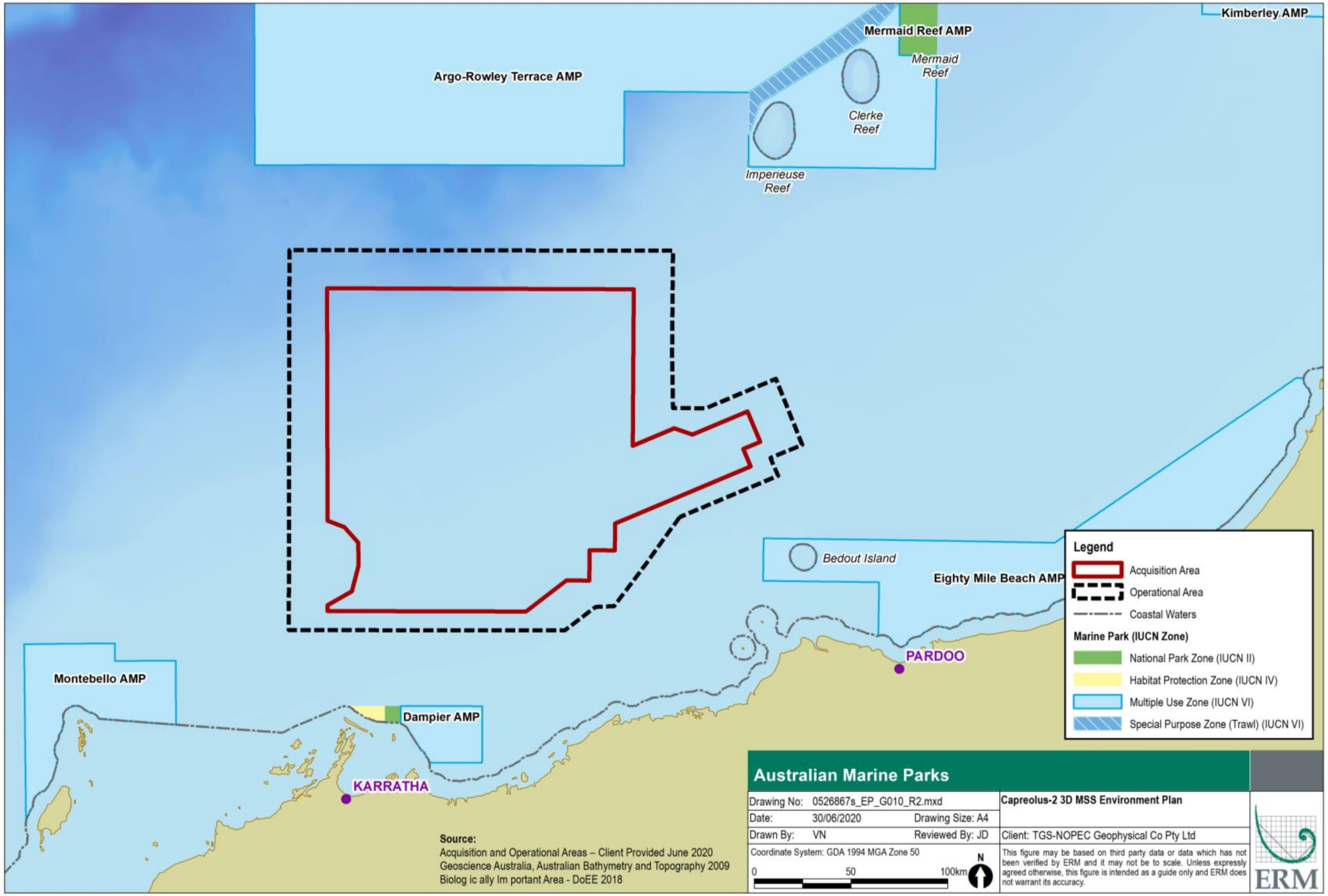


Figure 4.17 Australian Marine Parks

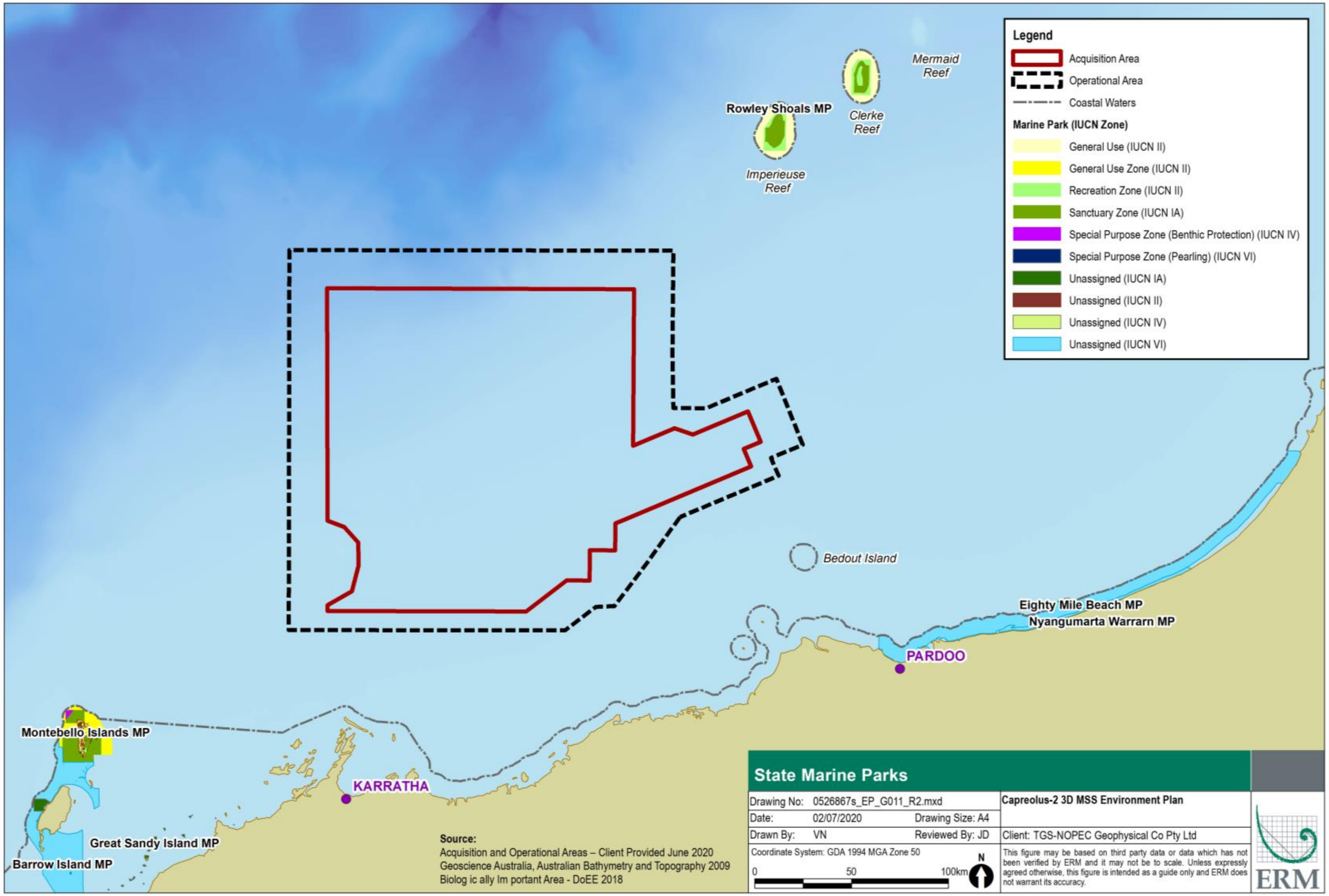


Figure 4.18 State Marine Parks

4.6.3 World Heritage and National Heritage Areas

World heritage sites are natural or man-made sites, areas, or structures recognized as being of outstanding universal value by the United Nations Educational, Scientific and Cultural Organization (UNESCO). No listed World or National Heritage places were identified within the Operational Area.

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.f). There is one Commonwealth Heritage listed place within the EMBA, the Mermaid Reef – Rowley Shoals, which is listed for values meeting Category A, B, C and D of the Commonwealth Heritage List criterion (Commonwealth of Australia n.d.).

The Dampier Archipelago (including Burrup Peninsula) (Indigenous site) and the Barrow Island and the Montebello-Barrow Islands Marine Conservation Reserves (natural site) are two listed places on the National Heritage List. They are located within the EMBA, approximately 35 km south and 115 km southwest of the Operational Area, respectively.

4.6.4 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.g). 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 110 km south-east of the Operational Area (outside of the EMBA).

4.6.5 Marine Archaeology

All shipwrecks and sunken aircraft more than 75 years old are protected under the *Underwater Cultural Heritage Act 2018.* A search of the Australasian Underwater Cultural Heritage Database (DoEE 2019b) indicated that there is one known historic shipwreck, the *Koombana* (protected under the Act) and no sunken aircraft within the Operational Area. The *Koombana* was wrecked in 1912 and is located in the south of the Operational Area (no overlap with the Acquisition Area) in water depths of approximately 60 m.

It is noted that another shipwreck, the *Haw Kiet* (wrecked in 2003) is located in the north of the Operational Area in water depths of approximately 800 m. Little is known about this wreck and its exact position is unconfirmed. The shipwreck is protected under the *Underwater Cultural Heritage Act 2018*, however, the wreck is of no national or international significance, no protection zone or prohibition of specific activities apply to the wreck, and the Capreolus-2 3D MSS is not expected to interact with or disturb the wreck.

Numerous other shipwrecks and sunken aircraft are located within the EMBA, however are not relevant to this EP.

4.6.6 Native Title

A desktop review of the National Native Title Tribunal (NNTT) confirms that there are no native titles overlapping the Operational Area (NNTT 2019). The closest neighbouring title is the Njamal 10 title (WAD26/2019) located inland from Port Hedland (NNTT 2019).

4.6.7 Commercial Fisheries

Commercial fishing in WA 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:

- North West Slope Trawl Fishery
- Western Tuna and Billfish Fishery
- Southern Bluefin Tuna
- Skipjack Tuna Fishery

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 and EMBA include the:

- Abalone Managed Fishery
- Beche- de- Mer Managed Fishery
- Broome Prawn Managed Fishery
- Hermit Crab Fishery
- Kimberley Gillnet and Barramundi Managed Fishery
- Mackerel Managed Fishery (MMF) (Area 2)
- Marine Aquarium Fish Managed Fishery
- Nickol Bay Prawn Managed Fishery
- Northern Demersal Scalefish Managed Fishery
- Onslow Prawn Managed Fishery
- Pearl Oyster Managed Fishery
- Pilbara Crab Managed Fishery
- Pilbara Line Managed Fishery
- Pilbara Trap Managed Fishery
- Pilbara Trawl Fish Trawl (Interim) Managed Fishery
- Specimen Shell Managed Fishery
- West Coast Deep Sea Crustacean Managed Fishery

The Commonwealth and WA State managed commercial fisheries with the license to operate within the Operational Area and/or EMBA are described in Table 4-14.

Table 4-14 Commonwealth and WA State Managed Fisheries

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Commonwealth Fisheries					
North West Slope Trawl Fishery (NWSTF)	✓	✓	**Extent**: Extends from 114° E to approximately 125° E off the WA coast between the 200 m isobath and the outer limit of the AFZ. Refer to Figure 4.19. **Effort:** Four fishing permits and two active vessels in the fishery during the 2016-17 fishing season (Patterson et al. 2018). Total catch in the 2016-17 fishing season was 57.8 tonnes over 114 days of fishing effort (Harte & Curtotti, 2018). Fishing effort increased in the 2017-2018 season. Total catch was 79.7 tonnes over 219 days (Patterson et al., 2019). **Resource**: Target species include snappers, Australian scampi (*Metanephrops australiensis*), velvet scampi (*M. velutinus*) and Boschma's scampi (*M. boschmai*) (Patterson et al. 2019). **Method:** The NWSTF has predominantly been a scampi fishery using demersal trawl gear (Patterson et al. 2019).	✓	Fishing effort is known to occur in water depths greater than 200 m. Effort is typically concentrated along the slope offshore from the Pilbara region, near the Rowley Shoals and north-east towards Scott Reef. The number of vessels involved in the fishery has been one or two vessels each year since 2008/2009. Two vessels were active in the fishery during the 2016-17 fishing season over 114 days of fishing effort. Therefore, there is potential for interaction with the Capreolus-2 3D MSS.
Skipjack Tuna	✓	✓	**Extent**: Covers the AFZ and extends westward from the South Australian/ Victorian border around the coast of Australia to	X	The fishery is currently not in operation.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Fishery (STF)			Cape York Peninsula in QLD (Patterson & Mobsby, 2019). Refer to Figure 4.19. **Resource**: Skipjack tuna (Patterson & Mobsby, 2019). Skipjack tuna are known to spawn throughout the continental shelf and slope waters of the Indian Ocean. **Effort:** There has been no fishing effort since the STF since the 2008-09 season (Patterson & Mobsby, 2019). **Method**: Predominantly purse-seine gear is used. A small amount of pole and line effort. (Patterson & Mobsby, 2019).		There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Southern Bluefin Tuna Fishery (SBTF)	✓	✓	**Extent**: Fishery includes all waters of Australia, out to 200 nm from the coast. Juvenile fish move from spawning grounds in the north-east Indian Ocean into the Australian EEZ and southward along the Western Australian coast (Patterson et al. 2019). Refer to Figure 4.19. **Effort**: No current effort on NWS, fishing activity is concentrated in the Great Australian Bight and off South-east Australia (Patterson et al. 2019). **Resource**: Key species is the Southern Bluefin tuna (*Thunnus maccoyii).* Migration and spawning locations outside of the Operational Area and EMBA. **Method**: Most of the Australian catch has been taken by purse seine, targeting juvenile tuna in the Great Australian Bight. Australian domestic longliners operating along the east coast	X	There is no effort currently reported in WA. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			catch some tuna and recreational fishing has increased (Patterson et al. 2019).		
Western Tuna and Billfish Fishery (WTBF)	✓	✓	**Extent**: The WTBF operates in Australia's Exclusive Economic Zone and high seas of the Indian Ocean. In recent years, fishing effort has been concentrated off south-west Western Australia, with occasional activity off South Australia (Patterson et al. 2019). Refer to Figure 4.19. **Effort**: Since 2005, there has been fewer than five vessels active in the Western Tuna and Billfish Fishery, down from 50 active vessels in 2000. In recent years, fishing effort has concentrated off south-west Western Australia and South Australia with no current effort on NWS (Patterson *et al.* 2018). **Resource**: Key species include Bigeye tuna (*Thunnus obesus*), yellowfin tuna (*T. albacares*), striped marlin (*Tetrapturus audux*) and swordfish (*X. gladius)* (Patterson et al. 2019). These species are known to spawn throughout the continental shelf and slope waters of the Indian Ocean. **Method:** The main fishing gear in the WTBF is pelagic longline, with low levels of minor-line fishing (Patterson et al. 2019).	X	The most recent reports indicate that the fishery does not operate on the NWS. This correlates with feedback from WAFIC during stakeholder consultation. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
State Fisheries					
Mackerel Managed Fishery	✓	✓	**Extent:** The Mackerel Managed Fishery (MMF) is divided into three zones. The Operation Area overlaps with Area 2 – Pilbara 114° E to 121°E. The fishery encompasses the entire	✓	Fishing effort occurs year round but typically takes place between May and

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
(Area 2) (MMF)			coastline of Western Australia from the North Territory border to Cape Leeuwin in the south-west. However, the fishery mainly operates between Geraldton and the WA/NT border (Lewis & Brand-Gardner, 2017). Refer to Figure 4.20. **Effort:** In 2017, the total catch for Spanish mackerel was 283 tonnes and 16 tonnes for grey mackerel (Lewis & Brand-Gardner, 2017). **Resource:** Target species comprise spanish and grey mackerel. Spanish mackerel are an offshore, pelagic (surface-dwelling) fish which inhabit offshore and coastal reefs (Lewis & Brand-Gardner, 2017). **Method**: Trolling or handline. Near-surface trolling gear from vessels in coastal areas around reefs, shoals and headlands (Lewis & Brand-Gardner).		November and is concentrated in waters less than 70 m. The southern zone of the Acquisition Area (water depths between 50 m – 80 m) will be acquired between April – May, primarily outside of the main fishing period. In addition, acquisition in the southern zone will avoid the main Spanish mackerel spawning period, which is understood to peak in waters off the Pilbara coast between September and December. FishCube data indicates that effort was reported in the south of the Operational Area from 2014 - 2018. Therefore, there is potential for interaction with the Capreolus-2 3D MSS.
Nickol Bay Prawn Managed Fishery (NBPMF)	✓	✓	**Extent:** The boundaries of the NBPMF are all the waters of the Indian Ocean and Nickol Bay between 116°45' east longitude and 120°east longitude on the landward side of the 200 m isobath. The NBPMF incorporates the Nickol Bay, Extended Nickol Bay, Depuch and De Grey size managed fish grounds (State of the Fisheries 2014-15). Refer to Figure 4.20.	✓	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. The target species may occur in the Operational Area, but are found predominantly in shallow, turbid nearshore waters.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			Effort: Fishing effort in 2017 increased to 281 boat days, from 43 boat days in 2016 (Kangas et al., 2017). **Resource:** NBPMF primarily targets banana prawns (*Penaeus merguiensis*) (Gaughan & Santoro, 2018). Banana Prawn spawning occurs in shallow coastal waters throughout the year there are two spawning peaks: the late dry season (September-November) and the late wet season (March-May) (AFMA website). **Method:** Trawling		There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Onslow Prawn Managed Fishery (OPMF)	✓	✓	**Extent:** The boundaries of the fishery are 'all the Western Australian waters between the Exmouth Prawn Fishery and the Nickol Bay prawn fishery east of 114º39.9' on the landward side of the 200 m depth isobath'. **Effort:** The total lands in 2017 were negligible. Only five days of fishing effort was undertaken in one boat in 2017 (Kangas et al., 2017). **Resource:** Banana prawns is the target species (Kangas et al., 2017). **Method:** The main method is high and low opening, otter prawn trawl systems (Kangas et al., 2017).	X	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Pearl Oyster Managed	✓	✓	**Extent**: The Operational Area overlaps the boundaries of Zone 1 and Zone 2 of the fishery. The collection of pearl oysters for the Pearl Oyster Managed Fishery is restricted to shallow diving depths below 35 m. Refer to Figure 4.22.	X	The Operational Area is located outside of the commercial fishing area, stock area and typical depth range.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Fishery (POMF)			**Effort:** In 2017, total catch was taken in zones 2 and 3 with no fishing in zone 1. The number of wild-caught peal oysters was 468,573 and total effort was 12,845 dive hours (Hart, Murphy & Jones, 2018). **Resource**: The breeding season of pearl oysters starts in the spring months of September or October, extending to the autumn months of April and May. Although there is variability from month to month, the primary spawning occurs from the middle of October to December (Daume *et al*. 2016). Spawning in the main fishing areas of the Eighty Mile Beach region is concentrated around broodstock distributed between 8 and 15 m depth, with potential smaller contributions from the north-east (Condie *et al*. 2006). These spawning events lead to recruitment locally and alongshore to the south-west and also feed larvae into neighbouring shallow coastal environments and deeper waters to the west (~20 m depth). Larval dispersion from known broodstock populations mostly travel less than 30 km, however, some have been modelled as potentially travelling up to 60 km (Condie *et al*. 2006). **Method**: Drift diving, harvesting oysters by hand.		Pearl diving activities does not intersect the Operational Area. FishCube data shows no effort within the Operational Area, due to the restriction of pearl diving activities to shallow diving depths below 35 m. Target species may occur in the shallow southern part of the Operational Area. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Pilbara Crab Managed Fishery (PCMF)	✓	✓	**Extent**: Effort for the PCMF is focused in inshore waters around Nickol Bay. **Effort**: In 2017, the total catch of blue swimmer crabs was 51 tonnes. **Resource**: Target species include blue swimmer crabs.	X	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. There is no potential for interaction with the Capreolus-2 3D MSS and

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			Method: Hourglass traps (Gaughan & Santoro, 2018).		therefore, the fishery is not considered further in this EP.
Pilbara Fish Trawl Interim Managed Fishery (PFTIMF)	✓	✓	**Extent**: The PFTIMF is situated in the Pilbara region in the north west of Australia. The PFTIMF boundaries are seaward of the 50 m isobath and landward of the 200 m isobath (Gaughan & Santoro, 2018). Refer to Figure 4.21. In the 2018/2019 season, there are 11 licences in the fishery and two active operators. **Effort**: In 2017, the total catch for the PTIMF was 1,795 tonnes, making up 71% of the total catch by the Pilbara Demersal Scalefish Fishery (PDSF), comprising the trawl, trap and line fisheries (Newman et al., 2017). **Resource**: The PFTIMF main target species include bluespotted emperor (*Lethrinus punctulatus*), red emperor (*Lutjanus sebae*), and rankin cod (*Epinephelus multinotatus*). Spawning of bluespotted emperor, red emperor, goldband snapper, pink snapper and rankin cod occur in operational area and within activity timing. **Method**: Trawling	✓	A review of historic fishing catch data indicates that effort was reported in the south of the Operational Area from 2012-2018. In 2018, approximately 900,000 kg of fish was caught in the south of the Operational Area from 4 vessels. Therefore, there is potential for interaction with the Capreolus-2 3D MSS.
Pilbara Line Managed	✓	✓	**Extent**: The PLMF fishing boat licensees are permitted to operate anywhere within "Pilbara waters" (Gaughan & Santoro, 2018). Refer to Figure 4.21.	✓	FishCube data indicates that effort was reported in the south of the Operational Area from 2012 - 2018. In 2017, in excess of 70,000 kg of fish

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Fishery (PLMF)			In the 2018/2019 season there are nine individual licences in the Pilbara Line Fishery, held by seven operators. **Effort**: The total catch in 2017 for the PLMF was 161 tonnes, making up 6% of the total catch by the PDSF (Newman et al., 2017). **Resource**: Main target species include goldband snapper and ruby snapper. Spawning of commercial snapper species may occur in the Operational Area and EMBA. **Method**: Longlining		was caught in the south of the Operational Area from 5 vessels. Therefore, there is potential for interaction with the Capreolus-2 3D MSS.
Pilbara Trap Managed Fishery (PTMF)	✓	✓	**Extent**: The PTMF lies on the landward side of a boundary approximating the 200 m isobath and seaward of a line generally following the 30 m isobath. Refer to Figure 4.21. **Effort**: In 2017, the total catch for the PTMF was 573 tonnes, making up 23% of the total catch by the PDSF (Newman et al., 2017). **Resource**: Main target species include bluespotted emperor (*Lethrinus punctulatus*), red emperor (*Lutjanus sebae*), and rankin cod (*Epinephelus multinotatus*). Spawning of bluespotted emperor, red emperor, goldband snapper and Rankin cod may occur in the Operational Area and EMBA. **Method**: Trap	✓	A review of historic fishing catch data indicates that effort was reported in the south of the Operational Area from 2012-2018. In 2018, in excess of 250,000 kg of fish was caught in the south of the Operational Area from 3 vessels. Therefore, there is potential for interaction with the Capreolus-2 3D MSS.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
South West Coast Salmon Fishery (SWCSF)	✓	✓	**Extent**: Fishery extends off the coast of the south-west of Australia, from north of Kalbarri (27ºS) to slightly east of Augusta (115º30'E). **Effort:** In 2017, the total catch by the SWCSF was 50.82 tonnes, accounting for 33% of the total catch (154 tonnes). There are six licenses for the SWCSF. **Resource:** Primary targeted species is the Western Australian Salmon**,** Estuary Cobbler and Black Bream **Method:** Beach-based and boat-based fishes in follow water including gill nets, haul net and beach seine**.**	X	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Specimen Shell Managed Fishery (SSMF)	✓	✓	**Extent**: While the fishery covers the entire Western Australian coastline, there is some concentration of effort in areas adjacent to population centres such as Broome, Exmouth, Shark Bay, Geraldton, Perth, Mandurah, the Capes are and Albany (Hart et al., 2018a). Refer to Figure 4.20. **Effort:** The fishery has 31 licenses with a maximum of two divers in the water at any one time per license. Of the 31 license, 23 were active in 2017. In the same year, effort was 674 days and 7,806 shells were caught (Hart et al., 2018a). **Resource:** During the 2017 season the catch rate was approximately 12 shells per day. There is some focus of effort on mollusc families most popular with shell collectors, such as cowries, cones, murexes and volutes. Cypraeidae or cowries are noted for their localised variations in both shape and colour, making them attractive to collectors. Habitat and	X	Collection typically occurs in shallow waters (outside of the Operational Area), however exception permits allow for the use of remote controlled underwater vehicles up to a depth of 300 m. FishCube data indicates that commercial collectors have previously been active in waters south-east of the Operational Area. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			ecosystem impacts are considered negligible. This is due to the small scale of the fishery and the hand collection methods. While the fisheries can potentially operate over large areas catches are relatively low due to the special handling requirement (Hart et al., 2018a). **Method:** The main method of specimen shell collection is by hand, by a small group of divers operating from small boats in shallow coastal waters or by wading along coastal beaches below the high water mark. A current Exemption permits the use of a remote controlled underwater vehicle at depths of up to 300 m. This is limited to one per license (hart et al., 2018a).		
West Coast Deep Sea Crustacean Managed Fishery (WCDSCMF)	✓	✓	**Extent**: Extends along the 150m isobath to the edge of the Australian EEZ. Most fishing is concentrated in deeper waters. **Effort:** 164.4 tonnes. Catch was dominated by crystal crabs (99% of catch). **Resource:** Primary targets crystal crabs. **Method:** baited pots	X	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. Fishing effort and the target species occurs on the west and south coasts of WA, primarily in water depths of 400 – 900 m. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Abalone Managed Fishery (AMF)	✓	✓	**Extent:** The fishery extents along the Western Australian coastline. Most of the fishing effort is located in the south-west region of WA. Commercial abalone fishing in the northern region occurs along the coastline and surrounding islands (Strain, Brown & Walters, 2018). **Effort:** Total catch of the commercial fishery in 2017 was 49 tonnes. The majority of catch and effort was in the south west region (Strain, Brown & Walters, 2018). **Resource:** Roe's abalone (Strain, Brown & Walters, 2018). **Method:** Dive and wade (Strain, Brown & Walters, 2018).	X	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. There is no potential for interaction with the Capreolus-2 3D MSS, therefore, the fishery is not considered further in this EP.
Beche de Mer Managed Fishery (BMF)	X	✓	**Extent:** The fishery has access to all Western Australian waters, however effort and catch is primarily based in the northern half of the State, from Exmouth Gulf to the Northern Territory border (WAFIC, 2019). **Effort:** Catch and effort occurs in shallow, inshore waters along the coastline and surrounding islands. Total catch in 2017 was 135 tonnes (Hart et al., 2018b). **Resource:** Beche-de-Mer (sea cucumbers) (WAFIC, 2019). **Method:** Collected by hand by divers and waders throughout the Kimberly region (WAFIC, 2019)	X	The fishery is located 72 km from the Operational Area (within the EMBA). There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Broome Prawn Managed	X	✓	**Extent**: Waters along the North-west Shelf surrounding Broome.	X	The fishery is located 98 km from the Operational Area (within the EMBA).

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Fishery (BPMF)			**Effort:** Extremely low fishing effort in 2017 occurred as only one boat was used to trial whether catch rates were sufficient for commercial fishing. **Resource:** Primarily banana prawns, western king prawns and brown tiger prawns **Method:** Low opening, otter prawn trawl systems (to target king prawns, brown tiger and endeavour prawns). High opening, otter prawn trawl systems to target banana prawns.		There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Hermit Crab Fishery (HCF)	X	✓	**Extent**: Fishing is permitted in Western Australian waters north of Exmouth Gulf. **Effort:** There were three active licenses in 2017 for the HCF. The total catch was 58,644 Australian land hermit crabs. **Resource:** Primarily targets Australian land hermit crabs **Method:** Harvested by hand**.**	X	The fishery is located 36 km south of the Operational Area (within the EMBA). There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Kimberley Gillnet and Barramundi Managed Fishery (KGBF)	X	✓	**Extent**: Operates in the nearshore and estuarine zones of the North Coast Bioregion and extends from the WA/NT border to the top end of Eighty Mile Beach, south of Broome. **Effort:** The KGBF is limited to four licenses. In 2017, the total catch was 79.9 tonnes. **Resource:** Primary species include barramundi and two species of threadfin. **Method:** Gillnet	X	The fishery is located 256 km from the Operational Area (within the EMBA). There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
Marine Aquarium Fish Managed Fishery (MAFMF)	✓	✓	**Extent:** The MAFMF operates in WA's state waters from the Northern Territory border in the north through to the South Australian border in the south. The effort is spread over a total gazetted area of 20,781 km^2 (Newman, Bruce & Kalinowski, P, 2018). **Effort:** The fishery is typically more active in waters south of Broome with higher levels of effort around the capes region. A total of 11 licenses were active in MAFAF (out of 12 licenses) during 2017. The total catch in MAFMF in 2017 was 150,544 fishes, 21.9 tonne of coral, live rock and living sand and 322 L of marine plants (Newman, Bruce & Kalinowski, P, 2018). **Resource:** MAFMF fish catches were dominated by scribbled angelfish, margined coral fish, blue and yellow wrasse, neon damsel and striped catfish. **Method:** Dive based, hand net operating from small boats.	X	FishCube data indicates that no fishing activity has occurred in the Operational Area since 2014. There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.
Northern Demersal Scalefish Managed Fishery (NDSMF)	X	✓	**Extent:** North-west coast of WA in the waters east of longitude 120°E to the edge of the AFZ. The fishery is divided into two fishing areas; an inshore sector (Area 1) and an offshore section (Area 2). Area 2 is further divided into zones. Zone A is an inshore area, Zone B comprises the area with most historical fishing activity and Zone C is an offshore deep slope area representing waters deeper than 200 m (Newman et al., 2017). **Effort:** Total catch in 2017 was 1,317 tonnes (Newman et al., 2017).	X	The fishery is located 85 km from the Operational Area (within the EMBA). There is no potential for interaction with the Capreolus-2 3D MSS and therefore, the fishery is not considered further in this EP.

Fishery	Management Area		Description	Fishing Effort Reported within the Operational Area	Relevance to EP
	Operational Area	EMBA			
			Resource: Demersal scale fish (red emperor, goldband snapper, cod species) (Newman et al., 2017). **Method:** Primarily trap, some line (Newman et al., 2017).		

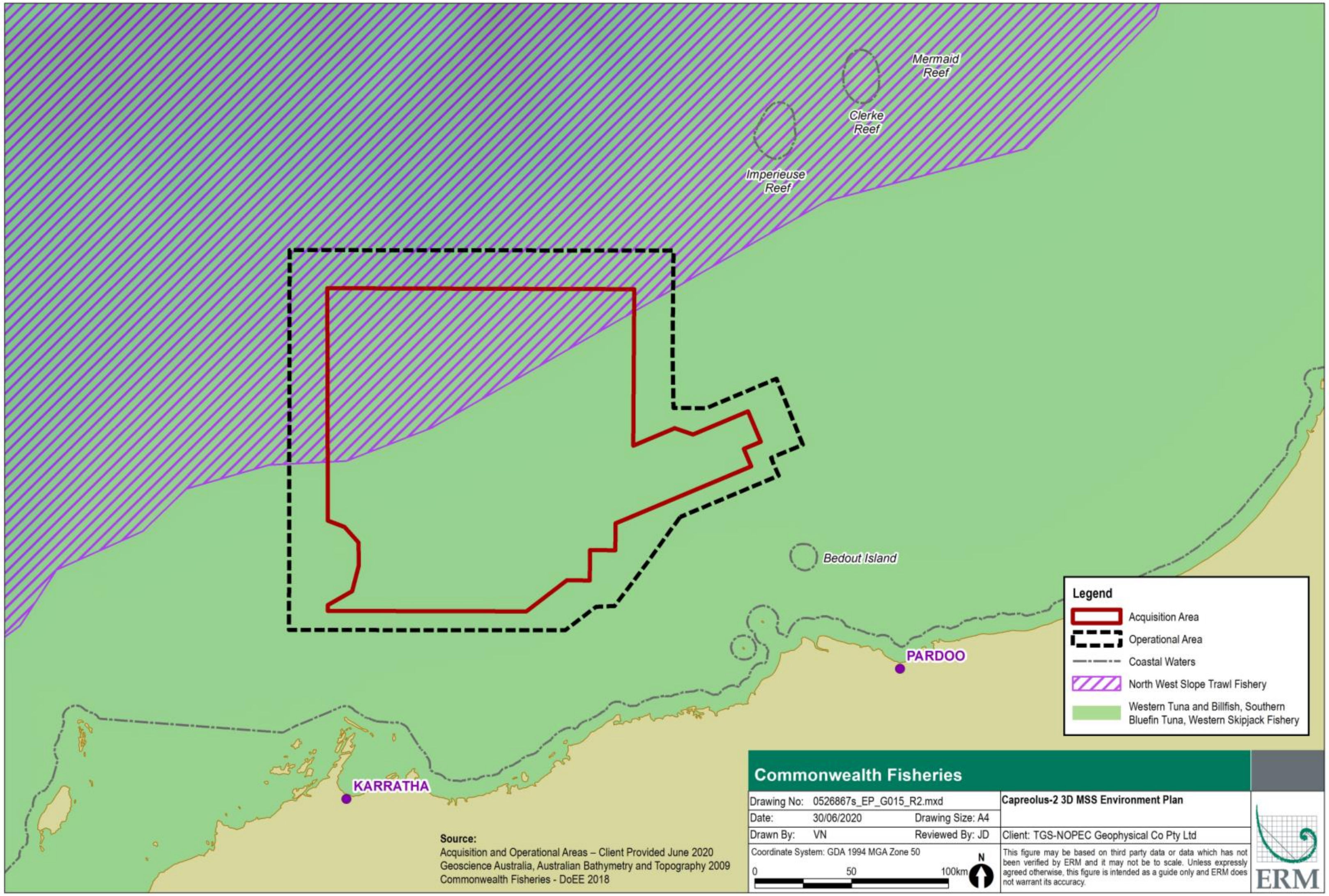


Figure 4.19 Relevant Commonwealth Managed Fisheries

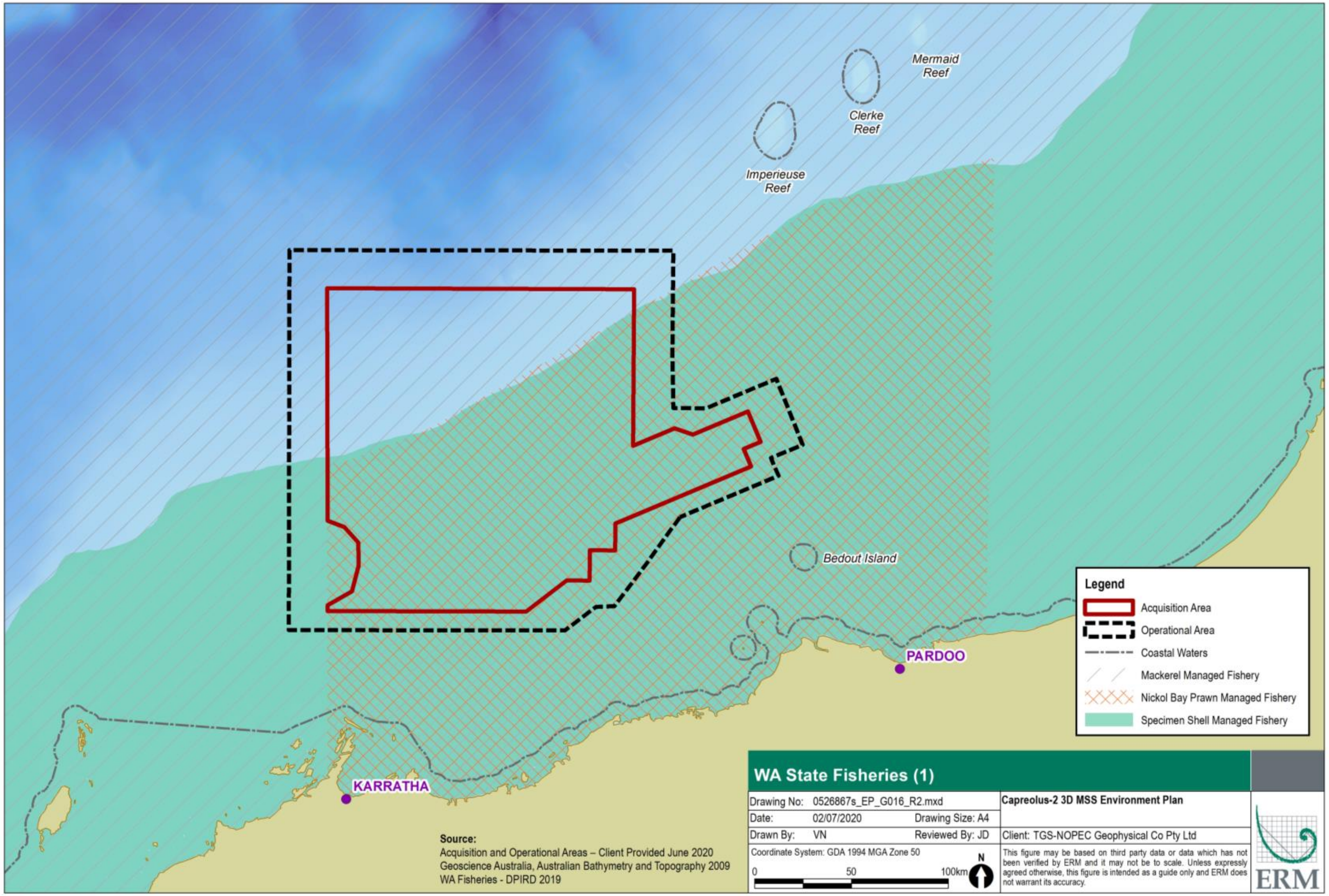


Figure 4.20 Relevant WA Managed Fisheries (1)

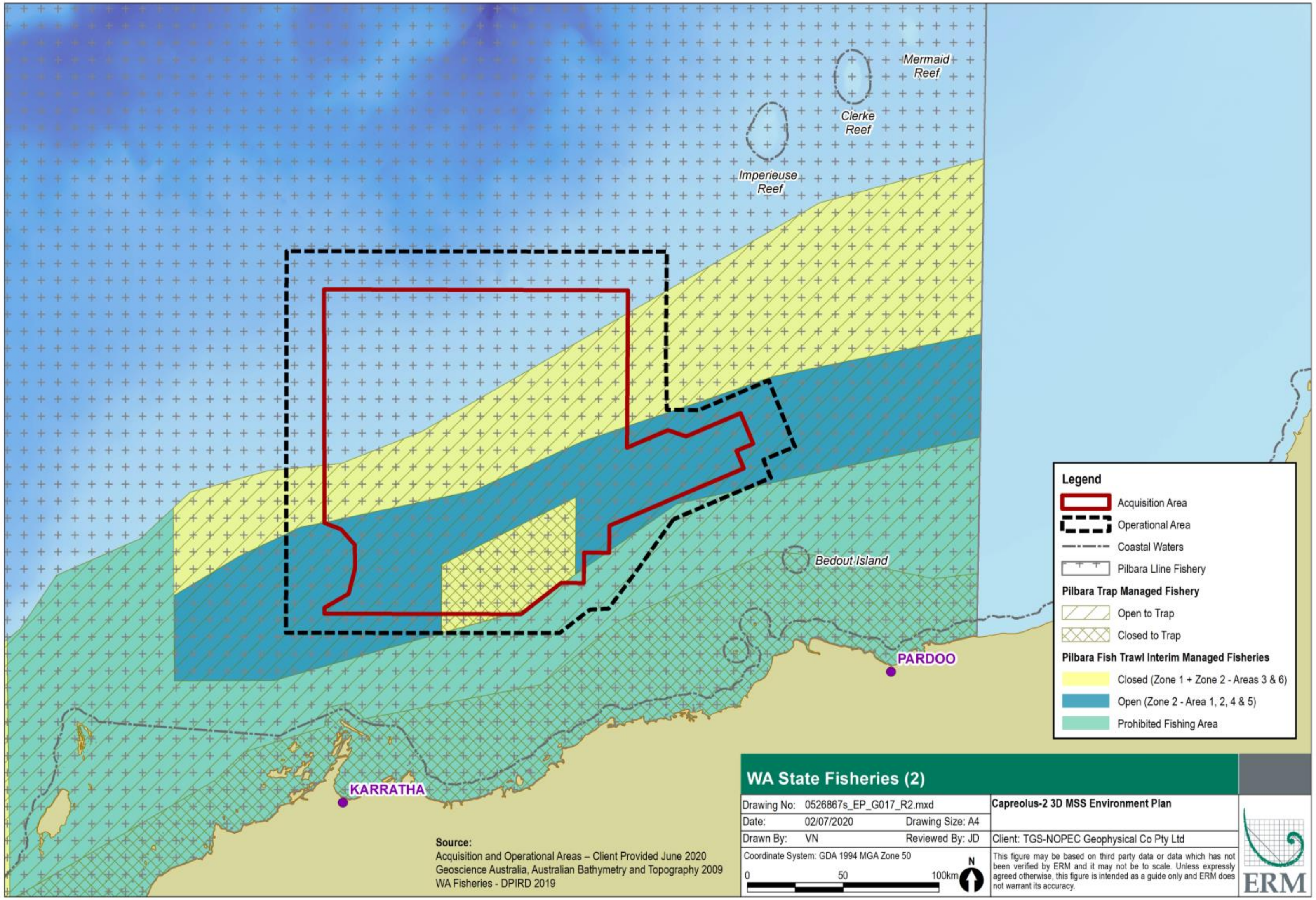


Figure 4.21 Relevant WA Managed Fisheries (2)

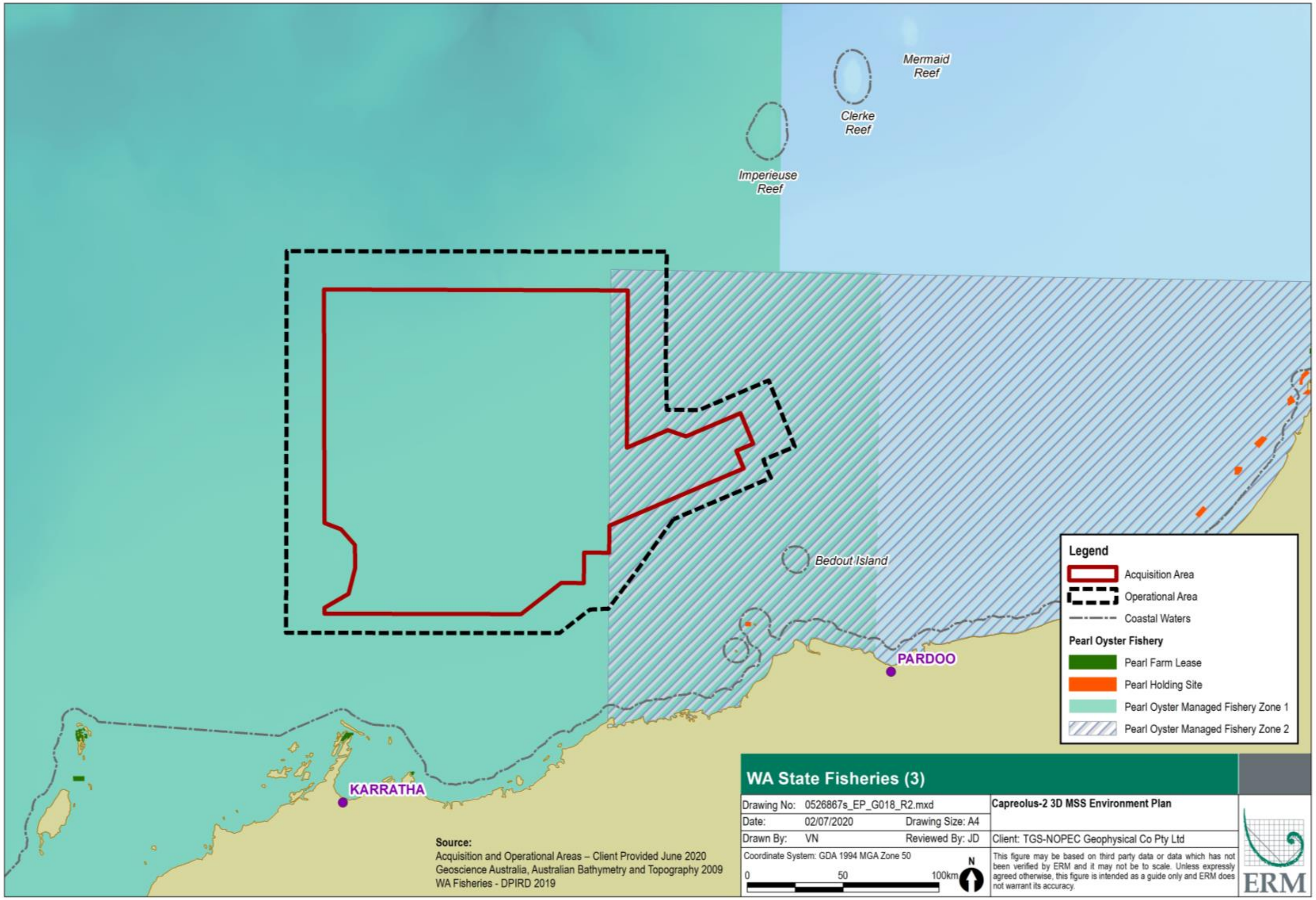


Figure 4.22 Relevant WA Managed Fisheries (3)

4.6.7.1 Review of Catch and Effort Data

TGS 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 x 60 nm and for 10 nm x 10 nm Catch and Effort System (CAES) blocks for annual catch and effort data for each of the most recent 5 years (2014 - 2018).

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

Data provided by DPIRD included:

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

Due to confidentiality reasons, DPIRD was 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 year). Where this applies, the Vessel Count is marked ‘Less than 3’, while Weight and Fishing Day Count are marked as ‘N/A’. CAES blocks where the results are provided in this way confirm that fishing effort did occur within the block during that period, but the associated catch and effort values are not available. CAES blocks where no fishing is recorded do not return any data.

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. In addition, TGS has used data reported for an aggregated 5-year period (2014-2018), which greatly reduces the number of blocks in a fishery where ‘Less than 3’ are reported. Where a block has been visited by less than three vessels over an entire 5-year period, it implies that fishing effort may be relatively low compared with other blocks where three or more vessels go to fish.

The following sections presents the FishCube data that has been mapped for the fisheries, which have a spatial overlap and recorded fishing effort within or near to the Operational Area.

Mackerel Managed Fishery

Analysis of FishCube data shows that the area of fishing effort in the Pilbara region of the MMS (Area 2) covers 50,571 km^2 for the five-year period between 2014 and 2018. The Operational Area overlaps with 5,110 km^2 (10.1%) of this fished area (refer to Figure 4.23). Fishing effort is restricted to the southern portion of the Operational Area in water depths less than 70 m.

The FishCube data also shows that the number of fishing vessels operating in the 10 nm blocks overlapping the Operational Area in the last five years was typically limited to one or two vessels per year (with the exception of a single 10 nm block at Glomar Shoals, refer to Figure 4.28).

Nickol Bay Prawn Managed Fishery

Analysis of Fishcube data shows that the area of fishing effort over the West Australian coast was 9,925 km^2 for the period between 2014 and 2018. The Operational Area does not overlap with the area of fishing effort (refer to Figure 4.25). The closest fishing effort is located 35 km south from the Operational Area. Fishing effort is generally located in shallow nearshore waters, around bays and river mouths such as De Grey Rivermouth.

Pearl Oyster Managed Fishery

Analysis of Fishcube data shows that the area of fishing effort over the West Australian coast was 15,646 km^2 for the period between 2014 and 2018. The Operational Area does not overlap with the area of fishing effort (refer to Figure 4.26). The closest fishing effort is located approximately 20 km south from the Operational Area.

Pilbara Demersal Scalefish Fisheries

Pilbara Fish Trawl (Interim) Managed Fishery

Analysis of FishCube data shows that the area of fishing effort over the West Australian coast is 25,922 km^2 for the period between 2014 and 2018. The Operational Area overlaps with approximately 14,364 km^2 (55.4%) of the area of fishing effort.

One or two vessels were active in the fishery in 2014, 2015 and 2017, three vessels were active in 2016 and four vessels were active in 2018. In 2018, the fishery accounted for approximately 75% of the total catch from the Pilbara Demersal Scalefish Fisheries (PFTIMF, PTMF and PLMF).

FishCube data for annual fishing effort in blocks within the Operational Area (for blocks where at least three vessels have fished and data is available) ranges from 7 days to 123 days per year between 2014 and 2018, with an average of 36 days per 10 nm block per year (refer to Figure 4.28).

Fishing effort occurs relatively consistently across the entire year with no identified peak periods.

Pilbara Line Managed Fishery

Analysis of FishCube data (refer to Section 4.6.7) shows that the area of fishing effort over the West Australian coast is 153,198 km^2 for the period between 2014 and 2018. The Operational Area overlaps with 24,205 km^2 (15.8%) of the area of fishing effort (refer to Figure 4.29). FishCube data for the PLMF 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.

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 3 vessels typically fishing across the fishery. In 2018, the PLMF accounted for 4% of the total catch for the Pilbara Demersal Scalefish Fisheries.

FishCube data reports that up to three vessels have typically operated in the Operational Area each year for the last 5 years (2014 to 2018), compared with greater fishing effort located to the south-west of the Operational Area, between Exmouth and Dampier.

FishCube data for annual fishing effort in blocks within the Operational Area (for blocks where at least three vessels have fished and data is available) ranges from 4 days to 214 days per year between 2014 and 2018, with an average of 84 days per 60 nm block per year (refer to Figure 4.30).

Pilbara Trap Managed Fishery

Analysis of FishCube data shows that the area of fishing effort over the West Australian coast was 116,804 km^2 for the period between 2014 and 2018. The Operational Area overlaps with 16,681 km^2 (14.3%) of the area of fishing effort (refer to Figure 4.31). FishCube data for the PTMF 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.

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 3 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 up to three vessels have typically operated in the Operational Area each year for the last 5 years (2014 - 2018), compared with greater fishing effort located to the south and south-west of the Operational Area, between Exmouth and Dampier (up to five vessels operating).

FishCube data for annual fishing effort in blocks within the Operational Area (for blocks where at least three vessels have fished and data is available) ranges from 19 days to 145 days per year between 2014 and 2018, with an average of 36 days per 60 nm block per year (refer to Figure 4.32).

Specimen Shell Managed Fishery

Analysis of Fishcube data shows that the area of fishing effort over the West Australian coast was 493,230 km^2 for the period between 2014 and 2018. The Operational Area overlaps with 1,062 km^2 (0.2%) of the area of fishing effort (refer to Figure 4.33). FishCube data for the SSMF 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.

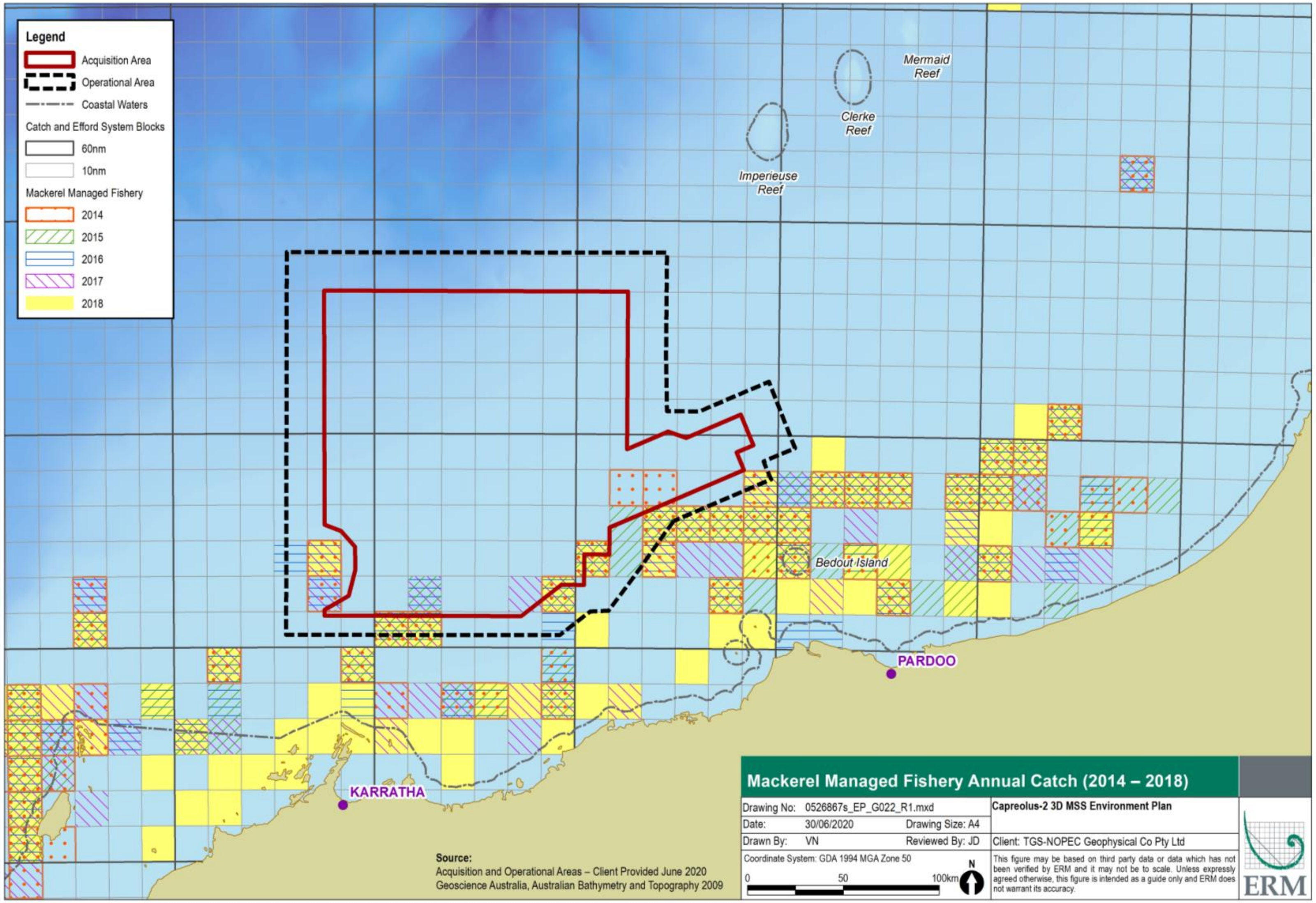


Figure 4.23 Mackerel Managed Fishery Annual Effort (2014 – 2018)

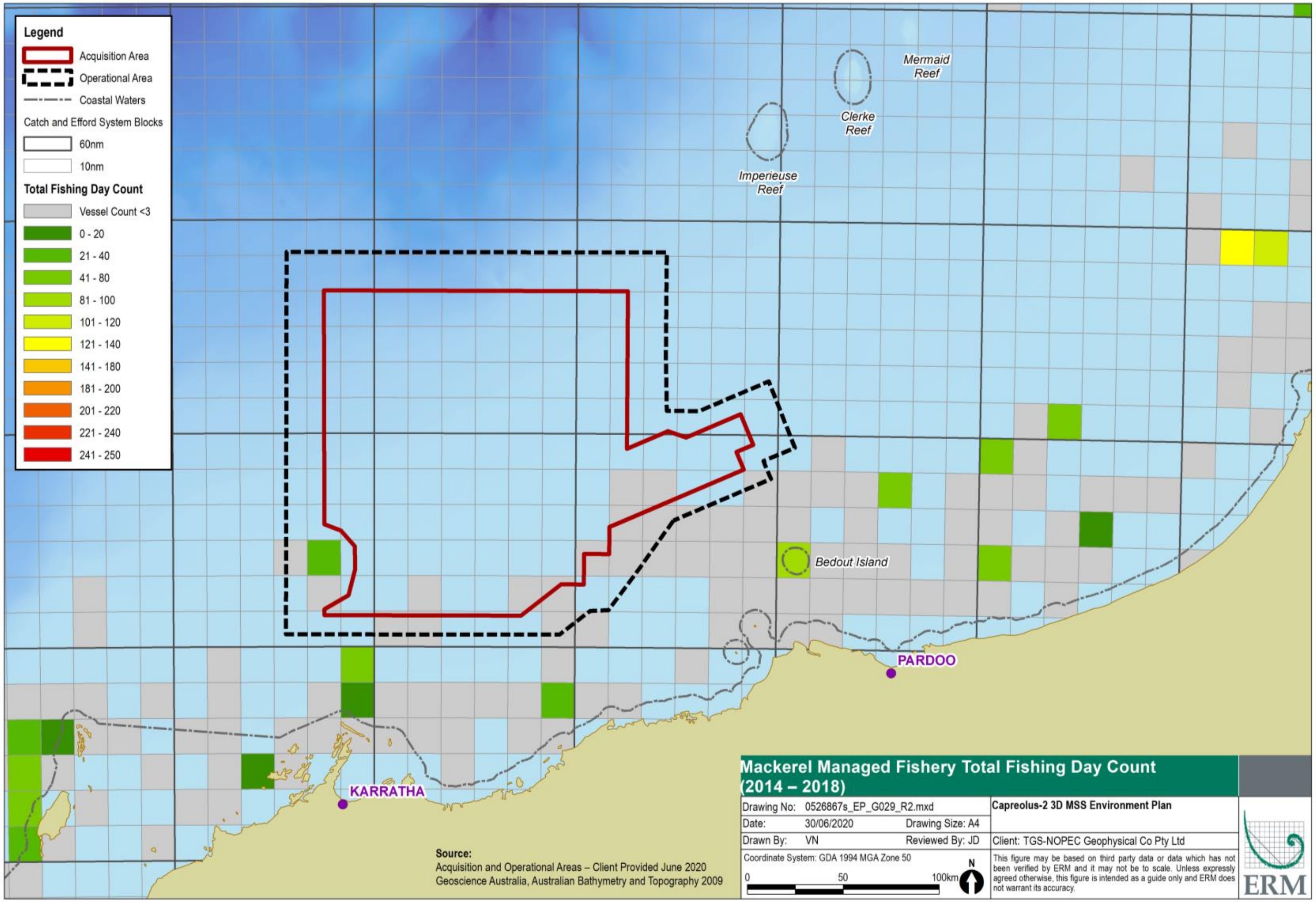


Figure 4.24 Mackerel Managed Fishery Total Fishing Day Count (2014 – 2018)

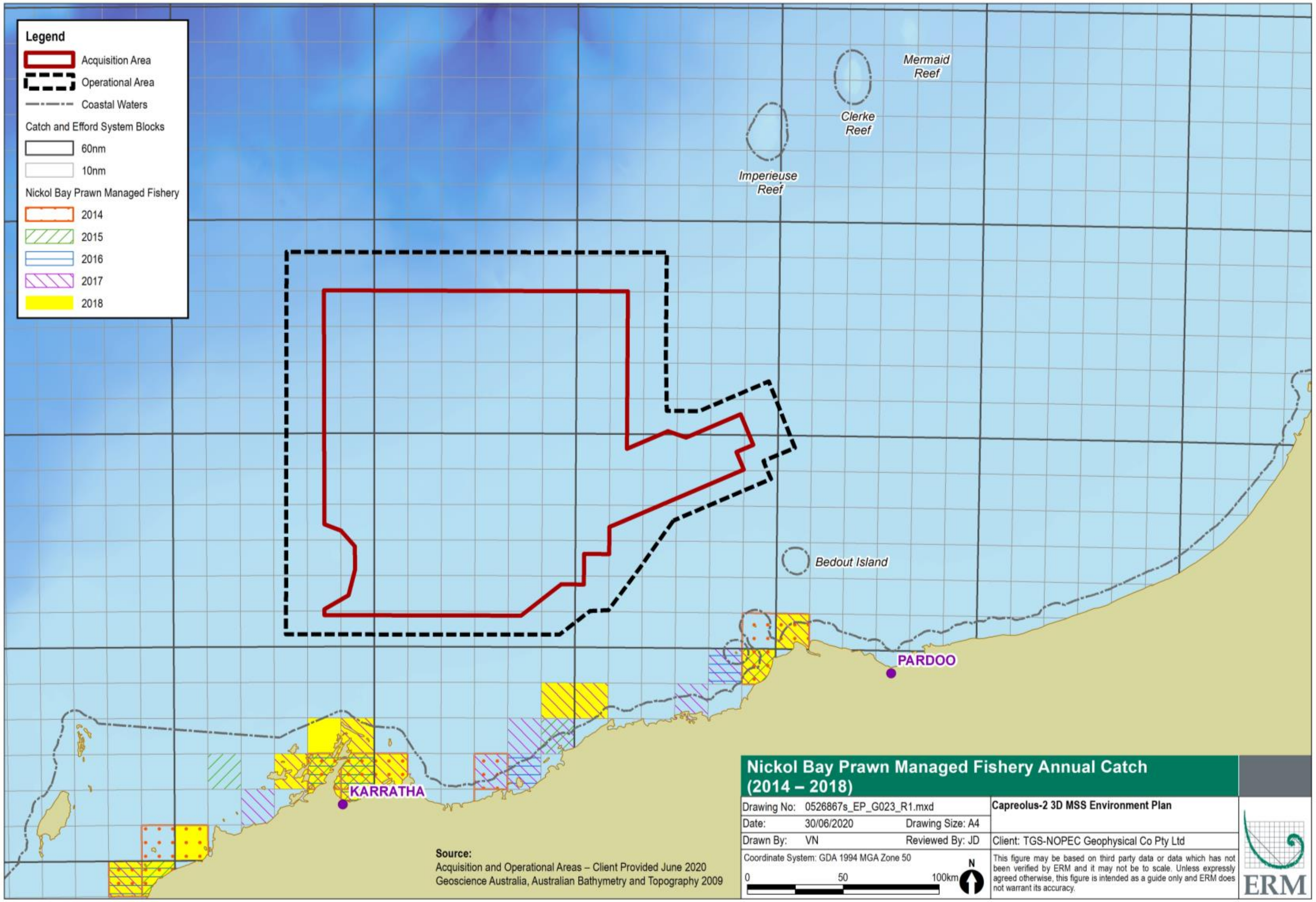


Figure 4.25 Nickol Bay Prawn Managed Fishery Annual Effort (2014 – 2018)

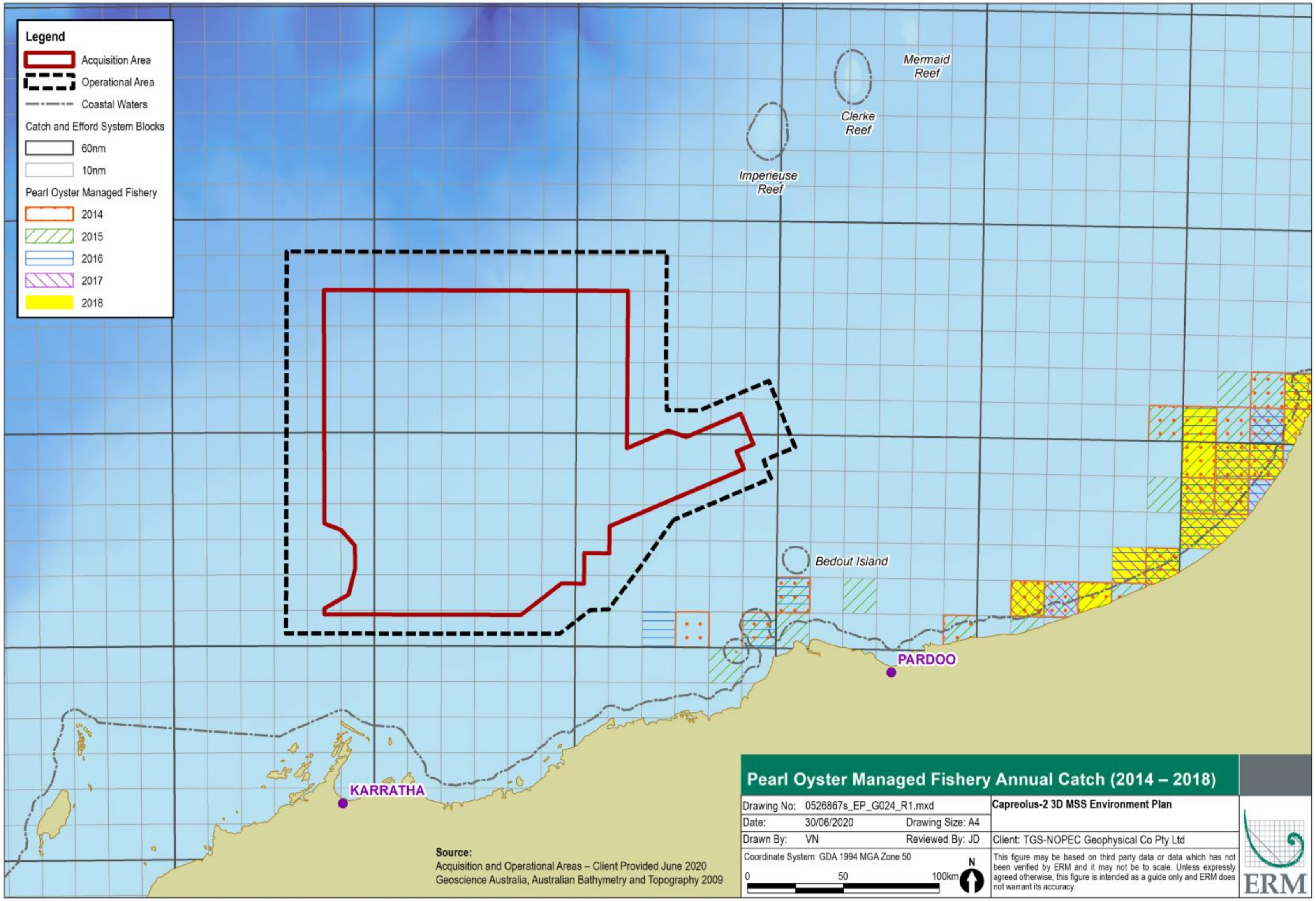


Figure 4.26 Pearl Oyster Managed Fishery Annual Effort (2014 - 2018)

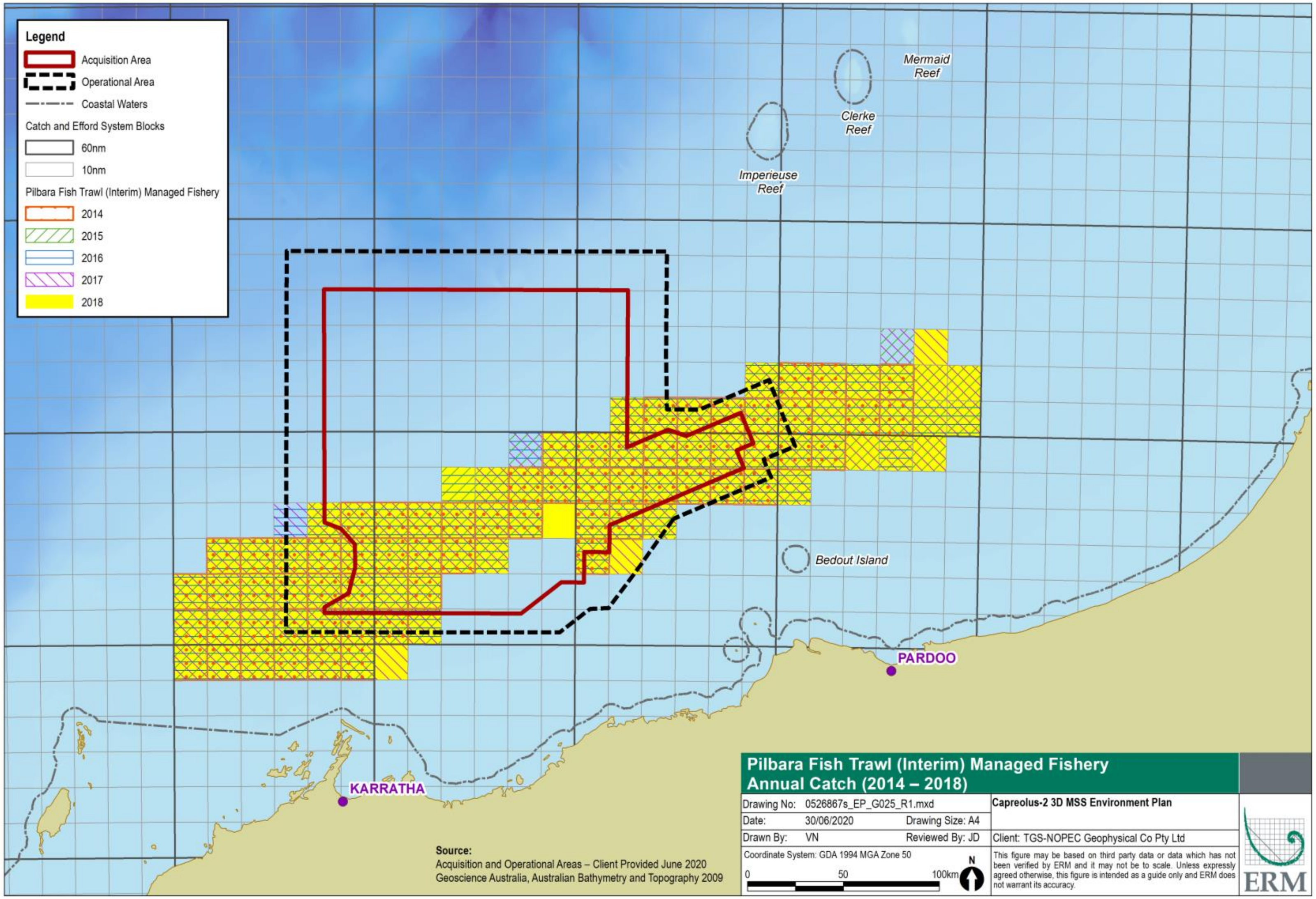


Figure 4.27 Pilbara Fish Trawl (Interim) Managed Fishery Annual Effort (2014 – 2018)

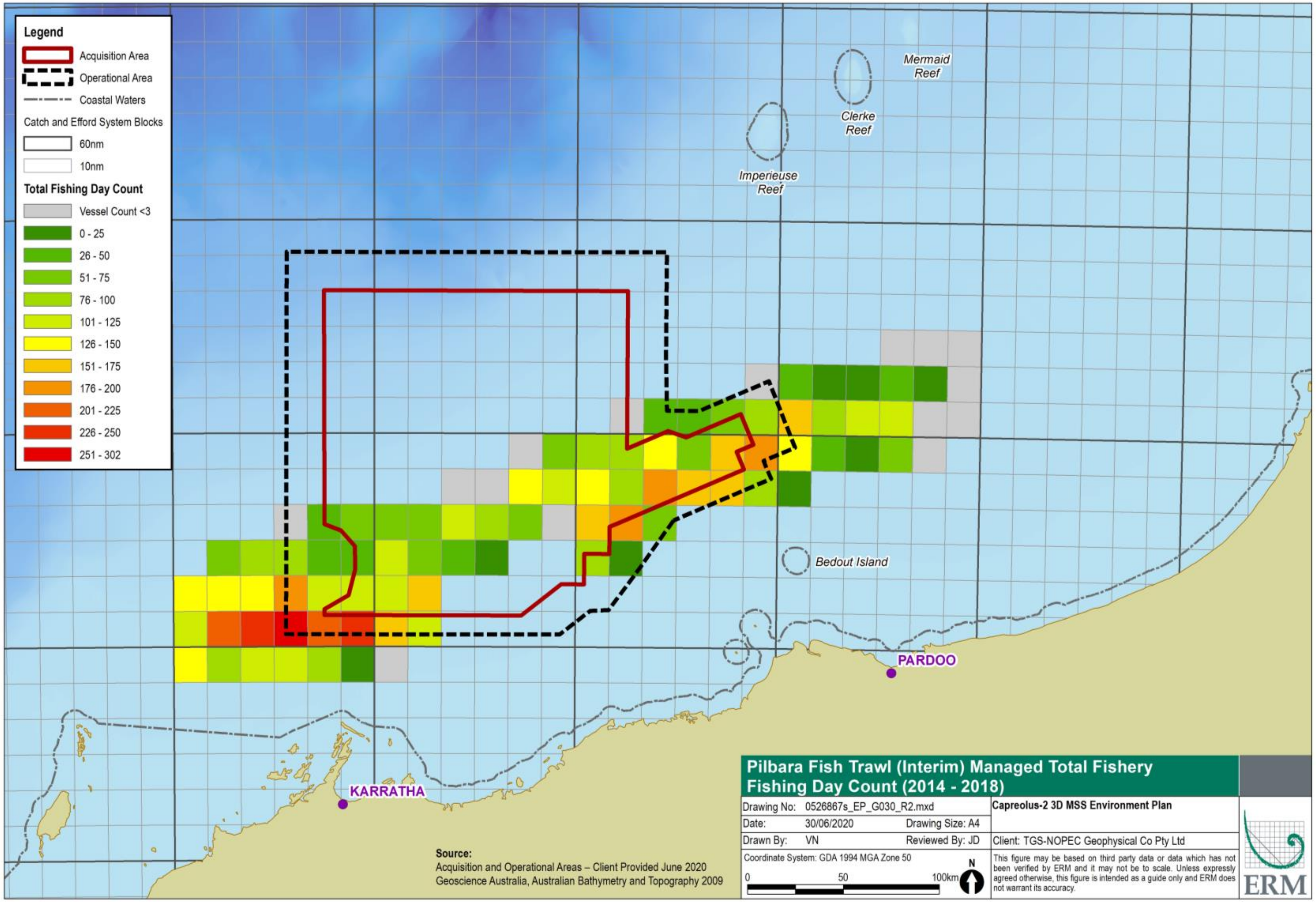


Figure 4.28 Pilbara Fish Trawl (Interim) Managed Fishery Total Fishing Day Count (2014 – 2018)

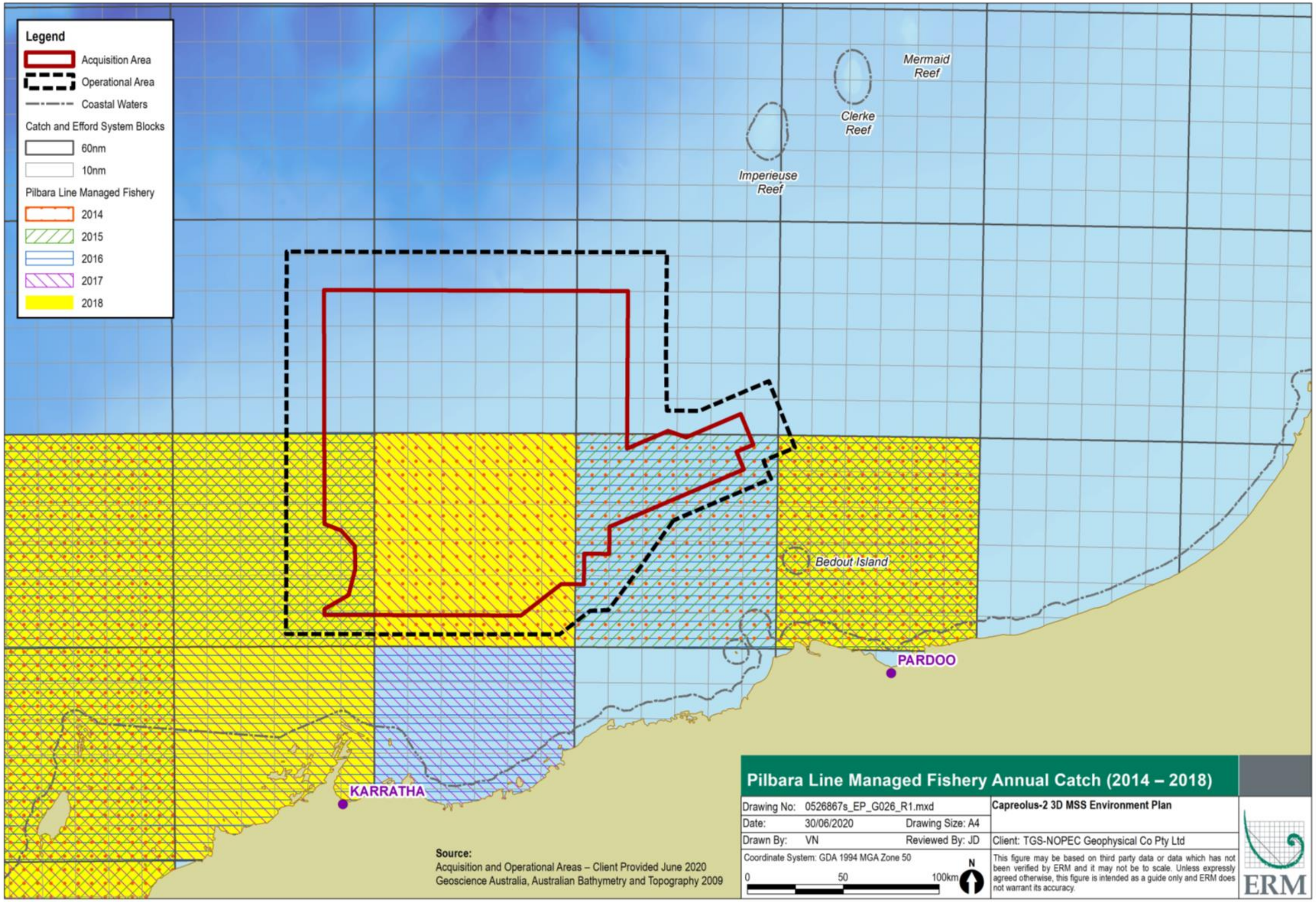


Figure 4.29 Pilbara Line Managed Fishery Annual Effort (2014 – 2018)

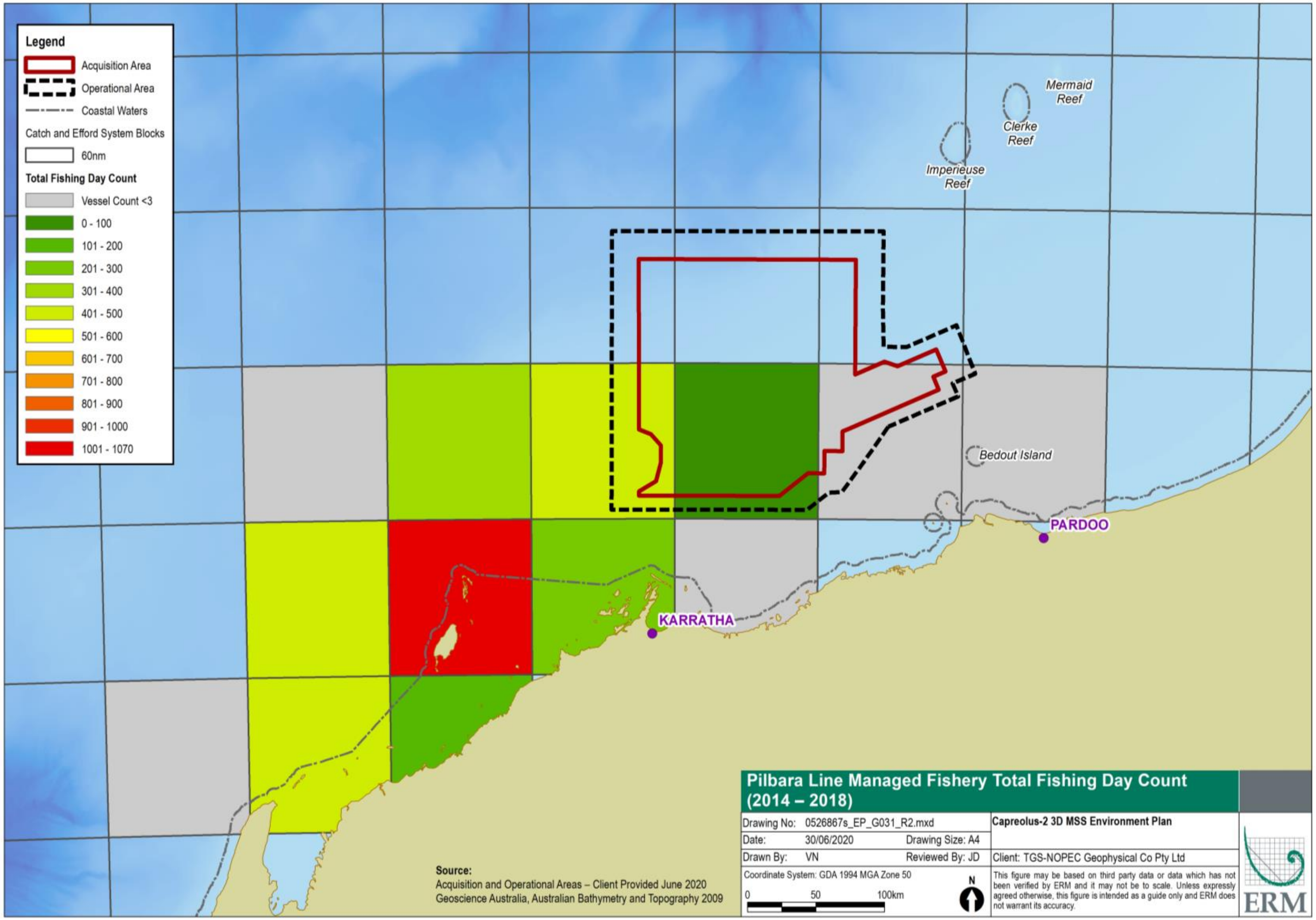


Figure 4.30 Pilbara Line Managed Fishery Total Fishing Day Count (2014 – 2018)

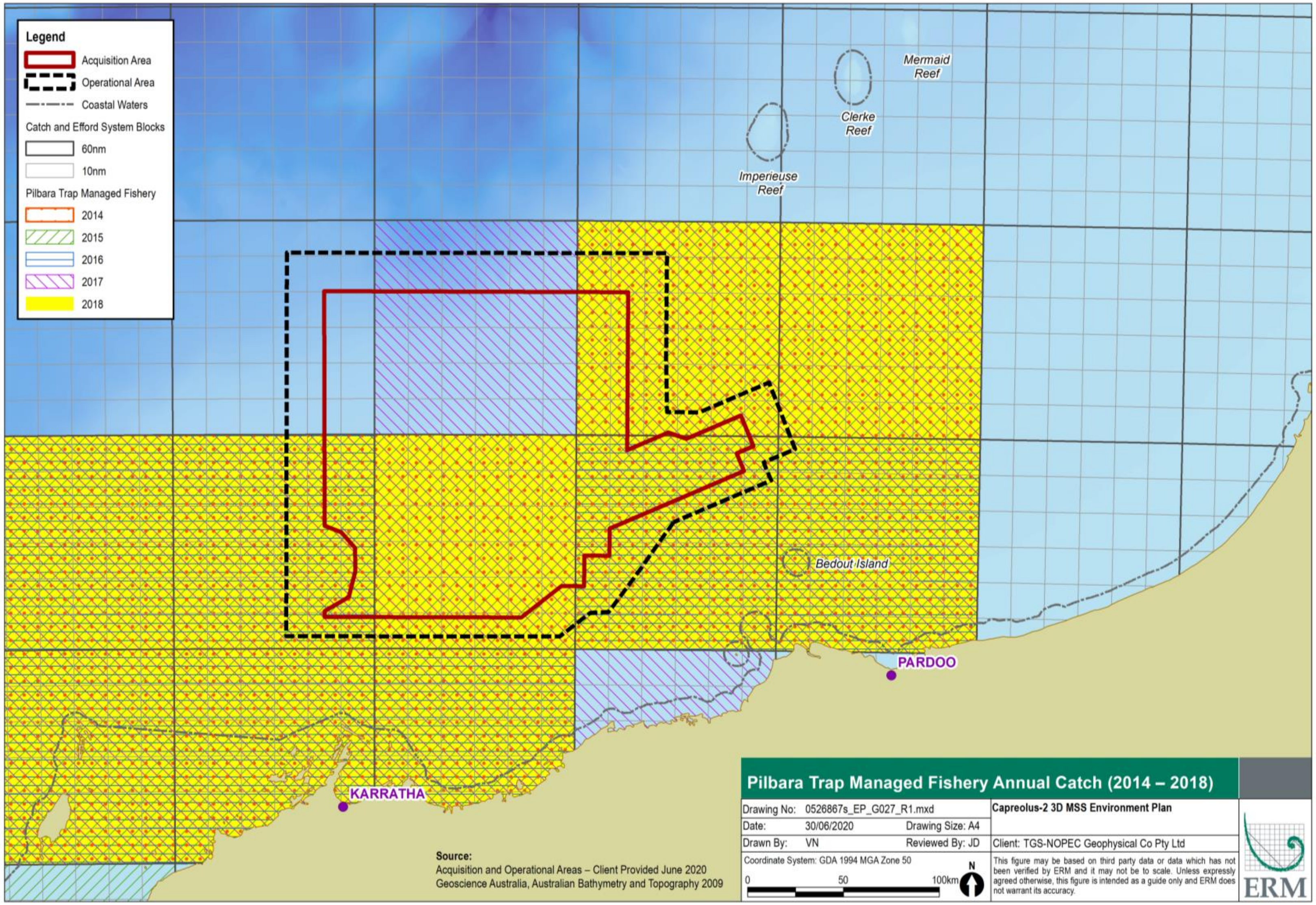


Figure 4.31 Pilbara Trap Managed Fishery Annual Effort (2014 – 2018)

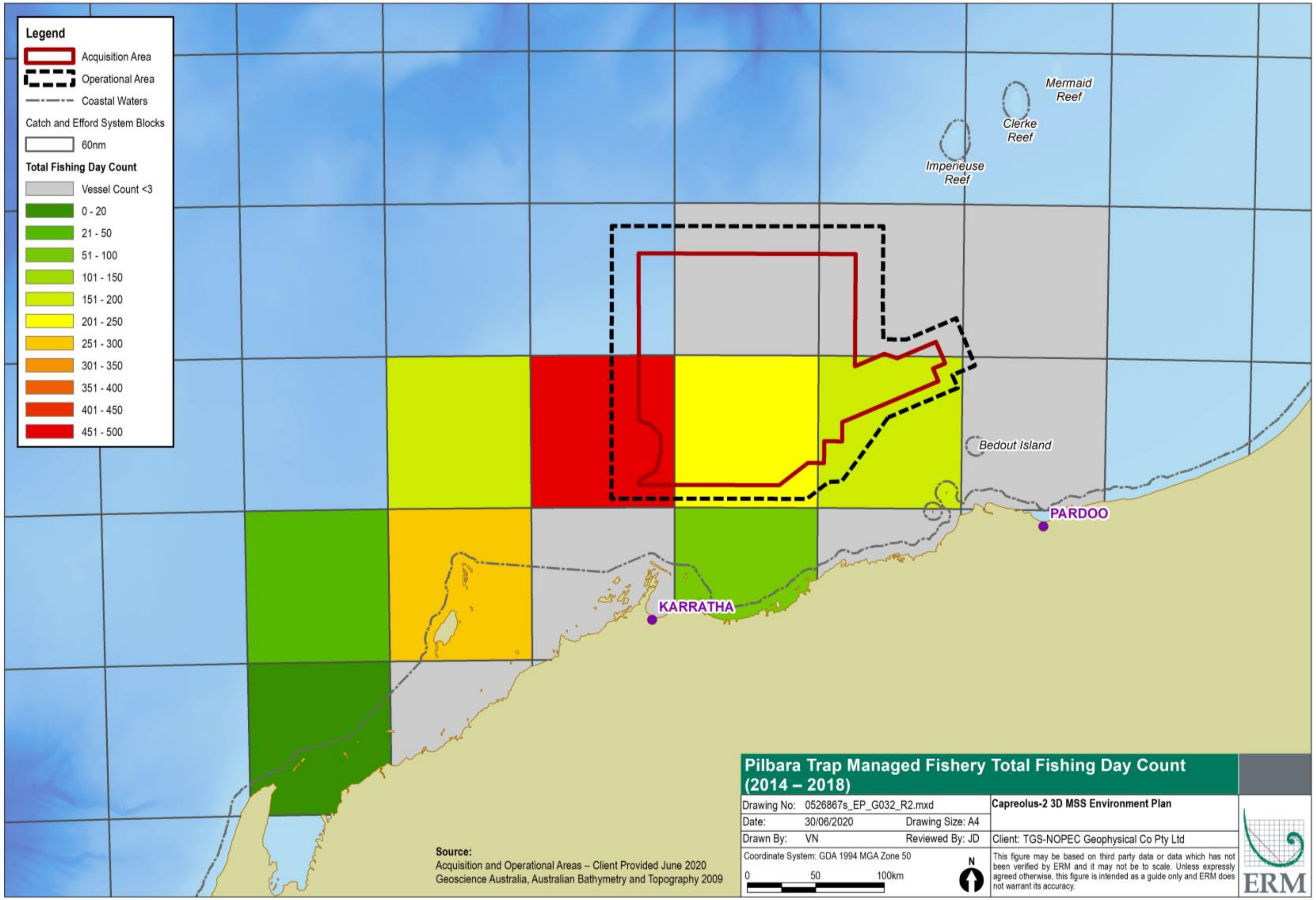


Figure 4.32 Pilbara Trap Managed Fishery Total Fishing Day Count (2014 – 2018)

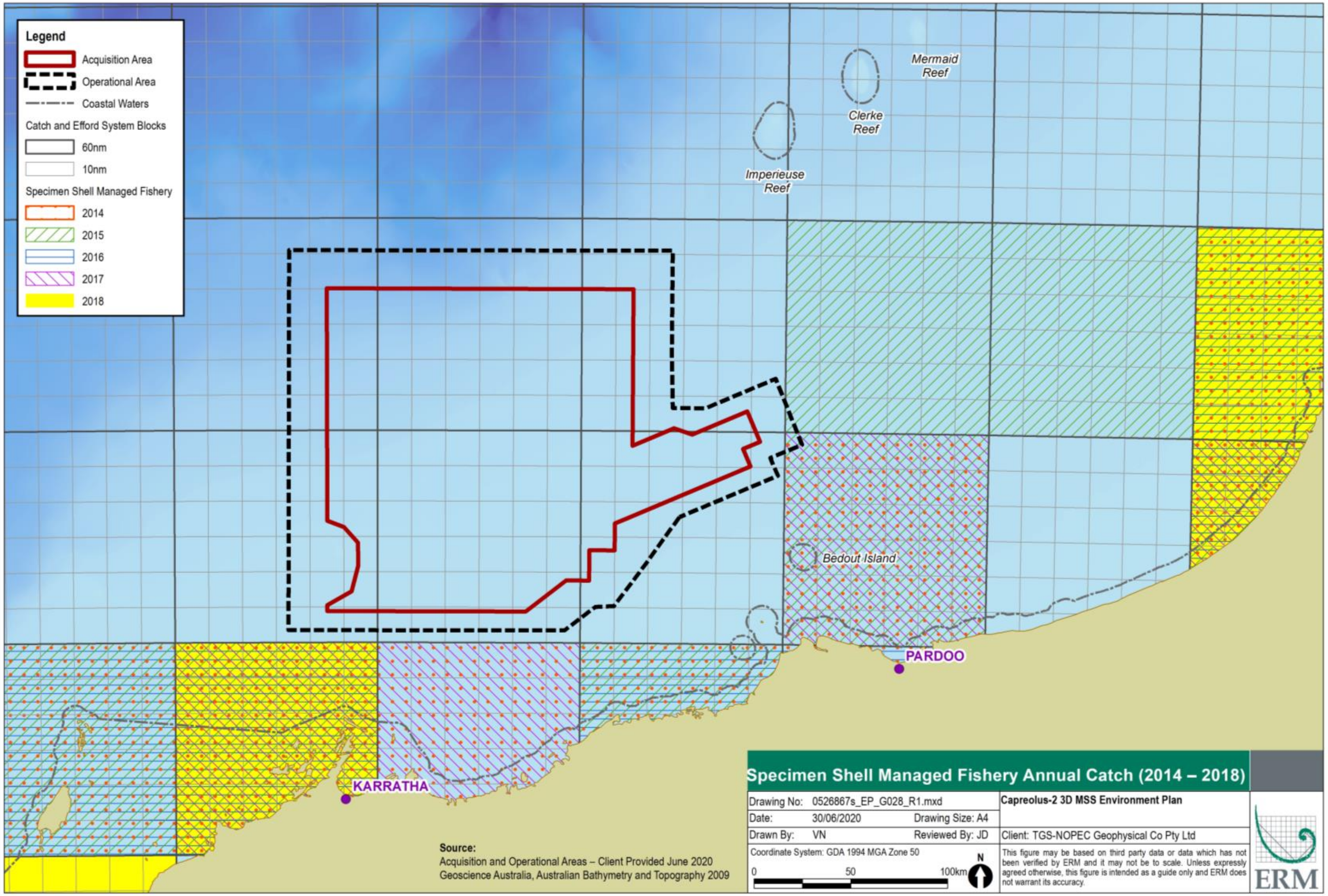


Figure 4.33 Specimen Shell Managed Fishery Annual Effort (2014 – 2018)

4.6.8 Tourism and Recreation

Recreational fishing in the NWMR 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 & Santoro 2012). Recreational fishing is not expected to occur with the Operational Area due to the distance offshore and water depths (22 m – 1,684 m).

Recreational fishing occurs at Rowley Shoals, which are located within the EMBA. Recreational fishing is not permitted at Rowley Shoals, which forms part of Mermaid Reef. Whilst recreational fishing does occur at Rowley Shoals, it is occasional due to the remote location. Clerke Reef and Imperieuse Reef are also places for 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).

In addition, recreational activities such as boating, diving and fishing may occur around Bedout Island (approximately 44 km from the Operational Area). However, there are no known tour operators that transit to Bedout Island.

4.6.9 Defence Activities

The Department of Defence operate military firing practice and exercise areas at several locations around the 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 550 km east of the Operational Area (outside of the EMBA. A search of the Department of Defence's unexploded ordinance (UXO) map confirmed UXO are not known to occur within the Operational Area (PSMA 2019).

4.6.10 Shipping Industry

The Pilbara offshore region facilitates 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. Shipping activities in the region include:

- international bulk freighters/tankers, including mineral ore, hydrocarbons (LNG, liquefied petroleum gas, condensate) and salt carriers;
- general cargo ships;
- domestic support/supply vessels servicing offshore facilities;
- construction vessels/barges/dredges; and
- offshore survey vessels.

The Australian Maritime Safety Authority (AMSA) has introduced a network of marine fairways on the NWS of WA to direct large vessels such as bulk carriers and LNG ships trading to the major ports into pre-defined routes to keep them clear of existing and planned offshore infrastructure. There are seven shipping fairways passing through the Operational Area (refer to Figure 4.34).

Frequent traffic throughout the Operational Area is expected due to vessels heading in and out of Port Hedland and Karratha. Some increased vessel activity surrounding established petroleum facilities (i.e. south-western boundary of the Operational Area) and other petroleum exploration interests (e.g. Santos Dorado on the western boundary of the Acquisition Area) are also noted.

Vessel traffic in waters overlapping the Operational Area between December 2019 to May 2020 (inclusive), based on the latest six months of automatic identification system (AIS) data supplied by AMSA, is presented in Figure 4.34 and Table 4-15. During the six month period, between 66 and 617 vessels passed through the shipping fairways per month, equivalent to 2.3 to 19.9 vessels per day. The data is indicative of the likely traffic volumes that may be expected during the proposed survey. The average number of days each vessel spent within the Operational Area ranged between 2.2 days to 2.8 days. This suggests that the majority of vessels were transiting through the Operational Area (refer to Table 4-15).

Table 4-15 Number of Vessels per Month within the Operational Area

	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
Total number of vessels within the Operational Area	91	599	70	81	638	641
Average number of days spent within the Operational Area (per vessel)	2.5	2.2	2.8	2.4	2.3	2.3

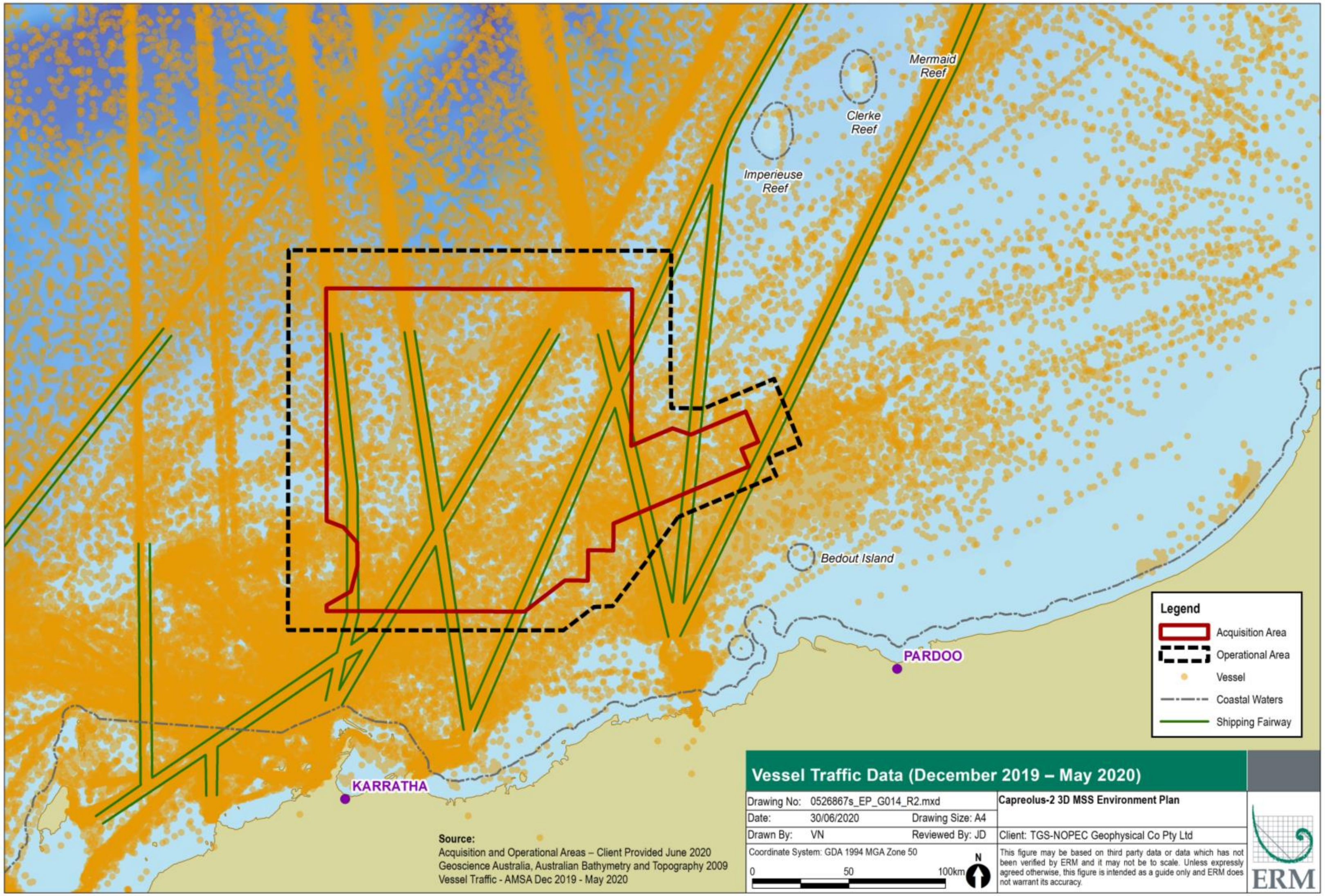


Figure 4.34 Vessel Traffic (AIS Data December 2019 – May 2020)

4.6.11 Petroleum Industry

The region currently supports a number of industries including petroleum exploration and production. The NWS is a major oil and gas hub in Australia, with several petroleum companies operating in the region. The Operational Area overlaps with Woodside's Angel platform located within WA-3-L (refer to Table 4-16). Other exploration activities, such as seismic surveys and exploration drilling, may occur within and surrounding the Operational Area over the life of this EP.

Petroleum titleholders with titles that are located within the Operational Area are listed in Table 4-16 and presented in Figure 4.35.

Table 4-16 Petroleum Titles within the Operational Area

Permit	Permit Type	Petroleum Operator
WA-191-P	Exploration	Santos Limited
WA-1-P	Exploration	Santos WA Northwest Pty Ltd
WA-208-P	Exploration	Santos WA Northwest Pty Ltd
WA-20-L	Production License	Santos WA Northwest Pty Ltd
WA-26-L	Production License	Santos Limited
WA-27-L	Production License	Santos Limited
WA-3-L	Production License	Woodside Energy Ltd.
WA-435-P	Exploration	Santos WA Northwest Pty Ltd
WA-437-P	Exploration	Santos WA Northwest Pty Ltd
WA-438-P	Exploration	Santos WA Northwest Pty Ltd
WA-458-P	Exploration	Lightmark Enterprises Pty Ltd
WA-482-P	Exploration	Santos WA Northwest Pty Ltd
WA-48-R	Retention Lease	Santos WA Northwest Pty Ltd
WA-4-L	Production License	Woodside Energy Ltd.
WA-503-P	Exploration	Pilot Energy Limited
WA-524-P	Exploration	Carnarvon Petroleum Limited
WA-541-P	Exploration	Santos WA Northwest Pty Ltd
WA-542-P	Exploration	Equinor Australia B.V.
WA-54-L	Production License	Santos Limited

Permit	Permit Type	Petroleum Operator
WA-8-L	Production License	Sky Energy Pty Ltd

4.6.11.1 Browse to NWS Project

Woodside Energy Ltd (Woodside), as Operator for and on behalf of the Browse Joint Venture (BJV), is proposing to develop the Brecknock, Calliance and Torosa fields located approximately 425 km north of Broome in the offshore Browse Basin.

The proposed Browse to NWS Project will comprise subsea infrastructure and two floating production storage offtake (FPSO) facilities, connected to existing NWS Project infrastructure via the ~900 km Browse Trunkline (BTL). A detailed description of the proposed Browse to NWS Project infrastructure is provided in Section 3.6 of the Environmental Impact Statement (EIS). Copies of the draft EIS are available on the Woodside website: www.woodside.com.au.

The proposed route of the BTL intersects the northern portion of the Capreolus-2 3D MSS Acquisition Area. Subject to all necessary joint venture and regulatory approvals being obtained and appropriate commercial arrangements being finalised, Woodside may commence construction and installation of the BTL as early as 2022.

TGS will work collaboratively with Woodside and other petroleum operators to ensure interactions offshore are minimised. TGS will develop a simultaneous operations (SIMOPS) plan in collaboration with Woodside, should seismic survey activity be undertaken during installation/construction of the BTL.

4.6.11.2 Potential Seismic Surveys in the Region

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 by NOPSEMA) are presented in Table 7-20.

Table 4-17 Other Potential Seismic Surveys Occurring in the Region

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
TGS Renaissance South	The Operational Area is 300,000 km^2. No defined Acquisition Area in the EP.	The Renaissance South Operational Area, partially overlaps with the TGS Capreolus-2 3D MSS.	2016 - 2021 The specific commencement dates and durations of individual surveys has not been confirmed. Note - TGS will not acquire the Renaissance South survey at the same time as the TGS Capreolus-2 3D MSS. Therefore, the survey has been excluded from the cumulative impact assessment.	The EP is accepted and valid to 2021.
PGS Rollo MC MSS	The Operational Area is 117,833 km^2. No defined Acquisition Area in the EP. Note – based on restrictions in the EP, it has been assumed for assessment purposes that acquisition is limited to a maximum of 25,000 km^2 per calendar year.	The Beagle Acquisition Area overlaps with the TGS Capreolus-2 3D MSS.	2018 – 2023 The specific commencement dates and durations of individual surveys has not been confirmed. .	The EP is accepted and valid to 2023.
3D Oil Sauropod 3D MSS	The Acquisition Area is 3,500 km^2.	The Sauropod 3D MSS Acquisition Area, is located approximately 83 km west of the Capreolus-2 3D MSS.	January – April 2021. No seismic acquisition is planned for 2020. Maximum of 60 days of acquisition.	The EP is accepted and valid to 2021.
INPEX 2D Seismic Survey (WA-532-P, WA-533-P, WA-50-L)	The Acquisition Area is 65,138 km^2.	The INPEX 2D Acquisition Area is located approximately 190 km from the Capreolus-2 3D MSS.	1 November 2020 – 31 December 2021. No acquisition between 1 June – 31 October in 2020 or 2021.	The EP is accepted and valid to 2021.

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
			Maximum of 210 days of acquisition.	
Santos Keraudren Extension 3D MSS	The full-fold acquisition area is 8,620 km^2.	The Keraudren Extension 3D MSS full-power zone is located 2 km from the TGS Capreolus-2 3D MSS.	1 February – 31 July, 2020 – 2022. No seismic acquisition is planned for 2020. Maximum of 162 days of acquisition.	The EP is accepted and valid to 2022.

4.6.12 Submarine Cables

The Operational Area overlaps with two submarine telecommunication cables – the JASURAUS system (also known as the Asia Pacific Cable Network (APCN) Australian Extension) and the North West Cable System (NWCS) (refer to Figure 4.36).

The JASURAUS system connects Australia with Indonesia (Jakarta), linking Australia to the APCN. The APCN is a consortium Intra-Asia submarine cable system linking Japan, Korea, Taiwan, Hong Kong, the Philippines, Indonesia, Singapore, Malaysia and Thailand. TGS understands the JASURAUS system was decommissioned in 2012.

The NWCS connects offshore oil and gas facilities in the Browse, Bonaparte and Carnarvon Basins to onshore locations. The subsea cable system was built by Nextgen Group, a national telecommunications operator which is now part of Vocus Communications. The subsea cable extends 2,000 km between landing stations Port Headland and Darwin.

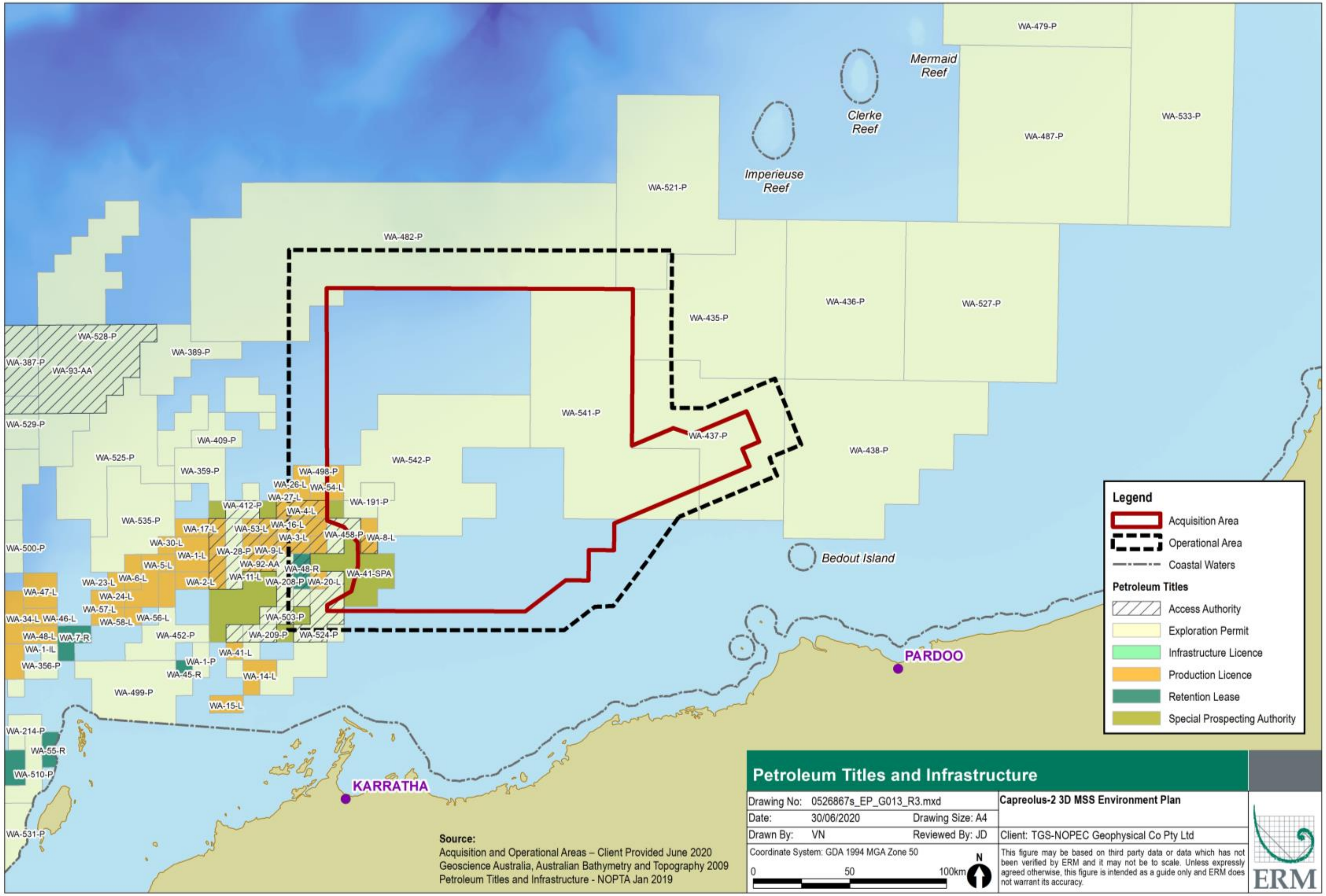


Figure 4.35 Petroleum Titles within the Operational Area

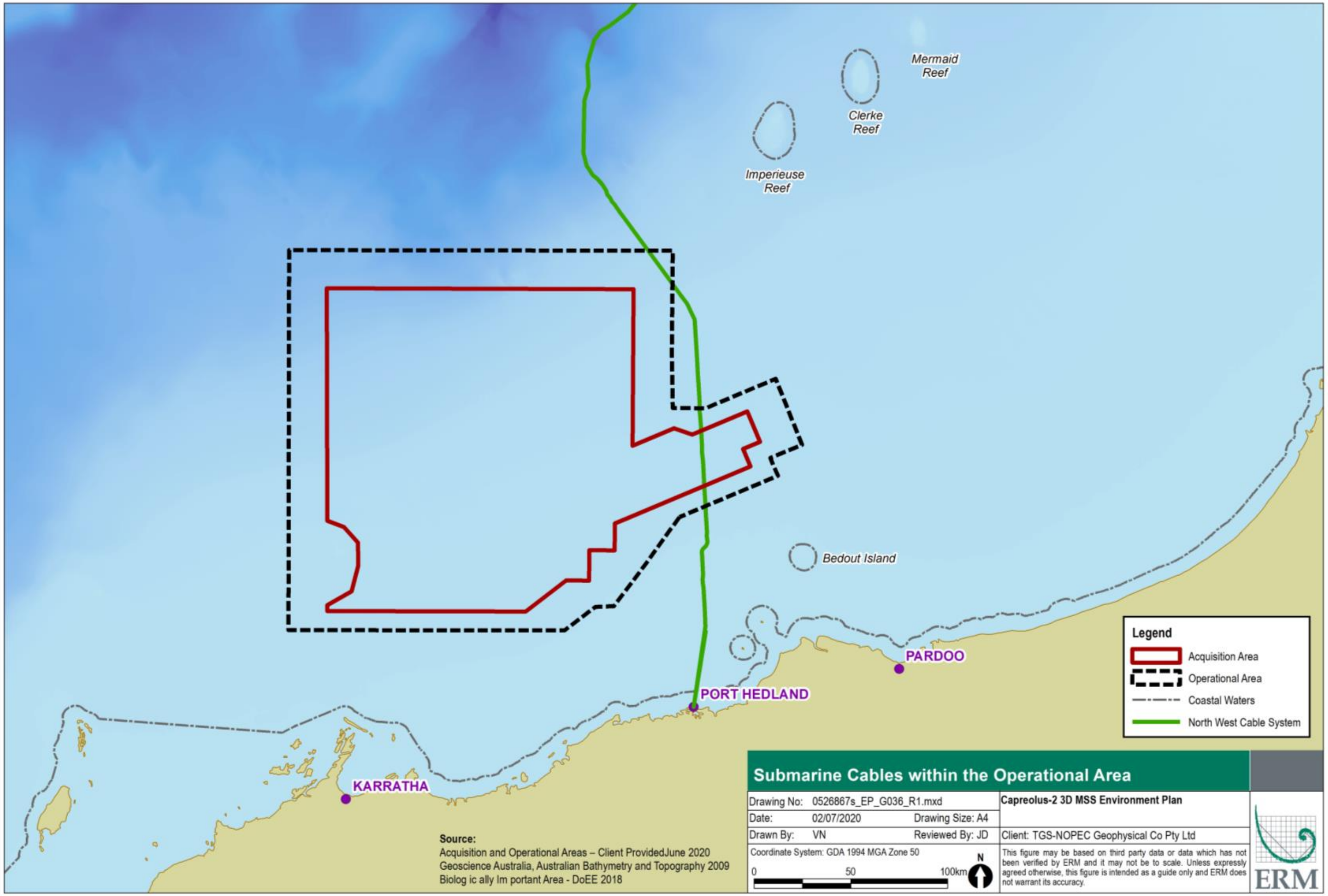


Figure 4.36 Submarine Cables within the Operational Area

5. STAKEHOLDER CONSULTATION

For the purposes of this EP, and in accordance with Regulation 11A of the OPPGS (E) Regulations 2009, relevant stakeholders are defined as person(s) whose functions, interests or activities may be affected by the activities to be carried out under this EP.

5.1 Consultation Approach

Consultation has been planned and undertaken with the aim of:

- Informing relevant stakeholders of the proposed activity;
- Collecting information about the stakeholders' interests and activities in the Operational Area; and
- Providing stakeholders with the opportunity to ask questions and raise concerns or issues about the proposed activity.

The consultation approach employed by TGS has been guided by the following material:

- NOPSEMA Information Paper IPI411 - Consultation requirements under the OPGGS (E) Regulations 2009, Rev 2, December 2014 (NOPSEMA 2014);
- NOPSEMA Brochure - Requirements for consultation and public comment on petroleum activities in Commonwealth waters – August 2018 (NOPSEMA 2018d);
- NOPSEMA Brochure – Public Comment on Environment Plans – March 2019 (NOPSEMA 2019c)
- AFMA - Petroleum industry consultation with the commercial fishing industry (AFMA 2019);
- DoIIS Offshore Petroleum and Greenhouse Gas Activities: Consultation with Australian Government agencies with responsibilities in the Commonwealth Marine Area (DoIIS 2016); and
- WA Department of Fisheries Guidance Statement: Oil and gas industry consultation with the Department of Fisheries (DoF 2013).

5.2 Relevant Stakeholders

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

For the consultation process TGS has used the requirements in the OPGGS (E) Regulations in regards to a relevant person:

- Each Department or agency of the Commonwealth to which the activities to be carried out under the EP, or the revision of the EP, may be relevant;
- Each Department or agency of the State to which the activities to be carried out under the EP, or the revision of the EP, may be relevant;
- The Department of the responsible State Minister;
- Person or organisation whose functions, interests or activities may be affected by the activities to be carried out under the EP, or the revision of the EP; and
- Any other person or organisation that is considered relevant.

A summary of the assessment process undertaken to determine stakeholder relevancy is provided in Table 5-1.

TGS understands 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 with sufficient information and invited to provide feedback.

Table 5-1 Assessment of Relevant Stakeholders

Stakeholder	Relevant (Y/N)	Reasoning / Validation
Each Department or agency of the Commonwealth to which the activities to be carried out under the EP, or the revision of the EP, may be relevant		
Australian Fisheries Management Authority (AFMA)	Y	Responsible for managing Commonwealth fisheries and the implementation of Commonwealth fisheries policy. AFMA is a relevant stakeholder, given the survey has the potential to impact Commonwealth managed fisheries.
Australian Hydrographic Service (AHS)	Y	Responsible for the publication and distribution of nautical products and other information required for the safety of ships navigating in Australian waters. TGS is required to notify AHS a minimum of 3 weeks prior to the commencement of activities.
Australian Maritime Safety Authority (AMSA)	Y	AMSA is a Commonwealth agency responsible for maritime safety, protection of the marine environment from ship-sourced pollution and maritime and aviation search and rescue. AMSA also implements and enforces a range of legislation relevant to the Commonwealth marine area, which give effect to Australia's obligations under various international treaties and conventions including the MARPOL International Convention for the Prevention of Pollution from Ships. Domestic legislation includes the *Navigation Act 2012* and the Protection of the Sea legislation.
Department of Agriculture, Water and the Environment (formerly the *Department of Agriculture*)	Y	The Department is responsible for managing biosecurity (in relation to animals and plants). The Department implements and enforces the *Biosecurity Act 2015* (including implementing ballast water requirements). The Department is a relevant stakeholder where an offshore activity has the potential to transfer marine pests into Commonwealth waters. The Department is also responsible for managing Commonwealth fisheries. The Department is a relevant stakeholder where an offshore activity has the potential to impact Commonwealth managed fisheries.
Department of Communications and the Arts (DoCA)	Y	The Department of Communications and the Arts has responsibility for Schedule 3A of the *Telecommunications Act 1997* that is administered by the Australian Communications Media Authority (ACMA). The *Telecommunications Act 1997* provides for submarine cable protection zones to be declared around international submarine cables that are considered to be of national significance. Consultation with the Department was undertaken to determine the presence of submarine cables within the Operational Area.

Stakeholder	Relevant (Y/N)	Reasoning / Validation
Department of Defence (DoD)	Y	The Australian Defence Force (ADF) utilises several maritime exercise areas in Australian waters to perform a unique role in support of Australia's strategic and national security interests. Defence is a relevant agency where the activity may impact on operational requirements. The Operational Area and EMBA do not overlap with known military firing practise and exercise areas. However, consultation with DoD was undertaken to ensure there are no overlaps with other areas.
Department of Industry, Innovation and Science (DoIIS)	Y	DoIIS regulate oil and gas activities in Australian waters under the OPGGSA 2006.
Director of National Parks (DoNP)	Y	The DoNP is the statutory authority responsible for administration, management and control of AMP. The DoNP was consulted for the activity, given the Agro-Rowley Terrace Maine Park, Dampier Marine Park and the Eighty Mile Beach Maine Park is located in close proximity, 45 km, 40 km and 0.1 km respectively.
National Native Title Tribunal (NNTT)	Y	The NNTT is an independent agency responsible for administration of the *Native Title Act 1993.* The NNTT was initially contacted to understand the baseline environment and potential Native Title interest.
Each Department or agency of a State to which the activities to be carried out under the EP, or the revision of the EP, may be relevant		
WA Department of Biodiversity, Conservation and Attractions (DBCA)	N	Responsible for managing WA parks, forests and reserves to conserve wildlife, provide sustainable recreation and tourism opportunities, protect communities and assets from bushfire and achieve other land, forest and wildlife management objectives. Given, the activity is not located within any State marine parks; consultation with the DBCA is not required.
WA Department of Primary Industries and Regional Development (Fisheries) (DPIRD)	Y	Responsible for managing WA fisheries and aquatic ecosystems, assessment and monitoring of fish stocks, enforcement and education, biosecurity management and licensing commercial and recreational fishing activity, including commercial aquaculture. DPIRD Fisheries has been consulted, given the survey has the potential to impact WA managed fisheries.
WA Department of Transport (DoT)	Y	Control agency for marine pollution emergencies if impact to State waters. DoT Offshore Petroleum Industry Guidance Note "Marine Oil Pollution: Response and Consultation Arrangements" (December 2017) - Section 10.1 requires petroleum titleholders to consult with DoT for activities that have the potential to cause a marine pollution emergency in State Waters.

Stakeholder	Relevant (Y/N)	Reasoning / Validation
		Based on oil spill modelling, WA State waters may be impacted by a marine diesel spill from a vessel; therefore, consultation with the DoT is required.
The Department of the responsible State Minister		
WA Department of Mines, Industry Regulation and Safety (DMIRS)	Y	Consultation required as per DMP Consultation Guidance Note (For the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009).
Person or organisation whose functions, interests or activities may be affected by the activities to be carried out under the EP, or the revision of the EP		
Australian Southern Bluefin Tuna Industry Association (ASBTIA)	Y	ASBTIA is the peak body representing Southern Bluefin Tuna ranching companies in Australia.
Commonwealth Fisheries Association (CFA)	Y	The CFA is non-profit organisation and is the peak body representing the collective rights, responsibilities and interests of a diverse commercial fishing industry in Commonwealth-regulated fisheries.
North West Slope Trawl Fishery - individual licence holders	Y	The Operational Area overlap with the fishery. Consultation undertaken with licence holders active in Western Australia. Additional information on the fishery can be found in Section 4.6.7.
Pearl Producers Association (PPA)	Y	The PPA is the peak representative organisation of The Australian South Sea Pearling Industry.
Recfishwest	Y	The organisation is the peak fishing recreational body.
Southern Bluefin Tuna Fishery	Y	The Operational Area overlaps with the fishery. Consultation undertaken with the ASBTIA. Additional information on the fishery can be found in Section 4.6.7.
WA Mackerel Managed Fishery (MMF)	Y	The Operational Area overlaps with the fishery. All licence holders have been contacted. Additional information of the fishery can be found in Section 4.6.7.
WA Nickol Bay Prawn Managed Fishery (NBPMF)	Y	The Operational Area overlaps with the fishery. All licence holders have been contacted. Additional information of the fishery can be found in Section 4.6.7.

Stakeholder	Relevant (Y/N)	Reasoning / Validation
WA Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)	Y	The Operational Area overlaps with the fishery. All licence holders have been contacted. Additional information of the fishery can be found in Section 4.6.7.
WA Pilbara Trap Managed Fishery (PTMF)	Y	The Operational Area overlaps with the fishery. All licence holders have been contacted. Additional information of the fishery can be found in Section 4.6.7.
WA Pilbara Line Managed Fishery (PLMF)	Y	The Operational Area overlaps with the fishery. All licence holders have been contacted. Additional information of the fishery can be found in Section 4.6.7.
WA Pearl Oyster Managed Fishery (POMF)	Y	The Operational Area overlaps with Zone 1 and 2 of the fishery. Consultation has been undertaken with the Pearl Producers Association. Additional information on the fishery can be found in Section 4.6.7.
WA Specimen Shell Manager Fishery (SSMF)	Y	The Operational Area overlaps with the fishery. All licence holders have been contacted. Additional information of the fishery can be found in Section 4.6.7.
Western Australian Fishing Industry Council (WAFIC)	Y	WAFIC represents professional fishing, pearling and aquaculture enterprises, processors and exporters in WA.
Western Tuna and Billfish Fishery	Y	The Operational Area overlaps the fishery. Consultation has been undertaken with licence holders active in WA. Additional information on the fishery can be found in Section 4.6.7.
Any other person or organisation that the titleholder considers relevant		
Australian Marine Oil Spill Centre (AMOSC)	Y	The Australian Marine Oil Spill Centre is an organisation set up by the petroleum industry to enable a quick and effective response to oil spills around the Australian coastline. AMOSC operates Australia's major marine spill response equipment stockpile for the Australian oil and gas industry on 24hr stand-by for rapid response anywhere around the Australian coast.
British Petroleum (BP)	Y	Nearby petroleum titleholder.
Carnarvon Petroleum Limited	Y	Nearby petroleum titleholder.
CGG Services (Australia) Pty Ltd	Y	Nearby petroleum titleholder.

Stakeholder	Relevant (Y/N)	Reasoning / Validation
Chevron	Y	Nearby petroleum titleholder.
Equinor Australia	Y	Nearby petroleum titleholder.
FAR Limited (Lightmark Enterprises Pty Ltd)	Y	Nearby petroleum titleholder.
Finder Exploration	Y	Nearby petroleum titleholder.
King Bay Game Fishing Club (Dampier)	Y	The King Bay Game Fishing Club is located in the Northwest of WA, responsible for promoting game fishing under rules and regulations. .
Marine Tourism Western Australia (MTWA)	Y	MTWA is an association made up of charter industry owners and operators and represents the charter sector to all relevant government departments.
PGS Australia Pty Ltd	Y	Nearby petroleum titleholder.
Pilbara Ports Authority (PPA)	Y	The PPA operates as a Western Australian Government Trading Enterprise and is governed under the *Port Authorities Act 1999 WA*.
Pilot Energy Limited	Y	Nearby petroleum titleholder.
Port Hedland Game Fishing Club	Y	The Port Hedland Game Fishing Club supports the Port Hedland fishing community. It organises monthly competitions for its members.
Santos Limited	Y	Nearby petroleum titleholder.
Shell Australia	Y	Nearby petroleum titleholder.
The Wilderness Society	Y	The Wilderness Society is an Australian, community-based, not-for-profit non-governmental environmental advocacy organisation with interests in the oil and gas industry.
Vocus Communications	Y	Vocus Communications is the operator of the North West Cable System (NWCS). The NWCS intersects the Acquisition Area. For more information on the NWCS, refer to Section 4.6.11.1.
Western Australian Game Fishing Association	Y	The WA Game Fishing Association co-ordinates the activities of game fishing throughout WA.

Stakeholder	Relevant (Y/N)	Reasoning / Validation
Woodside Energy Limited	Y	Nearby petroleum titleholder.
World Wildlife Fund (WWF)	Y	The international non-governmental organisation works in the field of the wilderness preservation, and the reduction of human impact on the environment. WWF is interested in receiving information from titleholders on offshore oil and gas activities.
Yamatji Land and Sea Council	Y	The Yamatji Land and Sea Council is a native title service provider to the Noongar People.
3D Oil Limited	Y	Nearby petroleum titleholder.

5.3 Consultation Method

The stakeholder consultation process undertaken for the survey is detailed in Table 5-2.

Where stakeholders could only be contacted via post (e.g. fishery licence holders) or phone, the appropriate communication channels were used, whereby those parties were either sent hard copies of the information sheet or contacted via phone to relay the corresponding details of the information sheet.

Follow-up emails and phone calls were undertaken as required following the distribution of relevant information.

Where concerns, objections or claims have been raised by stakeholders, these have been addressed in the assessment of environmental impacts and risks (Section 6 and 7). Stakeholders have been informed of how TGS has assessed the issues and if any relevant controls have been adopted to reduce the potential impacts and risks to ALARP and acceptable levels.

Table 5-2 Consultation Process

Stage	Timing	Information Provided
Initial Notification	October 2019	A notification was distributed to stakeholders providing information on the 3D MSS, and associated EP. An information sheet and map was issued.
Follow-up Notification	January 2020	A notification was distributed to stakeholders whom had not yet responded, requesting feedback.
Public Comment Period Open	March 2020	A notification was issued to stakeholders advising of the 30-day public comment period. The notification included details of how to make a comment.
Update Notification	June 2020	A notification was distributed to stakeholders advising of the changes to the Capreolus-2 3D MSS (i.e. activity timeframe extension and change in Acquisition Area boundary).
Repeat Public Comment Period Open	August 2020	A notification will be distributed to stakeholders advising of the 30-day repeat public comment period. The notification will include details on how to make a comment.
EP Acceptance	TBC	A notification will be issued to stakeholders with information on the acceptance of the EP. In addition, stakeholders will be advised of the scheduled survey commencement date (if possible).

5.4 Initial Public Comment Period

TGS submitted the Capreolus-2 3D MSS EP to NOPSEMA on 26 February 2020. The EP was deemed acceptable for public comment by NOPSEMA on 04 March 2020, in accordance with regulation 9AA of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations).

TGS placed advertisements in national, state and regional newspapers and included a notice on TGS' website, in accordance with NOPSEMA's Environment Plan Assessment Policy (N-04750-PL1347). The advertisements invited the general public to review and provide comment on the EP.

The EP was open for public comment for 30 days (04 March – 03 April 2020). During this period no comments were received from the public.

5.5 Repeat Public Comment Period

As outlined in NOPSEMA's Environment Plan Assessment Policy (N-04750-PL1347), if a titleholder significantly modifies the proposed seismic or exploratory drilling activity after the period for public comment but before NOPSEMA has made a final decision, the titleholder must resubmit the EP to NOPSEMA for a repeat public comment period.

The EP was required to undergo a repeat public comment period, due to the nature of the changes made to the proposed seismic survey.

TGS submitted the Capreolus-2 3D MSS EP to NOPSEMA on 10 August 2020. The EP was deemed acceptable for public comment by NOPSEMA on 10 August 2020, in accordance with regulation 9AA of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Environment Regulations).

TGS placed advertisements in national, state and regional newspapers and included a notice on TGS' website, in accordance with NOPSEMA's Environment Plan Assessment Policy (N-04750-PL1347). The advertisements invited the general public to review and provide comment on the EP.

The EP was open for public comment for 30 days (10 August – 09 September 2020). During this period no comments were received from the public.

5.6 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 included in Appendix D. Full copies of stakeholder correspondence are contained in the Sensitive Matters Report (submitted separately to NOPSEMA and not made public).

5.7 Ongoing Consultation and Notifications

TGS will continue to engage with the applicable Commonwealth and Western Australian authorities and other relevant stakeholders (as identified during the course of the consultation described here) prior to and during the survey, as appropriate. This includes ongoing engagement to inform stakeholders about key milestones and activities and any other relevant information or changes.

5.7.1 Stakeholder Notifications

Ongoing stakeholder consultation commitments are outlined in Table 5-3. Some stakeholders will be contacted solely for regulatory or operational notification purposes and these notification requirements are outlined separately in Section 5.7.2.

In addition, where an email address is available for fishery licence holders, TGS will provide regular updates (i.e. 48hr look-ahead notifications) throughout the survey (providing that the stakeholder has registered for the service).

The Stakeholder Consultation Log prepared to support consultations for this EP (Appendix D) will be kept live and used as a tool to trigger and record ongoing consultation. Additional stakeholders may be identified throughout the course of the survey, thus, these new stakeholders will be contacted and given the opportunity to provide feedback as relevant.

New feedback or concerns regarding the survey may be raised by stakeholders, over the life of the EP. Should any additional concerns be raised, or new information be provided by existing or new stakeholders prior to, or during the survey, these concerns and/or information will be assessed for their merits and a response provided.

As required, follow-up actions, including triggers for further consultation with relevant stakeholders, will be managed through the Management of Change Procedure (refer to Section 10.3.3) and, where relevant, in accordance with the provisions of Regulations 11A, 16 and 17 of the OPGGS (E) Regulations.

Table 5-3 Ongoing Consultation Requirements

Trigger / Event	Stakeholders	Timing	Method and Information
Prior to Survey Commencement			
Planned survey commencement date confirmed	All stakeholders, excluding agencies and organisations identified in Section 5.2 that have separate regulatory or operational notification requirements.	To be sent at least four weeks prior to the scheduled acquisition commencement date.	Emails and/or letters to include: ■ Proposed commencement date ■ Proposed duration and/or completion date ■ Location and coordinates ■ Details of communication (e.g. daily look-ahead) during the survey and details of how to register for updates
During Survey			
Daily update	All stakeholders who have registered for daily look-ahead emails.	Daily	Email detailing: ■ Location/survey lines planned for upcoming 72 hour period, including coordinates ■ On-the-water interaction/ safety requirements or advice ■ Any other on-the-water progress updates (e.g. schedule delays)
N.B. On-the-water communication to vessels via radio will also be undertaken as required.			
Survey Completion			
Survey complete	All stakeholders, excluding agencies and organisations identified in Section 5.2 that have separate regulatory or operational notification requirements.	Within two weeks of completion and demobilisation from Operational Area.	Emails and/or letters to include: ■ Completion date
Environment Plan and Activity Updates			
Public Comment Period (and Repeat Public Comment)	All stakeholders, excluding agencies and organisations identified in Section 5.2 that have separate regulatory or operational notification requirements.	To be sent within five days of public comment period opening.	Notification to stakeholders advising of the public comment period.
NOPSEMA acceptance of the EP		To be sent within one week of EP acceptance.	Notification confirming date of EP acceptance. TGS to provide WA Department of Transport with a copy of the accepted EP.
Significant modification of the Activity.		As soon as identified	Email or letter notification followed by meetings, phone calls, email or other correspondence as required. Initial notification shall provide opportunity for stakeholders to comment.
New stage (increase in			

Trigger / Event	Stakeholders	Timing	Method and Information
Acquisition Area, Operational Area or EP timeframe.			Stakeholders to be provided with sufficient information and time to review and respond to information and matters should be reasonably addressed prior to resubmission of the EP to NOPSEMA.
Revision and resubmission of the accepted EP			

5.7.2 Department Notifications

A number of Government agencies and organisations are identified as requiring notification prior to, during and/or after the survey. The required notifications are summarised in Table 5-4.

Note that notifications in the event of a spill event are summarised in Section 10.4.6.

Table 5-4 Survey Notifications

Agency / Organisation	Notification Details	Contact Details	Timing
Prior to Survey Commencement			
Australian Hydrographic Service (AHS)	Notification to AHS for promulgation of Notice to Mariners. Notification to include survey location (coordinates), timing, duration and details of the seismic survey vessel.	datacentre@hydro.gov.au.	Four weeks prior to commencement of the survey for inclusion in fortnightly Notice to Mariners.
NOPSEMA	Regulation 29 of the Environment Regulations requires that a titleholder must notify NOPSEMA that an activity is to commence at least 10 days before the activity commences.	Notify using the Regulation 29 Notification Form available at https://www.nopsema.gov.au/environmental-management/notification-and-reporting/.	At least 10 days prior to commencement of the survey.
WA Department of Mines, Industry Regulation and Safety (DMIRS)	Notification to WA DMIRS advising of survey commencement. Notification to include survey timing, duration and seismic survey vessel details.	petroleum.environment@dmirs.wa.gov.au	Approximately two weeks prior to commencement of the survey.
AMSA Joint Rescue Coordination Centre (AMSA JRCC)	Notification to AMSA JRCC for promulgation of AUSCOAST warning broadcasts. Notification to include seismic survey vessels details (including vessel name, call sign and Maritime Mobile Service Identity (MMSI)), satellite communications details (including INMARSAT-C and satellite telephone) and area of operation.	rccaus@amsa.gov.au 1800 641 792 or +61 2 6230 6811	24-48 hours before commencement of the survey.
Australian Border Force (ABF)	Email to ABF regarding vessel and crew arrival in Port.	Contact details to be determined depending on the Port of destination.	Prior to the vessel arriving in Australian territorial waters.
Department of Agriculture, Water the Environment (DAWE)	Submit Pre-Arrival prior to arrival in Australian Territorial Waters via MARS online reporting.	https://www.agriculture.gov.au/biosecurity/avm/vessels/mars	At least 12 hours prior to vessel arrival in Australian territorial waters.
National Offshore Petroleum Titles Administrator (NOPTA)	Email to NOPTA advising of survey commencement.	reporting@nopta.gov.au	48 hours prior to commencement of the survey.

Agency / Organisation	Notification Details	Contact Details	Timing
During the Survey			
AMSA JRCC	Daily updates to AMSA JRCC for promulgation of AUSCOAST warning broadcasts. Notification to include survey progress and vessel position. Note - the 72hr daily look-ahead report may replace the need for separate update to AMSA JRCC.	rccaus@amsa.gov.au 1800 641 792 or +61 2 6230 6811	Daily
NOPTA	A weekly seismic report is to be submitted to NOPTA each week the survey is undertaken.	reporting@nopta.gov.au	Weekly
Completion of Survey			
AMSA JRCC	Notification to AMSA JRCC for the cessation of AUSCOAST warning broadcasts.	rccaus@amsa.gov.au 1800 641 792 or +61 2 6230 6811	Upon completion of the survey
AHS	Notification to AHS advising of survey completion for the promulgation of a Notice to Mariners.	datacentre@hydro.gov.au.	Within two weeks of completion of the survey for inclusion in fortnightly Notice to Mariners.
NOPSEMA	Regulation 29 of the Environment Regulations requires that a titleholder must notify NOPSEMA that an activity is completed within 10 days after the completion.	Notify using the Regulation 29 Notification Form available at https://www.nopsema.gov.au/environmental-management/notification-and-reporting/.	Within 10 days of completion of the survey.
NOPTA	Notification to NOPTA advising of survey completion.	reporting@nopta.gov.au	Upon completion of the survey.
WA DMIRS	Notification to WA DMIRS advising of survey completion.	petroleum.environment@dmirs.wa.gov.au	Within approximately one week following completion of the survey.
Completion of the EP			
NOPSEMA	Regulation 25A of the Environment Regulations provides that the operation of an environment plan ends when the titleholder notifies NOPSEMA that: ■ the activity or activities to which the plan relates have ended; and	Titleholders may provide NOPSEMA with written notification directly by email, letter, or by using the form available at https://www.nopsema.gov.au/environmental-management/notification-and-reporting/.	When the activity has ended and all of the obligations under the EP have been completed.

Agency / Organisation	Notification Details	Contact Details	Timing
	■ all of the obligations under the environment plan have been completed; and ■ NOPSEMA accepts the notification.	Written notifications can be submitted via the Securefile Transfer service on the NOPSEMA website or by email to submissions@nopsema.gov.au.	
Change of Titleholder / Nominated Liaison Person or Contact Details			
NOPSEMA	Notify NOPSEMA if there is a change in the titleholder, a change in the titleholder's nominated liaison person or a change in the contact details for either the titleholder or the liaison person.	submissions@nopsema.gov.au	When there is a change in the titleholder, a change in the titleholder's nominated liaison person or a change in the contact details for either the titleholder or the liaison person.

6. RISK ASSESSMENT METHOD

6.1 Approach

The environmental impact and risk assessment methodology applied to this EP, is consistent with the approach outlined in ISO 14001 (Environmental Management Systems), ISO 31000:2009 (Risk Management) and HB203:2012 (Environmental Risk Management – Principles and Process).

Figure 6.1 provides the process adopted for managing impacts and risks associated with the Capreolus-2 3D MSS.

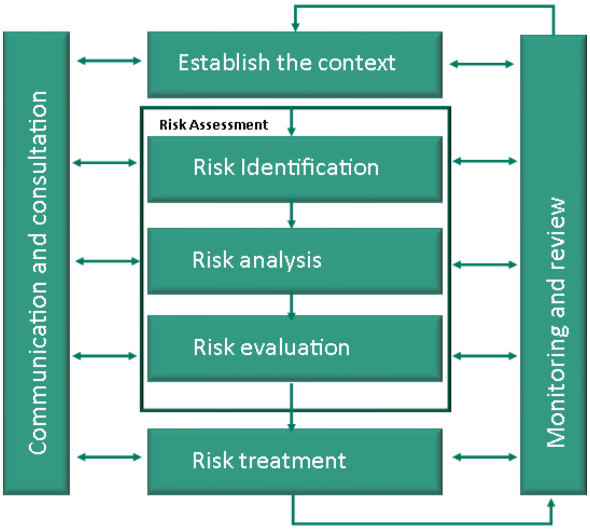


Figure 6.1 AS/NZS ISO 3100 – Risk Management Methodology

The risk assessment process consists of the following steps:

Establish the context of the activity:

- Define the activity and identify aspects that have potential environmental impacts and risks associated with planned activities and credible unplanned incidents (Section 6.2).
- Identify physical, biological, and socio-economic receptors, and environmental values and sensitivities (within and adjacent to the Operational Area) that may be affected by the activity (planned and unplanned events) (Section 4).
- Identify the relevant requirements in the context of legislation, standards and other environmental approval requirements that apply to the activity (Section 2).

Impact/risk assessment:

- Identify the 'Decision Type' within the Decision Support Framework outlined in Section 6.3.
- Identify and evaluate appropriate control measures in relation to the overall context of the activity in accordance with the hierarchy of controls outlined in Section 6.2.
- Assess the environmental impacts and risks to determine the potential consequence and likelihood and predict the residual risk using the qualitative risk matrix (Table 6-4), taking into consideration the magnitude of the impact or risk and the value and sensitivity of the potentially impacted receptor.

Impact/risk evaluation:

- Impacts and risks will be evaluated to determine that they have been reduced to a level that is ALARP and acceptable in accordance with TGS' acceptance criteria (Section 6.4);

- Development of environmental performance outcomes, performance standards, and measurement criteria (Section 6.5).

Environmental Impact and Risk Identification

An environmental impact and risk identification (ENVID) workshop was undertaken in December 2019, to identify and assess the impacts and risks associated with the survey. The workshop was supported by background literature and discussions with relevant seismic operations personnel and environmental specialists. The identification of impacts and risks and the selection of appropriate controls for these risks were also informed by TGS' experience in conducting other seismic surveys in Australia.

The ENVID considered the following:

- Activities that will occur during the Capreolus-2 3D MSS and the equipment and vessels to be utilised in those activities;
- The environmental sensitivity of the receiving environment with respect to species distribution, subsea habitat types and location of environmentally sensitive areas (e.g. breeding, resting, feeding) identified as part of desktop studies; and
- Feedback from stakeholders to understand socio-economic activities that may coincide with Capreolus-2 3D MSS operations via communication and consultation activities.

Within this context, a listing of credible activity-related environmental aspects and possible impacts and risks were identified for the activity. The following sections detail the risk assessment steps.

6.2 Impact and Risk Evaluation

For this activity, TGS has defined impacts and risks as follows:

- **Impacts** result from activities that by their very nature will result in a change to the environment or a component of the environment, whether adverse or beneficial. Impacts are an inherent part of the activity. For example, there will be underwater sound emissions with associated impacts from the seismic source and vessel activity.
- **Risks** result from activities where a change to the environment or component of the environment may occur from the activity (i.e. there may be consequences if the incident event occurs). Risk is a combination of the consequences of an event and the associated likelihood of its occurrence. For example, a hydrocarbon spill may occur if a vessel's fuel tank is punctured by a collision incident during the survey. The risk of this event is determined by assessing the consequence of the impact (using factors such as the type and volume of fuel and the nature of the receiving environment) and the likelihood of this event happening (which may be determined qualitatively or quantitatively).

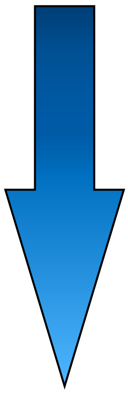
The purpose of the impact and risk evaluation is to assist in making decisions, based on the outcomes of the analysis, about the control measures required to reduce an impact or risk to ALARP and acceptable levels. All impacts and risks are subject to these steps in the same manner.

1. **Calculate the inherent impact or risk for an activity aspect:**
   a. Select the consequence level: Determine the worst-case credible outcome associated with the activity aspect assuming all existing preventative controls have failed. Where more than one impact or risk applies (e.g., environmental and social/cultural), the highest consequence level is recorded (refer to Table 6-2);
   b. Select the likelihood level from the description that best fits the chance of the identified consequence occurring (refer to Table 6-3); and
   c. Calculate the inherent risk ranking by comparing the selected consequence and likelihood levels using the qualitative risk matrix in Table 6-4.
2. **Identify control measures (i.e. impact/risk treatment)**

For each identified impact and risk, control measures are identified to reduce the impact or risk. The hierarchy of controls philosophy is a useful framework to identify and assess controls that are effective (Table 6-1) and is used in this assessment process to determine suitable controls.

Multiple controls selected from this hierarchy provide a depth (number) and breadth (control type) to prevent an impact or risk from occurring. Control types listed in the upper section of the hierarchy are recognised as being more effective in terms of functionality, availability, reliability, survivability, independence and compatibility given their inherent design characteristics.

Table 6-1 Hierarchy of Controls

Control Type	Effectiveness	Relevant Example
Eliminate: Complete removal of hazard		Eliminate activity within sensitive timeframes.
Prevent: Prevent hazardous events		Adopt spatial controls to isolate activity from sensitivity
Reduce: Reduce the consequence should the event occur		Adopt shutdown procedures if cetacean is within power-down zone.
Mitigate: Practices to mitigate the consequences once realised.		Implement Shipboard Oil Pollution Emergency Plan (SOPEP) to mitigate spill impacts

3. <u>Calculate the residual impact or risk</u>

With control measures implemented, all inherent impacts and risks are then reassessed for their residual consequence and likelihood according to the TGS Qualitative Risk Matrix (refer Table 6-4). If the residual impact or risk does not meet the criteria provided in Table 6-6 and Table 6-7, iterations of the assessment process continue until the impact or risk is considered broadly acceptable or additional controls have been identified and/or rejected or accepted via an ALARP demonstration.

Table 6-2 Consequence Definitions

Consequence Category	Biodiversity and Ecosystem Function			Environmental Quality			Social	
	Protected Species	Marine Primary Producer Habitat	Ecological Diversity	Water Quality	Sediment Quality	Air Quality	Protected Areas	Cultural
Catastrophic	Local population eradication and/or loss of critical habitats/activities	Permanent eradication at regional scale	Permanent effects at regional scale	Permanent reduction in water quality. Known biological effect on a regional scale	Permanent contamination with known biological on a regional scale	Continuous damage to the environment and/or human health	Significant permanent effects on one or more of protected areas values	Significant, permanent effects on aesthetic, economic or recreational values. Overall societal benefits do not outweigh impacts
Massive	Extensive population-level effects. Significant effect on critical habitats/activities	Large-scale, long term effects. Recovery >10 years, or effects permanent	Large-scale, long term effects. Recovery >10 years or effects permanent	Continuous or regular discharge. Known biological effect concentrations on large scale (1-100 km²)	Long term contamination above background. Known biological effect concentrations on large scale	Sustained, exceedance over national/international air quality standards. Potential harm to the environment or human health	Significant long term effects on one or more of protected areas values	Significant long term effects on aesthetic, economic or recreational values. Overall societal benefits do not outweigh impacts
Major	Minor disruption to significant portion of population. Minor effects on critical habitats/activities. No threats to population	Localised but long term effects. Recovery >10 years, or effects permanent	Localised, long term effects. Community maintains ecological integrity with significant change in	Continuous or regular discharge. Known biological effect concentrations on medium scale (1-10	Short to medium-term contamination above background. Known biological effect concentrations	Major and temporary exceedance over national/international air quality standards. Potential harm to the environment or human health	Minor but long term or permanent effects on one or more of protected areas values	Major effects on aesthetic, economic or recreational values. Overall societal benefits do not outweigh impacts

Consequence Category	Biodiversity and Ecosystem Function			Environmental Quality			Social	
	Protected Species	**Marine Primary Producer Habitat**	**Ecological Diversity**	**Water Quality**	**Sediment Quality**	**Air Quality**	**Protected Areas**	**Cultural**
	viability		composition	km²)	on large scale			
Moderate	Minor disruption to small portion of population. Minor, temporary effects on critical habitats/activities. No threat to population viability	Localised, medium-term effects. Recovery 5-10 years	Localised, medium-term effects. Ecological integrity maintained with insignificant change to species composition	Continuous or regular discharge. Known biological effect concentrations on small scale (<1 km²)	Short to medium-term contamination above background. Known biological effect concentrations on medium scale	Moderate and temporary exceedance over national/international air quality standards. No harm to the environment or human health expected	Minor and medium-term effects on one or more of protected areas values. Full recovery expected	Moderate effects on aesthetic, economic or recreational values but overall societal benefits outweigh impacts
Minor	Minor and temporary disruption to small portion of population. No effects on critical habitats/activities	Localised, short term effects. Recovery in the timescale of months to <5 years	Localised, short to medium-term effects. Full recovery expected	Temporary discharge with contamination above background levels. Known biological effect concentrations on medium scale (<10 km²)	Temporary contamination above background. Known biological effect concentrations on medium scale	Minor and temporary exceedance over national/international air quality standards. No harm to the environment or human health expected	Minor and short term effects on one or more of protected areas values. Full recovery expected	Minor and temporary effects on aesthetic, economic or recreational values
Slight	Possible incidental effects to flora and fauna in a locally affected environmental setting	Localised, temporary effects. Recovery in the timescale of days to weeks	Localised, temporary effects. Slight impact on ecological integrity or species	Temporary discharge with contamination above background levels. Known biological effect	Temporary contamination above background. Known biological effect concentrations	Slight, temporary exceedance over national/international air quality standards. No harm to the environment or human health	Slight to negligible effects on any protected area values	Slight to negligible effects on aesthetic, economic or recreational values

Consequence Category	Biodiversity and Ecosystem Function			Environmental Quality			Social	
	Protected Species	Marine Primary Producer Habitat	Ecological Diversity	Water Quality	Sediment Quality	Air Quality	Protected Areas	Cultural
			composition	concentrations on small scale (<1 km²)	on small scale	expected		

Table 6-3 Definition of Likelihood

Categories	Likelihood Description		
	Frequency Continuous operations	**Probability** Single activity (e.g. survey)	**Experience** History of occurrence in Company or industry
Remote	Once every 10,000-100,000 years at location	1 in 100,000-1,000,000	Unheard of in the industry
Highly Unlikely	Once every 1,000-10,000 years at location	1 in 10,000-100,000	Has occurred once or twice in the industry
Unlikely	Once every 100-1,000 years at location	1 in 1,000-10,000	Has occurred many times in the industry, but not in the Company
Possible	Once every 10-100 years at location	1 in 100-1,000	Has occurred once or twice in the Company
Likely	Once every 1-10 years at location	1 in 10-100	Has occurred frequently in the Company
Highly Likely	More than once a year at location or continuously	>1 in 10	Has occurred frequently at the location

Table 6-4 Qualitative Risk Matrix

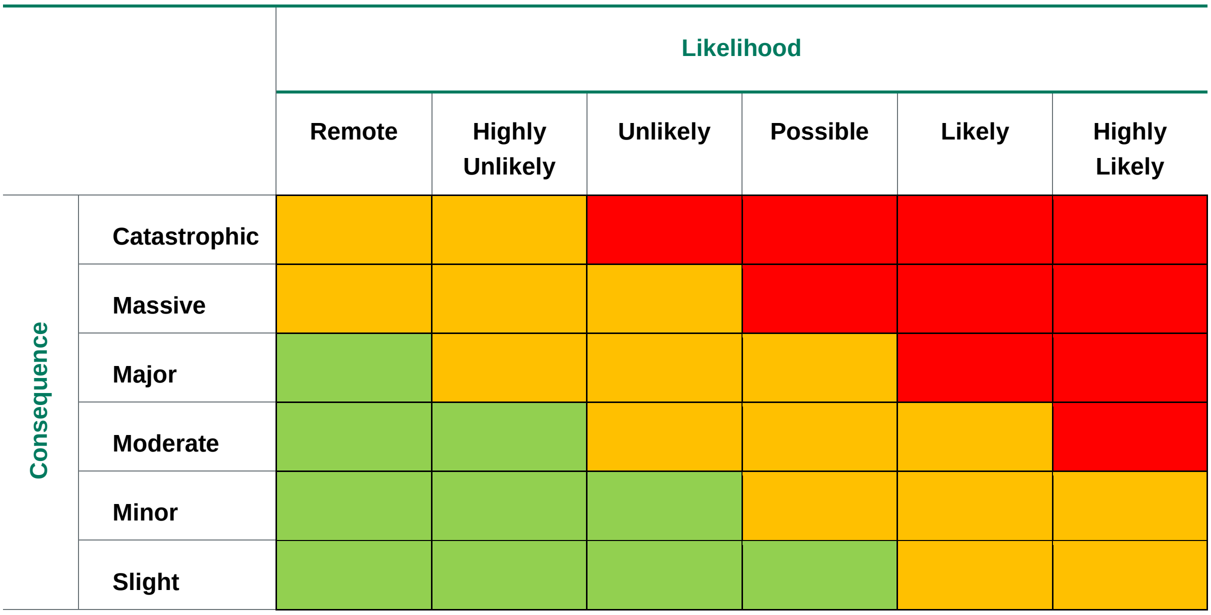


Table 6-5 Definition of Risk

Risk Ranking	Interpretation
LOW RISK	No additional controls are required if ALARP. Acceptable level of risk. Consideration may be given to effective solutions or improvements that impose no significant cost burden. Monitoring is required to ensure that the controls are maintained.
MEDIUM RISK	Efforts should be made to reduce the risk, but the cost of prevention should be measured and limited. Risk reduction methods should be implemented within a defined time period.

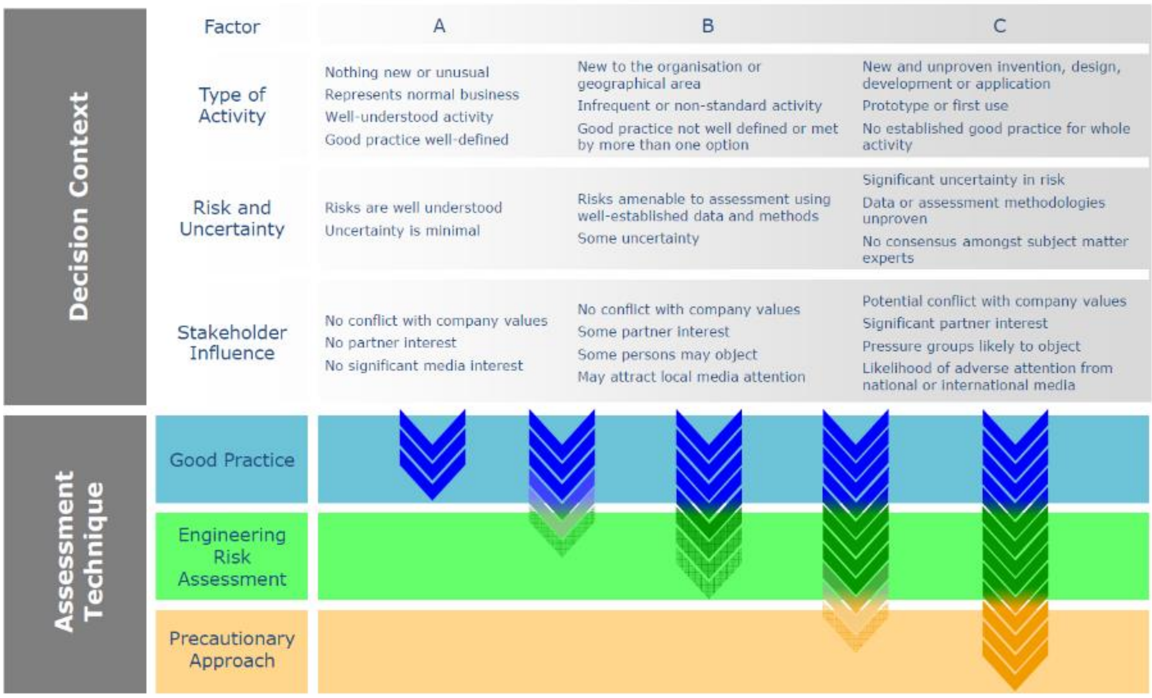
Risk Ranking	Interpretation
	Generally acceptable level of risk where further risk reduction is shown not to be practicable.
HIGH RISK	Work should not be started or continued until the risk has been reduced to an acceptable level. If it is not possible to reduce the risk even with unlimited resources, work has to remain prohibited.

6.3 Demonstration of ALARP

This section provides the methodology for determining whether impacts and risks are ALARP and reflects the principles outlined in the NOPSEMA Decision-making – Criterion 10(a)(b) ALARP Guideline (GL1721) (Rev 3, May 2017). The EP must demonstrate that impacts and risks are reduced to ALARP, which requires that available control measures are implemented where the cost is not grossly disproportionate to the environmental benefit gained from implementing the control measure.

In considering impact and risk-related decision making, TGS utilises the risk-related decision making framework developed by the UK offshore oil and gas (Oil & Gas UK, 2014) to assist with the basis for their decisions. A summary of the framework is shown in Figure 6.2. The framework takes the form of three different decision contexts (A, B & C). Initially the decision context needs to be determined with guidance provided on factors affecting that context (i.e. activity type, risk and uncertainty, and stakeholder influence). The assessment techniques used depend on the selected decision context (refer to Table 6-6).

Figure 6.2 provides a description of the decision types and the associated assessment techniques utilised to make an ALARP decision.



Source: Oil and Gas UK, 2014

Figure 6.2 Impact and Risk Decision Making Framework

Table 6-6 ALARP Decision-making Methodologies

Decision Context	Description	Decision Methodologies
A	Risks classified as Decision Type A are well understood with minimal uncertainty and good practice is well-defined, often within legislation, standards and guidelines.	**Legislative Requirements:** Identifies the requirements of legislation, codes and standards that are to be complied with for the activity. **Good Industry Practice:** Identifies further engineering control standards and guidelines that may be applied over and above that required to meet the legislation, codes and standards. **Professional Judgement:** Uses relevant personnel with the knowledge and experience to identify alternative controls. When formulating control measures for each environmental impact or risk, the 'Hierarchy of Controls' philosophy, which is a system used in the industry to identify effective controls to minimise or eliminate exposure to impacts or risks, is applied.
B	Risks classified as a Decision Type B are typically in areas of increased environmental sensitivity with some stakeholder concerns. These risks may be associated with infrequent, non-standard activities and have more uncertainty, with good practice less well-defined. Further analysis is required in addition to using the tools described for a Decision Type A.	**Risk-based tools such as cost based analysis or modelling:** Assesses the results of probabilistic analyses such as modelling, quantitative risk assessment and/or cost benefit analysis to support the selection of control measures identified during the risk assessment process.
C	Risks classified as a Decision Type C will typically have significant risks related to environmental performance. The risks may be uncertain or result in significant environmental impact; significant project risk/ exposure; or may elicit strong stakeholder awareness and negative perception. For these risks, in addition to Decision Type A and B tools, company and societal values need to be considered by undertaking broader internal and external stakeholder consultation as part of the risk assessment process.	**Societal Values:** Identifies the views, concerns and perceptions of relevant stakeholders and addresses relevant stakeholder concerns as gathered through consultation.

In addition to the decision-making framework, for higher-level impacts and risks, ALARP assessments shall assess:

1. Alternative/substitute control measures that may be potentially effective (which lie higher on the hierarchy of controls); and
2. Additional controls that add to the suite of control measures to reduce the environmental impact.

For risks classified as Decision-Type A, if the residual risk is determined to be low, TGS considers the control measures adopted to be sufficient to demonstrate that potential impacts and risks are managed to ALARP. However, TGS considers the implementation of additional control measures when there is the potential to further reduce the likelihood of the impact occurring (i.e. preventative) and/or reduce the consequence of the impact (i.e. mitigation).

All control measures considered are documented and the justification for accepting or not adopting the controls is documented as part of the assessment. Assessment of the control measures includes a comparison of the environmental benefit of adopting the control against the cost of implementation. For higher level impacts and risks, this also includes an assessment of the activity design on a temporal and spatial basis to reduce impacts.

6.4 Demonstration of Acceptability

TGS considers a range of factors when evaluating the acceptability of environmental impacts or risks associated with its activities. This evaluation is outlined in Table 6-7 and is based on NOPSEMA's Guidance Notes for EP Content Requirements (N-04750-GN1344, Rev 4, April 2019) and guidance issued in Decision-making – Criterion 10A(c) Acceptable Level (GL1721, Rev 5, June 2018).

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.

Impacts and risks classified as decision 'Type B' are acceptable if the criteria outlined in Table 6-7 are met and it can be determined that the predicted levels of impacts and/or residual risk, are at or below pre-defined acceptable level(s) for that impact or risk.

Acceptable levels are defined for relevant values and sensitivities and are informed by relevant external context. This includes the principles of ecologically sustainable development (ESD), input from relevant persons, relevant statutory instruments (such as published recovery plans, conservation advice and management plans), good practice guidance and applicable scientific information. Predicted levels of impact or risk to relevant values and sensitivities are evaluated to demonstrate how the activity will be managed to ensure acceptable levels are met. Environmental Performance Outcomes (EPOs) are then established that are linked to the pre-defined acceptable levels of impact/risk.

TGS considers an impact or risk to be unacceptable when, despite the application of all reasonable practicable control measures, the residual risk is still determined to be high. In these circumstances, TGS will not undertake the activity until the residual risk rating is reduced to either low or medium.

Table 6-7 Acceptability Criteria

Context	Factor	Criteria	Demonstration
Risk	Residual Risk	Is the level of residual risk determined to be low or medium?	***The impact or risk has been determined to be low or medium***
Internal	Company Policy	Is the proposed management of impact or risk aligned with TGS's Environment Policy?	***The impact or risk must be compliant with the objectives of this policy.***

Context	Factor	Criteria	Demonstration
External	Values and Sensitivities of the Natural Environment	Are the values and sensitivities of the environment, including matters protected under Part 3 of the EPBC Act (World Heritage, National Heritage, Wetlands of International Importance, listed threatened species and communities, listed migratory species, Commonwealth marine environment) protected so that no significant impacts result to the environment?	***Impacts and risks are demonstrated not to have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1 – Significance Guidelines.***
		Have applicable objectives and actions within relevant species conservation or recovery plans, threat abatement plans, conservation advices, bioregional plans been met?	***Compliance with relevant conservation advice, recovery plans and other guidance is demonstrated.***
		Have applicable objectives and actions within relevant AMP management plans, been met?	***Compliance with relevant AMP management plans is demonstrated.***
	Relevant Persons Expectations	Have relevant persons raised any objections or claims about adverse impacts associated with the activity, and if so, have merits of the objection been assessed? For those objections and claims with merit, have measures been put in place to manage those concerns?	***Stakeholder concerns have been assessed, responded to and controls adopted for objections and claims which hold merit.***
Legislation & Other	Legal Requirements	Is the impact or risk managed in accordance with existing Australian, State and/or international laws/obligations?	***Compliance with specific laws/obligations is demonstrated.***
Industry Standards	Industry Standards and Best Practices	Do standards adopted reflect best practice guidance (i.e. IAGC Guidelines, IPIECA Guidelines, APPEA Guidelines, IOGP Guidelines)?	***Compliance with best practice guidance is demonstrated.***
Ecologically Sustainable Development (ESD) (refer below)	ESD Application	Does the proposed risk/impact comply with the APPEA Principles of Conduct (APPEA, 2016), requiring integration of ESD principles into company decision-making, and Government policy frameworks that integrate ESD principles into implementation strategies?	***The overall operations are consistent with the APPEA Principles of Conduct and Commonwealth environmental strategy documents.***

Ecologically Sustainable Development

Section 3A of the EPBC Act 1999 defines ESD, which is based on Australia's National Strategy for Ecological Sustainable Development (1992), defines ESD as 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased'.

ESD Principles are outlined below:

- Decision making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations (*This principle is inherently met through the EP assessment process. This principal is not considered separately for each acceptability evaluation*).
- 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. If there is, the project shall assess whether there is significant uncertainty in the evaluation, and if so, whether the precautionary approach should be applied.
- 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. (*The EP assessment methodology ensures that potential impacts and risks are ALARP, and where the potential impacts and risk are determined to be serious or irreversible the precautionary principle is implemented to ensure the environment is maintained for the benefit of future generations. Consequently, this principal is not considered separately for each acceptability evaluation*).
- The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making (*EP to consider if there is the potential to affect biological diversity and ecological integrity*).
- Improved valuation, pricing and incentive mechanisms should be promoted (*not relevant to this EP).*

6.5 Environmental Performance Outcomes, Standards and Measurement Criteria

To meet the requirements of Regulation 13 (7) of the OPGGS (E) Regulations, environmental performance outcomes, performance standards, and measurement criteria have been identified in Section 9 of this EP. 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 to manage impacts and risks to ALARP and acceptable levels; and
- Measurement Criteria (MC) – defines the measure by which environmental performance will be measured to determine whether the EPO has been met.

7. ENVIRONMENTAL RISKS AND MANAGEMENT – PLANNED

This section presents the evaluation of the environmental impacts and risks completed for planned / routine aspects of the Capreolus-2 3D MSS using the methodology described in Section 6.

In accordance with regulation 13(5) of the OPGGS (E) Regulations, each subsection is structured to include:

- an assessment summary that includes the source of predicted impacts and risks, receptors that may be affected, adopted control measures and a summary of the inherent and residual risk evaluation;
- a detailed evaluation of impacts and risks (including sources, potential events, consequences and likelihood) of the survey and estimate of the magnitude of the impacts and risks;
- identification of the control measures to be used to reduce impacts and risks and demonstration of ALARP; and
- demonstration that impacts and risks are reduced to ‘acceptable levels’.

A summary of the residual risk rankings for all impacts and risks identified and assessed in this Section are summarised in Table 7-1.

Table 7-1 Residual Environmental Impact and Risk Summary

Impact/Risk	EP Section No.	Residual Risk*		
		Consequence	Likelihood	Risk Ranking
Noise Emissions: Seismic Source	7.1	Minor	Unlikely	Low
Cumulative: Seismic Sound & Interference with Commercial Fisheries	7.2	Minor	Unlikely	Low
Noise Emissions: Vessels, Helicopter and Mechanical Equipment	7.3	Slight	Unlikely	Low
Physical Presence: Interference with Commercial Fisheries	7.4	Minor	Unlikely	Low
Physical Presence: Interference with Other Marine Users	7.5	Minor	Highly Unlikely	Low
Discharge: Liquid Waste Management	7.6	Slight	Highly Unlikely	Low
Atmospheric Emissions: Vessels and Mechanical Equipment	7.7	Slight	Highly Unlikely	Low
Artificial Light Emissions: Vessels	7.8	Slight	Highly Unlikely	Low

* The residual risk ranking is based on the ranking of the most sensitive receptor to the impact/risk.

7.1 Noise Emissions: Seismic Source

7.1.1 Assessment Summary

Source of Impact / Risk
Acquisition of the Capreolus-2 3D MSS will involve the use of a seismic source, consisting of an airgun array with a maximum capacity of 3,480 cui, towed at a water depth of 6 m – 10 m. The source will be used to generate acoustic pulses by periodically discharging compressed air into the water column, at intervals of approximately five seconds as the vessel transits along pre-determined survey lines within the Acquisition Area. The seismic source may also be operated (at or below full power) for short durations elsewhere in the Operational Area in a controlled manner; for the purpose of source maintenance and testing (refer to Section 3.3.1) The 3,480 cui seismic source will produce far-field source levels up to a maximum of 248.6 dB re 1 µPa m (PK) and per-pulse source sound exposure levels (SEL) of 225.2 dB re 1 µPa^{2}m^{2}s (at 10–2,000 Hz) in the horizontal plane (broadside direction). In the vertical direction, directly beneath the source array, the source levels will be approximately 258 dB re 1 µPa m (PK) and per-pulse source sound exposure levels (SEL) of approximately 231-234 dB re 1 µPa^{2}m^{2}s (at 10–2,000 Hz). 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 in most cases; ■ Through disturbance leading to temporary changes in behaviour or distribution of fauna. The occurrence and intensity of disturbance is highly variable and depends on a range of factors relating to the animal and situation; and ■ By masking or interference with other biologically important sounds (including vocal communication, echolocation, signals and sounds produced by predators or prey).
Receptors
Without appropriate control measures in place, noise emitted from the seismic source used during the Capreolus-2 3D MSS has the potential to cause impacts to a range of sensitive receptors, including: ■ Cetaceans; ■ Marine reptiles; ■ Marine birds; ■ Fishes and elasmobranchs; ■ Benthic invertebrates; ■ Zooplankton; ■ Fish spawning; ■ Commercial fisheries; ■ Tourism and recreation; ■ Marine protected areas; and ■ Submarine cables.
Summary of Impacts and Risks
The potential impacts of noise emissions from the seismic source on marine fauna and marine protected areas are generally considered to be temporary, with no long term impacts at a population or community level. The potential impacts to different receptor groups are summarised as follows:

<table>
<tr><td colspan="2">

- Cetaceans – Potential temporary behavioural disturbance to transient cetaceans that may pass within 4 – 10 km of the seismic source, as well as potential temporary hearing impairment (TTS) if an animal remains in proximity to the seismic source for an extended period of time. The Capreolus-2 3D MSS will be scheduled to avoid the pygmy blue whale and humpback whale migration BIAs during their respective migration periods.
- Marine reptiles – Potential temporary behavioural disturbance to transient turtles that may pass within 5 km of the seismic source. The Capreolus-2 3D MSS will be scheduled to avoid turtle internesting BIAs and Habitat Critical during the nesting and internesting period.
- Marine birds – Localised behavioural disturbances to diving seabirds may occur if foraging near the seismic source. Short-term and localised changes in the behaviours and distribution of target prey species may also occur.
- Fishes and elasmobranchs – Potential temporary behavioural disturbance to demersal and pelagic fishes may occur, primarily within hundreds of metres of the seismic source given fishes' hearing abilities and primary sensitivity to particle motion rather than sound pressure. There is also the potential for TTS to occur in some fish if exposed in close proximity to the seismic source for an extended period of time.
- Benthic invertebrates – A range of lethal and sublethal effects may occur to benthic invertebrates on the seafloor beneath the operating seismic source. Should lethal and sub-lethal impacts occur in benthic invertebrates following exposure, benthic community composition and structure is expected to recover in the weeks and months following the survey.
- Zooplankton – Highly localised mortality and sub-lethal effects may occur to zooplankton (within tens of metres of the seismic source), but the impacts will be negligible in the context of natural zooplankton mortality and turnover rates in the region.
- Fish spawning – Temporary behavioural disturbances to demersal and pelagic fishes may interrupt isolated groups of fishes during spawning events. However, the impacts are expected to be small in the context of populations and stocks given that the key commercial species in the region spawn multiple times over several months, and there is genetic connectivity and recruitment within the stocks at a larger regional scale.
- Commercial fisheries – Localised and temporary disturbances to commercially targeted fish species may occur, with corresponding effects on fisheries catch rates if fishing in close proximity to the seismic source. Although each of the commercial fisheries has other viable fishing grounds accessible outside of the Operational Area, disruption to fishers in the same area as the operating seismic vessel is acknowledged. TGS is committed to working with relevant commercial fishers to enable fair and reasonable concurrent operations.
- Tourism and recreation – Received sound levels at key sites of significance for recreational fishing and diving are predicted to have fallen below levels that may impact these activities.
- Marine protected areas – Given the proposed scheduling of the survey and proposed avoidance of humpback whale migration and turtle internesting habitats, the survey is expected to have limited impacts on the natural values of AMPs or State Marine Parks.
- Submarine cables – No impacts to the North West Cable System (NWCS) are predicted to occur.

With the control measures in place, the Capreolus-2 3D MSS will not result in significant impacts to commercial fisheries and tourism/recreational activities operating within or adjacent to the Operational Area.
</td></tr>
<tr><td colspan="2">Decision Content</td></tr>
<tr><td>B</td><td>The decision context for noise emissions from the seismic source has been assessed as 'Type B', given there is stakeholder interest and there may be some uncertainty as to the exact magnitude, extent or duration of effects to some receptors. Therefore, acoustic modelling has been used to inform the assessment of potential impacts and risks, and the selection of control measures to reduce the risk to ALARP has</td></tr>
</table>

	considered the cost/effort of implementing the controls against the potential benefit of implementing them.

Adopted Control Measures	EPS #
Minimum source size selected (3,480 cui) to acquire survey data and meet the geophysical objectives of the survey.	1.1
Acquisition will be limited to a maximum of 10,000 km^2 per calendar year.	1.2
Part A of EPBC Policy Statement 2.1 will be applied in full to mitigate potential impacts to whales, including: ■ 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 ■ Soft-start Procedures ■ Start-up Delay Procedures ■ Operational Shut-down and Low-power Procedures ■ Night-time and Low Visibility Procedures ■ Sighting Reports	1.3
EPBC Act Policy Statement 2.1 Part B.6 - Adaptive Management Measures will be applied to minimise potential impacts to whales, including: ■ If the survey is required to shut-down/power-down three or more times per day for three consecutive days as a result of sighting a whale, the shut-down zone will be extended to a 2 km horizontal radius from the seismic source. ■ If less than three shutdowns occur in the preceding 24 hours, normal precaution zones and shut-down procedures may recommence, as per EPBC Act Policy Statement 2.1 Part A.	1.4
EPBC Act Policy Statement 2.1 Part B.6 - Adaptive Management Measures will be applied to minimise potential impacts to migrating humpback whales, including: ■ Ceasing seismic acquisition in the humpback whale migration BIA for 24 hours if the survey is required to shut-down/power-down three or more times per day for three consecutive days as a result of sighting a humpback whale in the migration BIA. ■ Seismic acquisition may recommence in the humpback whale migration BIA after 24 hours if there has been no further sightings of humpback whales. ■ No further seismic acquisition will occur within the humpback whale migration BIA (until after the migration period – June to October), if there is 3 consecutive days of no seismic acquisition due to the presence of migrating humpback whales.	1.5
Two MFOs will be available on board the seismic survey vessel to manage shift duties during daylight hours. At least one MFO will have >12 months experience on a seismic survey vessel as an MFO in Australian waters.	1.6
A 100 m shut-down zone from the operating source will be applied to dolphins.	1.7
A 500 m shut-down zone from the operating source, as per the shut-down zone for whales in EPBC Act Policy Statement 2.1, will also be applied to dugongs.	1.8
A 250 m shut-down zone from the operating source will be applied to whale sharks and turtles.	1.9

Pre-start visual observations to include observations for dolphins, marine turtles, whale sharks and dugongs.				1.10
Vessel crews will complete an environmental induction covering the requirements for vessel interactions with marine fauna.				1.11
No operation of the seismic source in water depths less than 50 m.				1.12
No operation of the seismic source in the designated Glomar Shoals KEF.				1.13
The seismic survey vessel will not return to acquire adjacent lines within 5.86 km of the KEF within a 24 hour period to enable for recovery of TTS in fishes associated with Glomar Shoal.				1.14
No operation of the seismic source within 24 km of the pygmy blue whale migration BIA (consistent with the Northern Zone presented in Figure 3.1) during the migration period (April – August and October – December).				1.15
No operation of the seismic source in the humpback whale migration BIA during the peak migration period (July to October).				1.16
No operation of the seismic source in the flatback turtle internesting BIA during the internesting period (October – March).				1.17
Notification to scuba divers that are undertaking diving activities within 45 km of the seismic source.				1.18
A joint risk assessment will be conducted, where scuba diving and seismic activity occur within 30 km of each other.				1.19
Notification to fisheries stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within 2 weeks of survey completion.				1.20
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.				1.21
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).				1.22
Daily look-ahead reports will be provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.				1.23
Receptor	**Risk Ranking**	**Consequence**	**Likelihood**	**Risk**
Cetaceans	Inherent	Minor	Possible	**Medium**
	Residual	Minor	Unlikely	**Low**
Marine Reptiles	Inherent	Minor	Possible	**Medium**
	Residual	Minor	Unlikely	**Low**
Seabirds	Inherent	Slight	Highly Unlikely	**Low**
	Residual	Slight	Highly Unlikely	**Low**
	Inherent	Slight	Possible	**Low**

Fishes & Elasmobranchs	Residual	Slight	Possible	**Low**
Benthic Invertebrates	Inherent	Slight	Possible	**Low**
	Residual	Slight	Possible	**Low**
Zooplankton	Inherent	Slight	Possible	**Low**
	Residual	Slight	Possible	**Low**
Fish Spawning	Inherent	Minor	Unlikely	**Low**
	Residual	Minor	Unlikely	**Low**
Commercial Fisheries	Inherent	Minor	Possible	**Medium**
	Residual	Minor	Unlikely	**Low**
Tourism and Recreation	Inherent	Slight	Unlikely	**Low**
	Residual	Slight	Unlikely	**Low**
Marine Protected Areas	Inherent	Slight	Unlikely	**Low**
	Residual	Slight	Unlikely	**Low**
Submarine Cables	Inherent	Minor	Unlikely	**Low**
	Residual	Minor	Unlikely	**Low**

7.1.2 Detailed Evaluation of Impacts / Risks

The area over which seismic sound may adversely impact marine species depends upon multiple factors including characteristics of the sound source, the extent of sound propagation relative to the location of receptors, and the sensitivity and range of spectral hearing of different species (Slabbekoorn et al. 2010; Popper and Hawkins 2012). A description of the seismic sound source and acoustic modelling of sound propagation is provided below.

A detailed evaluation of marine fauna sensitivity to sound and assessment of potential impacts is provided in Section 7.1.2.2 and Section 7.1.2.3.

7.1.2.1 Acoustic Modelling of Sound Propagation

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).

The rate of sound attenuation from the seismic source is dependent on local sound propagation characteristics, including seawater 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.

To assess the potential magnitude and extent of impacts from underwater noise produced during the Capreolus-2 3D MSS, TGS commissioned JASCO Applied Sciences (JASCO) to model sound propagation at several locations that were representative of the different water depths, bathymetry and seabed properties within the Acquisition Area (Koessler et al. 2020; Appendix E).

The objective of this acoustic modelling study was to evaluate the potential effects of sound on marine fauna including cetaceans, marine reptiles, fishes, elasmobranchs, benthic invertebrates and zooplankton, and on socio-economic receptors such as commercial fisheries and marine protected areas. Preliminary source modelling was conducted to determine the source with the highest equivalent far-field acoustic output of four comparable source arrays (which were defined as being between 3090 - 3480 in^3 to meet the technical specification and objectives of the Capreolus-2 3D MSS). These arrays were coupled with single impulse propagation modelling to determine the array most likely to produce the largest ranges to thresholds. This was determined to be a 3480 in^3 seismic source with a 6 m tow depth. Therefore, the acoustic modelling considered the 3480 in^3 seismic source in a triple source configuration, towed at 6 m depth behind a single vessel (Koessler et al. 2020; Appendix E). 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 nine sites within the Acquisition Area, with water depths between 47 and 567 m. Accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 hours (refer to Figure 7.1).

The modelling sites and scenarios were selected based upon a previous iteration of the TGS Capreolus-2 3D MSS Acquisition Area (as presented in Version 0 and Version 1 of the EP, submitted to NOPSEMA on 26th February 2020 and 7th April 2020 respectively). Since these EP submissions, the eastern boundary of the Acquisition Area and Operational Area has been modified. The modelling site locations remain within the current Acquisition Area, with the exception of Site 9, located in a water depth of 47 m (refer to Figure 7.1); this site is now located outside of the Acquisition Area. However, the modelling sites and scenarios are still considered to be representative of the water depths (which range from 50 m to 1,133 m), the bathymetry and seabed geoacoustic properties within the current Acquisition Area. Therefore, the sound fields presented by the modelling are considered to be representative of the sound fields that will be produced during the survey.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL), zero-to-peak pressure levels (PK), peak-to-peak pressure levels (PK-PK), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL) as appropriate for comparison with different sound exposure impact thresholds for marine fauna. A conservative sound speed profile that incorporated worst-case sound propagation conditions for the period of the survey was defined and applied to all modelling (Koessler et al. 2020; Appendix E).

Analysis of the modelling considered the distances away from the seismic source at which the sound exposure thresholds for marine fauna (outlined in Section 7.1.2.2 and 7.1.2.3) were reached. In addition to the sound exposure thresholds, the distance to an unweighted single pulse SEL of 160 dB re 1 µPa^2·s was modelled to assess the size of the low-power zone required under the EPBC Act Policy Statement 2.1 (DEWHA 2008b).

Contours of the modelled underwater sound fields were computed, sampled either as the maximum value over all modelled depths (maximum-over-depth: MOD) or at the seafloor for the nine single pulse locations, and for the two cumulative SEL_{24h} scenarios. The modelled distances to each of the sound exposure thresholds for marine fauna were computed from these contours. Two distances relative to the source are reported for each sound level:

- R_{max} - the maximum range to the given sound level over all azimuths; and
- $R_{95\%}$ - the range to the given sound level after the 5% farthest points were excluded.

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

The results of the sound propagation modelling are presented in relation to the relevant sound exposure thresholds for marine fauna groups in Section 7.1.2.3. The detailed results are provided in the acoustic modelling report (Koessler et al. 2020; Appendix E).

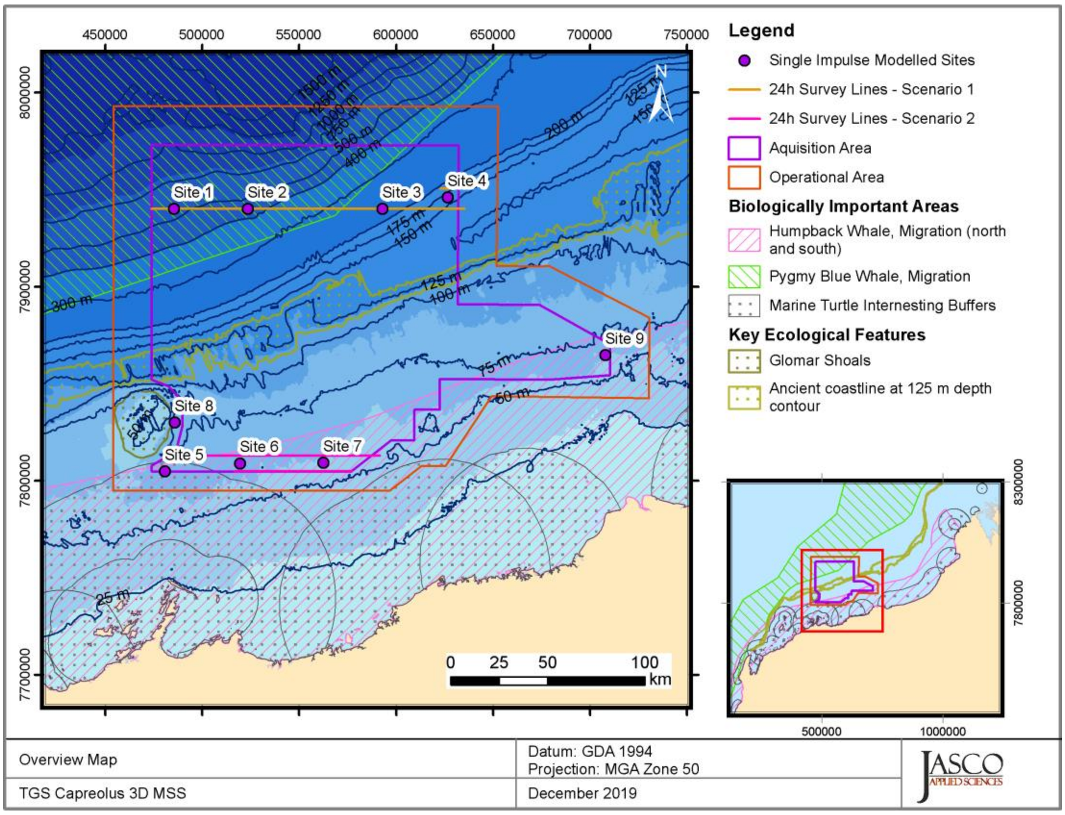


Figure 7.1 Capreolus-2 3D MSS Acoustic Modelling – Overview of Single Pulse Sites and SEL_{24h} Scenarios

7.1.2.2 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 detailed for each receptor in Section 7.1.2.3. They have been selected on the basis that they include 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. For marine mammals the appropriate period is recommended 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 over a 24 period 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 for mobile seismic surveys, as the levels received by the receptor change between impulses due to the mobile source. For marine mammals and many fish species, 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, the sound energy accumulated during the minutes or hours when the seismic source passes a location at the closest point of approach is the most relevant to the received accumulated sound exposures and thresholds based on a 24-hour exposure period are considered to be a conservative measure of the potential effect.

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/s^2) (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 $\mu m/s^2$) (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 in very close proximity to the source where it is the dominant component of a sound wave, while sound 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 very close range where the particle accelerations are greatest (Popper et al. 2014; Edmonds et al. 2016; Popper and Hawkins 2018) (i.e. directly beneath the seismic source and within distances in the order of tens of metres, as illustrated in Figure 7.4 in the assessment of potential impacts to benthic invertebrates below.

7.1.2.3 Impact Assessment

Cetaceans

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 generally 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 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 7-2, and are explained in more detail in the acoustic modelling report (Appendix E). Frequency weighting is also explained in Appendix A.3 of the acoustic modelling report (Appendix E). The peak pressure levels (PK) and frequency-weighted accumulated sound exposure levels (SEL) presented in Table 7-2 are from the U.S. National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2018) for the onset of PTS and TTS in marine mammals. The marine mammal behavioural threshold presented in Table 7-2 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 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 7-2 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)	
	Unweighted SPL (dB re 1 µPa)	Frequency Weighted SEL_{24h} (dB re 1 µPa^2·s)	PK (dB re 1 µPa)	Frequency Weighted SEL_{24h} (dB re 1 µPa^2·s)	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.

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 injury or changes to hearing (PTS and TTS) as a result of high sound levels at close range to the seismic source, or behavioural disturbance impacts (refer to the sound exposure thresholds for PTS, TTS and behavioural disturbance described above).

As described in Section 4.5.7, the Operational Area overlaps with the humpback whale migration BIA and the pygmy blue whale migration BIA. These species are expected to be present in greater numbers during peak migration periods. No seismic acquisition will occur within the defined BIAs during peak migration periods, and the Operational Area has been subdivided into zones to accommodate these seasonal avoidance commitments, as described in Section 3.2. The waters surrounding the Acquisition Area and Operational Area are not areas that are recognised for significant life stages or activities such as breeding, calving, resting or foraging and, therefore, cetaceans will be migratory and generally transient transit through the Operational Area during the survey.

As summarised in Table 4-10, there is the possibility that a number of other cetacean species may be present in the Operational Area and wider EMBA during acquisition of the survey including sei, fin, killer and Bryde's whales. The presence of these species within the Operational Area is likely to be limited to occasional transits of isolated individuals or small pods.

High-frequency (HF) cetaceans (e.g. beaked whales) are unlikely to be present in the Operational Area and surrounding waters, and accordingly the impact assessment is focused on low-frequency (LF) cetaceans (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 foraging BIAs, preferred water depths (<10 m) and lack of nearby suitable habitats. Impacts to dugong as a result of underwater sound from the seismic source are therefore not expected.

Table 7-3 presents the results of the acoustic modelling study for maximum predicted R_{max} distances to PTS (injury), TTS and behavioural response thresholds for cetaceans, for all modelled scenarios (nine single impulse sites and two multiple pulse scenarios). The results for the thresholds applied for cetacean PTS and TTS consider both metrics (single pulse 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 7-3 Maximum Predicted Horizontal Distances (R_{max}) to PTS, TTS and Behavioural Response Thresholds in Cetaceans, for All Modelled Scenarios

Hearing Group	Sound Exposure Threshold	R_{max} distance (km)*
PTS		
LF-cetaceans	219 dB re 1 µPa (PK)	0.03
	183 dB re 1 µPa^2.s (SEL_{24h})	2.34
MF-cetaceans	230 dB re 1 µPa (PK)	0.02
	185 dB re 1 µPa^2.s (SEL_{24h})	-
TTS		

Hearing Group	Sound Exposure Threshold	R_{max} distance (km)*
LF-cetaceans	213 dB re 1 µPa (PK)	0.10
	168 dB re 1 µPa^2.s (SEL_{24h})	65.4
MF-cetaceans	224 dB re 1 µPa (PK)	0.02
	170 dB re 1 µPa^2.s (SEL_{24h})	0.02
Behavioural Response		
LF-cetaceans	160 dB re 1 µPa (SPL)	4.32 - 9.56
MF-cetaceans		

* Model does not account for shutdowns. A dash indicates that the threshold is not reached.

As shown in Table 7-3, considering the NMFS (2018) SEL_{24h} threshold criterion, LF-cetaceans (such as pygmy blue whales and humpback whales) are predicted to have the potential to experience PTS at a maximum predicted distance of 2.34 km from the nearest survey line, based on application of the multiple pulse SEL_{24h} threshold across all water depths modelled (maximum-over-depth: MOD), but within less than 30 m based on the single pulse PK metric. For MF-cetaceans the maximum predicted distance to PTS effects reduces to <20 m, based on the application of the single pulse PK metric as the SEL_{24h} threshold was not exceeded.

The modelling results show that the corresponding SEL_{24h} radii for LF-cetaceans were considerably larger than those for peak pressure criteria. The maximum predicted distance to the TTS thresholds for LF-cetaceans is 65.4 km from the nearest survey line, based on application of the multiple pulse SEL_{24h} threshold, and within 100 m based on the single pulse PK metric. Note that the distance of 65.4 km is the R_{max} associated with downslope sound propagation from survey lines on the northern edge of the Acquisition Area and so is only relevant to propagation northward from lines acquired in this area and on the edge of the continental slope. In most other acquisition scenarios, the maximum range to TTS varies from within approximately 15 km from survey lines in the shallow southern portion of the Acquisition Area to within approximately 35 km to the south of survey lines in the northern portion of the Acquisition Area. For MF-cetaceans the maximum predicted distance to TTS effects reduces to <20 m in any location, based on the application of the single pulse PK metric as the SEL_{24h} threshold was not exceeded.

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. This represents a conservative worst-case scenario. More realistically, whales would not stay in the same location and may not remain within range of the survey line 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 (Koessler et al. 2020). The concept of an individual whale remaining within a range of 2.34 km (maximum predicted distance for PTS, based on the SEL_{24h} metric) from the operating seismic source (which is moving) for a full 24-hour period, or even for a few hours, is not credible. Should an individual remain within the range for potential impact, some recoverable TTS could occur. However, the likelihood of TTS occurring is reduced to some degree by the implementation of control measures including a shut-down zone of 500 m and a low-power zone of 2 km under Part A of EPBC Policy Statement 2.1, which reduces the potential for close range sound exposures where the greatest sound contribution is received. In addition, if the seismic survey vessel is required to shut-down/power-down three or more times per day for three consecutive days as a result of sighting a whale, TGS will extend the shut-down zone to a 2 km horizontal radius from the seismic source.

As shown in Table 7-3, predicted maximum R_{max} distances to PTS and TTS thresholds for LF-cetaceans based on the single pulse (PK) metric are considerably lower than those predicted using the multiple pulse SEL_{24h} thresholds. Application of the 219 dB re 1 µPa (PK) PTS threshold and of the 213 dB re 1 µPa (PK) TTS threshold indicates that R_{max} radii from individual shot points would be in the range of 20–100 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. PTS impacts are highly unlikely to occur given the precaution zones, soft-start, shut down and low power control measures that will be in place during acquisition of the survey.

The Blue Whale Conservation Management Plan (Action Area 2) states that anthropogenic noise in BIAs should be managed such that any blue whale continues to utilise the area without injury. Although TTS has previously been regarded as hearing impairment, not injury, advice from NOPSEMA and DAWE is that TTS should be considered a form of injury to pygmy blue whales and this should be prevented within the BIAs. Therefore, the potential for TTS effects (and therefore injury) to pygmy blue whales and management of this risk warrants further evaluation.

Pygmy blue whales migrate as solitary animals or in small groups along the continental slope, typically at depths between 500 m and 1,000 m on the way to the Banda and Molucca seas near Indonesia, where calving is understood to occur (Double et al. 2014). The northern migration typically passes north-western Australia between approximately April to August with the return southern migration between October and December.

The modelled range to TTS effects in LFCs of 65.4 km, resulting from the modelling scenario on the continental slope adjacent to the pygmy blue whale migration BIA, may be overly conservative for the following reasons:

- The 65.4 km range to TTS is based on the modelled maximum-over-depth range. Therefore, this range may be driven be the influence of downslope sound propagation, whereby sound produced near the surface over the continental slope becomes refracted towards the Deep Sound Channel (Salgado Kent et al. 2016). Therefore, the 65.4 km maximum-over-depth range may correspond with water depths that are greater than the depths at which pygmy blue whales may typically swim and dive to.
- As explained above, the SEL_{24h} criterion is a cumulative metric that reflects the dosimetric impact of sound energy accumulated over a 24-hour period and assumes that an animal is consistently exposed to such noise levels at a fixed location. The radii that correspond to SEL_{24h} typically represent an unlikely worst-case scenario for SEL-based exposure since, more realistically, marine fauna would not stay in the same location or at the same range for 24 hours (Koessler et al. 2020). It is noted that the accumulation of sound energy is not linear and rapid growth in accumulated exposures may occur over a matter of hours as the seismic source approaches an animal's location, but the criterion and modelling are still limited by the assumption that animals remain in a fixed location for this period.

To account for the movement of pygmy blue whales within the water column, TGS commissioned JASCO to undertake animal movement (animat) modelling. The purpose of the modelling was to predict a more realistic range at which animals experience the effects of PTS and TTS from accumulated sound exposures (Weirathmueller et al. 2020; Appendix F). Sound exposure distribution estimates were determined by moving large numbers of simulated animals through modelled time-evolving cumulative sound fields. The exposure modelling scenario considered a total of six days of parallel acquisition lines in the central and northern parts of the Acquisition Area, where the Acquisition Area overlaps with the pygmy blue whale migration BIA (refer to Figure 7.2). The exposure ranges are strongly dependent on the location of the source relative to the continental slope and the migration BIA. To understand this effect, exposures were analysed in 24-hour segments, including lines in some of the deepest waters of the Acquisition Area and also lines in progressively shallower waters of the continental slope and continental shelf. Each 24-hour exposure scenario considered the sound produced from two acquisition lines, in order to maximise the accumulated sound exposure in the north-west corner of the Acquisition Area, propagating towards the BIA.

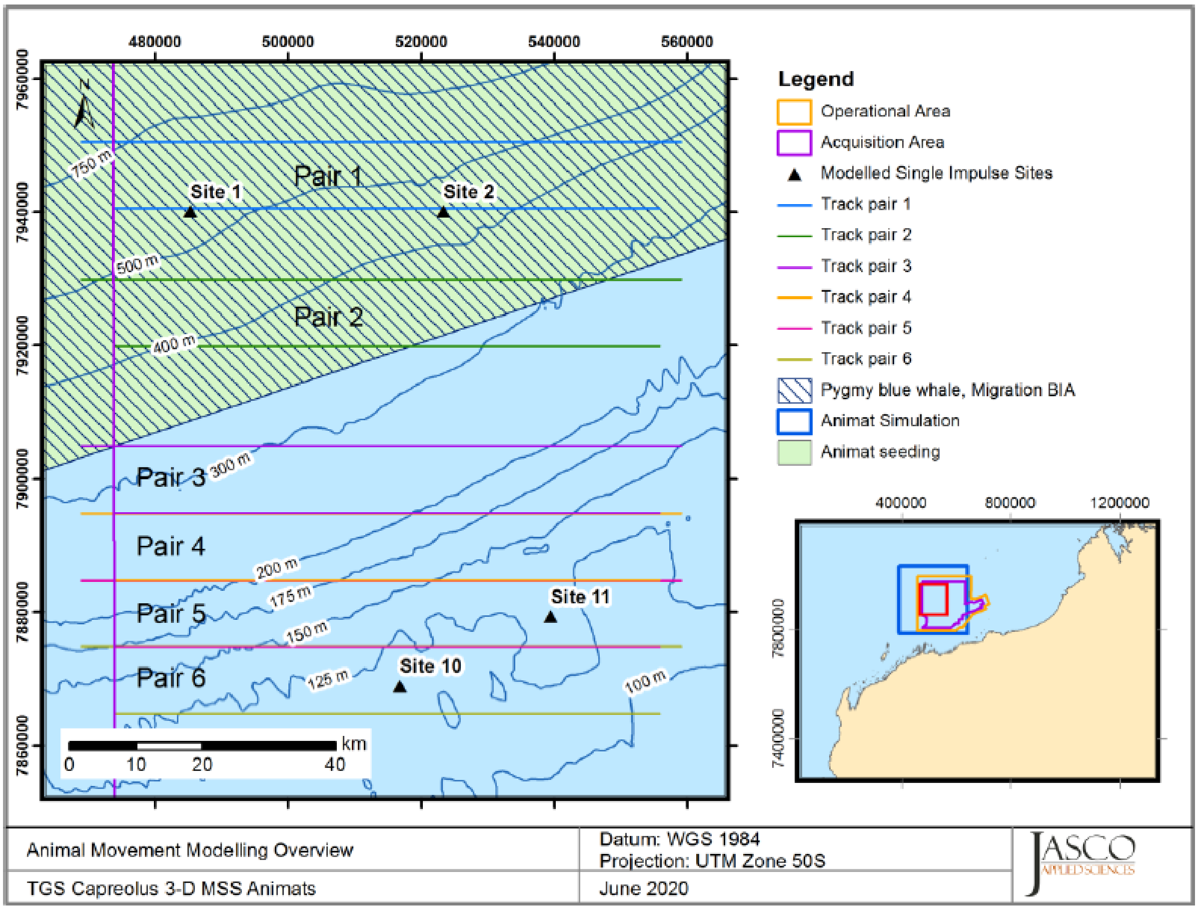


Figure 7.2 Seismic Source Tracks Used in Animal Movement Modelling, Coloured by Day of Survey (Weirathmueller et al. 2020)

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to model the movement of pygmy blue whales through the predicted sound field. Biologically meaningful movement rules were applied to each animal in the model to represent pygmy blue whale behaviours. This included swim speeds, direction, diving and ascent rates, dive depths (for both migratory dives near the surface and deeper exploratory or feeding dives), and time spent at or near the surface before diving again. Further detail on the movement and behaviour parameters and how the animat modelling was set up are provided in Appendix F.

The behavioural profile applied for pygmy blue whales was based on the available research for migrating pygmy blue whales and blue whales. Owen et al. (2016) monitored the fine-scale movement and diving behaviours of a migrating sub-adult pygmy blue whale off the west coast of WA. To reduce energy expenditure during migration, the whale dives to a depth that is likely to allow it to avoid surface wave drag and maximize horizontal movement. The mean depth of migratory dives (82% of all dives) was 14 m ± 4 m, and the whale spent 94% of observed time and completed 99% of observed migratory dives at water depths of less than 24 m. Feeding dives were undertaken to a mean maximum depth of 129 ± 183 m (range 13–505 m). The mean maximum depth of exploratory dives (107 ± 81 m, range 23–320 m) was similar to the mean maximum depth of feeding dives (129 m) and did not appear to be related to seafloor depth.

The diving behaviour of another pygmy blue whale, tagged off north-west Australia, is reported to have completed most dives between just 0 – 10 m with deeper dives occurring to between 50 m and 100 m, and a maximum of 250 m (AIMS 2019). This is preliminary data, which may require further review and validation, but the data suggests that the movements and diving behaviours may be consistent with the findings of Owen et al. (2016).

Croll et al. (2001) reports that the migratory dives of larger blue whales have a mean depth of 26.9 m ± 1.2 m. Given the blue whale's slightly deeper migration depth, this has been used instead of the sub-adult dive depth presented in Owen et al. (2016) in order to provide some conservatism in relation to the depth that the whales will spend the majority of their time swimming. However, the exploratory dive depth data was based on Owen et al. (2016).

The speed at which the whales swim can vary. For example, satellite tagging studies of pygmy blue whales during their northbound migration off WA by Double et al. (2012, 2014) reported that whales had a low occupancy rate in the region, with corresponding average travel rates at these latitudes between approximately 70 and 120 km/day (approximately 3 – 5 km/hr). This would indicate that pygmy blue whales passing along the continental slope in this area are likely to transit through the area within less than a day. Owen et al. (2016) report a slightly slower mean swim speed of 2.8 ± 2.2 km/hr. Sears and Perrin (2009) also report similar speeds for blue whale. Therefore, the lower travel rate of Owen et al. (2016) was selected as a conservative approach for the model so that animals were more likely to be exposed to sound in the same location for a greater amount of time.

Given the limited data available on pygmy blue whale movements and dive behaviours, additional conservative assumptions were applied to ensure that the analysis adopted a precautionary approach:

- The animat component of the model did not include any migration bias, i.e. all whales in the model were resident in the modelling area over the entire modelling period. In reality, if whales were migrating through the area at the rates reported in Owen et al. (2016) and Double et al. (2014, 2016), they would pass through the area and would likely be out of range in less than half a day.
- Migratory dives and exploratory dives were modelled at an even (50%) probability of occurrence. When compared with the 94% of time that the tagged pygmy blue whale in Owen et al. (2016) spent in shallow migratory dives, this forces the animat whales to spend a far greater proportion of time at depth and potentially exposed to greater sound levels. Such a dive profile is highly unlikely as it would be highly demanding for the whale energetically and in terms of oxygen consumption.
- The model did not include any aversion behaviour, i.e. whales exhibited no behavioural response or attempt at avoidance of the sound source. In reality, some avoidance by some animals is likely, particularly when the seismic source is at close range to a whale.

Based on the above, the results of the animat modelling exercise are expected to be very conservative.

A summary of the animat simulation results for migratory pygmy blue whales are presented for the 95th percentile exposure ranges (km) in Table 7-4. Exposure ranges to SEL thresholds on the day of greatest exposure were 0.12 km and 23.79 km for PTS and TTS respectively.. Based on these results, the conservative range for potential TTS effects in pygmy blue whales within the migration BIA is approximately 20 – 24 km, compared with the 65.4 km range previously predicted in Koessler et al. (2020) where animal movement was not factored into the model. Consequently, to prevent TTS in pygmy blue whales in the migration BIA, no operation of the seismic source will occur within 24 km of the pygmy blue whale migration BIA during the species migration periods (April – August and October – December). This exclusion is accounted for in the northern zone boundary presented in Figure 3.1).

Table 7-4 Exposure Ranges for PTS and TTS SEL_{24h} Thresholds for each day of the Simulated Survey

Track line pair (refer to Figure 7.2)	Range, $ER_{95\%}$, km	
	PTS, SEL_{24h}	TTS, SEL_{24h}
1	0.10	22.92
2	0.12	20.47
3	0.11	23.80

Track line pair (refer to Figure 7.2)	Range, $ER_{95\%}$, km	
	PTS, SEL_{24h}	TTS, SEL_{24h}
4	-	23.29
5	-	23.79
6	-	-

Overall, the potential impacts of noise emissions from the seismic source on cetaceans at any one time during acquisition of the Capreolus-2 3D MSS are mainly expected to be temporary behavioural changes (e.g. avoidance) by transient individuals. The potential for such disturbances to different individuals may be present somewhere within the Acquisition Area over a number of months during each calendar year of acquisition. Potential TTS effects may also occur to a few individuals, but long term or ecologically significant effects are highly unlikely. Given the proposed control measures and avoidance of acquisition in cetacean migration BIAs during the migration periods, predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean that may be present within the Operational Area.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbances to individual transient cetaceans over the duration of the survey is **Minor**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Marine Reptiles

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 (PK) for PTS effects and 226 dB re 1 μPa (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), as referenced in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017), 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; Finneran et al. 2017) were also applied for this impact assessment. The sound exposure thresholds applied for marine turtles are explained in more detail in the acoustic modelling report (Koessler et al. 2020; Appendix E).

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.

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 to Table 4-7).

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

Table 7-5 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 (nine single pulse sites and two multiple pulse scenarios).

Table 7-5 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 (PK)	<0.02
TTS	226 dB re 1 µPa (PK)	<0.02
Behavioural response	175 dB re 1 µPa (SPL)*	1.02 – 1.7
	166 dB re 1 µPa (SPL)#	2.3 – 5.08

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 7-5, the Finneran et al. (2017) 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 x 8 m in the horizontal plane), the actual effect range from the edge of the array will be less than 20 m. Therefore, it is highly unlikely that a turtle (or sea snake) would be exposed at such close range given that the source is towed directly behind the seismic vessel and some attempt to swim away from the approaching vessel and/or increasing sound levels from the seismic source is likely.

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 seismic source, and the Moein et al. (1995) criterion of 175 dB re 1 µPa (SPL) for an increased swimming response could be exceeded within approximately 1.7 km of the source.

As described in Section 4.5.8, the Operational Area partially overlaps with the internesting BIA for the flatback turtle and a Habitat Critical for the flatback turtle. However, no seismic acquisition will occur within the defined internesting BIA and Habitat Critical area during the nesting period (October – March). No known foraging BIAs are located within the Operational Area.

The 60 km internesting buffer for flatback turtles in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017) is based primarily on the movements of tagged internesting flatback turtles along the NWS reported by Whittock et al. (2014), which found that flatback turtles may demonstrate internesting displacement distances up to 62 km from nesting beaches. However, these movements were confined to longshore movements in nearshore coastal waters or travel between island rookeries and the adjacent mainland (Whittock et al., 2014). There is no evidence to date to indicate flatback turtles swim out into deep offshore waters during the internesting period.

A more recent paper by the same authors (Whittock et al., 2016) has more precisely defined flatback turtle internesting habitat along the NWS. The Whittock et al. (2016) study developed a habitat suitability map to identify areas where internesting flatback turtles may be present along the NWS, based on data compiled for a suite of environmental variables and satellite tracks of 47 internesting flatback turtles from five different mainland and island rookeries tracked over 1,289 days. Whittock et al. (2016) defined suitable internesting habitat as water 0–16 m deep and within 5–10 km of the coastline, while unsuitable internesting flatback habitat was defined as waters >25 m deep and >27 km from the coastline (refer to Figure 7.3).

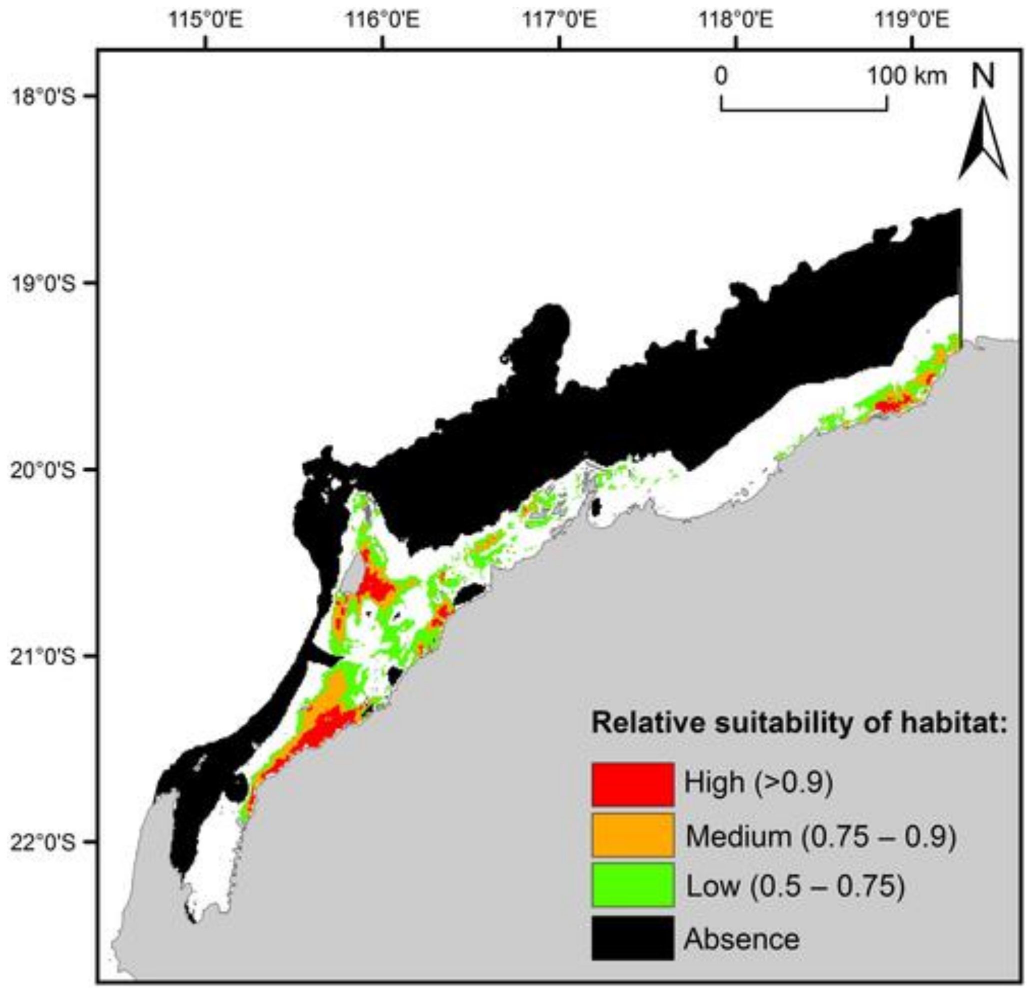


Figure 7.3 Relative Suitability of Habitat for Flatback Turtles along the NWS (Whittock et al., 2016)[3]

The primary environmental variables that influenced flatback internesting movement were bathymetry, distance from coastline, and sea surface temperature. Suitable areas of internesting habitat were located close to many known flatback turtle rookeries across the region (Whittock et al., 2016). This modelling study demonstrates that the internesting buffer BIA and 'habitat critical' overlapped by the Operational Area, or immediately adjacent to it, are unlikely to represent suitable habitat for flatback turtles during internesting periods. Hence it is highly unlikely that significant numbers of flatback turtles will be in these offshore, deep waters.

The evidence that suitable internesting habitat for flatback turtles is likely to be limited to relatively shallow waters within close proximity of the coastline is further supported by data from satellite telemetry of internesting flatback turtles at the Lacepede Islands (Thums et al., 2017). Flatback turtles remained at an average distance of 15.75 ± 12.25 km from West Lacepede Island, in water depths of 16 ± 3 m. None of the tagged turtles travelled into deeper offshore waters during internesting.

It is important to note that flatback turtle hatchlings do not have an offshore pelagic phase. Instead, hatchlings grow to maturity in shallow coastal waters close to their natal beaches (DoEE 2017). Flatback turtle hatchlings do not undertake oceanic migrations like the juveniles of other turtle species do, but spend their juvenile life phase within continental shelf waters (Limpus 2009; Walker 1994; Walker & Parmenter 1990).

[3] Areas of absence are where environmental variable values are outside the range of environmental variable values that overlap areas of suitable habitat (Whittock et al., 2016).

The majority of the Operational Area is located in water depths greater than 60 m, outside of the preferred depth range for marine turtles. The occurrence of marine turtles within the Operational Area is therefore expected to be relatively low, in particular in the deeper waters. Occasional individual marine turtles may transit through the Operational Area during the survey. Therefore, behavioural disturbances to turtles are expected to be temporary and localised and affect a relatively small number of the species. These disturbances are not expected to affect a significant proportion of populations in the Pilbara region or occur in habitat of any particular significance to key life stages. Even so, consistent with the Recovery Plan for Marine Turtles, no operation of the seismic source will take place in the flatback turtle internesting BIA during the internesting period (October – March).

At least 20 species of sea snake occur within the region (DEWHA 2008a). Amongst these species, one threatened and 14 listed marine sea snake species were identified to potentially occur in the Operational Area from a search of the EPBC Act Protected Matters Database. No coral reefs occur within or in close proximity to the Operational Area. Therefore sea snakes are also expected to occur in low numbers and behavioural disturbances are expected to be localised and temporary.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to marine reptiles is **Minor**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Marine Birds

Impact Assessment

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. As described in Section 4.5.9, the Operational Area overlaps with breeding BIAs for eight marine bird species and one resting BIA. No foraging BIAs are located within the Operational Area.

Impacts to foraging marine birds have not been observed previously during seismic surveys. Only birds diving and foraging within the Operational Area have the potential to be exposed to increased sound levels generated by the operating seismic source, while diving for small pelagic fishes near the sea surface. Such behaviours may result in a startle response during diving. Birds resting on the surface of the water in proximity to the seismic vessel have limited potential to be affected by sound emissions underwater due to the limited transmission of sound energy between the water/air interface, but may be startled by seismic pulses in close proximity to the seismic source. However, given the likely avoidance response from fish and other prey species in waters immediately surrounding the seismic source, birds are unlikely to forage near the operating seismic source. In the unlikely event that birds dive and forage near the seismic source, this is likely to only affect individual birds, resulting in a startle response with the affected birds expected to move away from the area as a result. The consequence of this is expected to be negligible and impacts at a population level are extremely unlikely to occur. It is expected that no species will be displaced from the wider areas of the breeding BIAs.

The behaviour and distribution of some fishes may be affected for short periods during and after exposure to the seismic source, which may result in short-term and localised changes in the distribution of target prey species for some species. However, these effects are unlikely to be discernible to foraging birds in the context of the normal movements and variation in the distribution of fishes. The behaviours and distribution of prey at any one time will remain largely unaffected in the Operational Area. Therefore, impacts to seabird populations are unlikely to occur.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to marine birds is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Fishes and Elasmobranchs

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 very few species can detect sounds 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 hearing sensitivity of fishes varies depending upon the auditory structures in the inner ear (otoliths surrounded by an epithelium of hair cells) and, if present, the swim bladder (Finneran & 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 fish‘s own motions (Nedwell et al. 2004). Therefore, all fish are sensitive to the particle motion component of sound 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 & 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 & Grande 2008; Popper et al. 2014; Popper & 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 Pilbara 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.

The modelling study (Koessler et al. 2020; Appendix E) assessed the ranges for quantitative threshold criteria based on the Popper et al. (2014) guidelines, and considered both PK and SEL_{24h} metrics for both water column and seafloor associated with mortality/potential mortal injury (PMI), recoverable injury and hearing impairment in the following categories reflective of the different hearing mechanisms and sensitivity to sound:

- 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; and
- 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 7-6 and explained in more detail in the acoustic modelling report (Appendix E). Note that the following assessment primarily focuses on impacts to fishes.

Table 7-6 Thresholds for Seismic Sound Exposure for Fish, Fish Eggs and Larvae, Adopted from Popper et al. (2014)

Type	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

Peak sound level (PK) dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s. All exposure thresholds 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 free-swimming 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 fish 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) did not reference an actual occurrence of this effect. At the time of developing the guidelines, no quantified data on injury and mortality from seismic sources on fishes had been reviewed by the Working Group. Therefore, the Popper et al. (2014) exposure guidelines for mortality/potential mortal injury and recoverable injury for fishes exposed to seismic source emissions are based solely on data from pile driving conducted on predominantly temperate, freshwater fish species. Although seismic surveys and pile driving both produce impulsive sound, their sound characteristics are markedly different; pile driving impulses result in a more rapid rise time in sound pressure than seismic pulses and it is this rapid rise time that has the greatest potential for trauma (Caltrans 2001, 2004; Hastings & Popper 2005; Popper et al. 2006).

Environmental Resources Management Australia (ERM) undertook a detailed literature review of potential fish mortality and physical injury as a result of exposure to seismic sources (ERM 2017). Of the 28 studies reviewed, only three observed direct mortality and in each case, mortalities occurred to caged fish at very close proximity to the seismic source (<2 m), which is not representative of real-life exposures from seismic surveys because fish are free-swimming and are not typically exposed at such close range. The received sound levels that resulted in mortality ranged from 220 to 241 dB re 1 µPa PK, however, other studies reported no mortality or injury at levels as high as 246 dB re 1 µPa PK. Therefore, the sound exposure criteria proposed by Popper et al. (2014) for mortality and injury are considered to be highly conservative and provide a precautionary approach in the assessment of potential injury and mortality effects to fishes from exposure to underwater noise from marine seismic surveys.

Temporary Threshold Shift

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 µPa^2·s proposed by Popper et al. (2014) in Table 7-6 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 Capreolus-2 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 for cetaceans, the 186 dB re 1 µPa^2·s SEL_{24h} criteria in Table 7-6 includes a level of conservatism as:

- The types of fish that are likely to occur in the 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 µPa^2·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 Operational Area; and
- 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 will be temporary and recoverable.

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 & 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 & MacLennan 2005; McCauley et al. 2000a; Fewtrell & 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 & 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 1µPa 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 & 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 Capreolus-2 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 uPa^2.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 & 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 & 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 & 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 PK-PK (equivalent to approximately 194, 196 and 206 dB re 1 µPa 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 that 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, has 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. However, the results of this research were not available at the time of preparing this EP.

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 were 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 & 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 weren't 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 & Løkkeborg (2002) reported on the effects of seismic surveys on Atlantic cod and haddock (Gadidae) and found that the abundance of fish were 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 5 days after the survey was completed (Engås et al. 1996; Engås & 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 6-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 µPa^2.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 & McCauley 2012; Miller & 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 µPa^2.s SEL or 168 – 190 dB re 1 µPa SPL and varying depending on hearing sensitivity and context) (e.g. Simmonds & MacLennan 2005; McCauley et al. 2000, 2003; Fewtrell & 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 & McCauley 2012; Miller & Cripps 2013).
- 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 & 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 has 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 & 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 7-6). 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. The 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 TGS' 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 aren't.

Impact Assessment

As described in Section 4.5.3, 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, red emperor and Spanish mackerel). The Operational Area overlaps with the Ancient Coastline at 125 m depth contour KEF. Parts of this KEF, represented as rocky escarpment, are considered to provide biologically important habitat in an area otherwise dominated by soft sediment. These areas of hard substrate may represent significant habitat for both demersal and benthic fish assemblages.

In addition, the Operational Area overlaps with a foraging BIA for the whale shark, which extends northwards from Ningaloo along the 200 m isobath (refer to Figure 4.11). Whale sharks may be present within the Operational Area between January and March, while they migrate between Christmas Island and Ningaloo Reef.

The EPBC Protected Matters Search (refer to Section 4.5.3) identified 29 pipefish species, six seahorse species, five pipehorse species and one seadragon that may potentially occur in the EMBA. 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. Due to the absence of suitable habitat within the Operational Area, pipefish and seahorses are unlikely to occur within the Operational Area and surrounding waters. Consequently, these listed marine species are not considered further in this impact assessment.

As described in Section 4.3, the Operational Area overlaps with the Glomar Shoals KEF. The KEF is located entirely outside of the Acquisition Area. Glomar Shoal (in water depths between 33 m to 77 m) is the main seabed feature identified within the Operational Area where significant shallow water benthic habitat is present that may support site-attached fish assemblages. For the purposes of the risk assessment, site-attached fishes are defined as fishes that rely on the benthic habitat and demonstrate a very high degree of site fidelity to the extent that they are unlikely or unable to flee an approaching seismic source and are instead likely to remain and/or seek refuge within habitat structures.

The biomass, diversity and abundance of fishes is typically greatest in the photic and upper meso-photic zones (<60 m depth) where biota such as hard corals are most abundant. The disappearance of live coral cover and corresponding lower fish diversity is often reported in water depths greater than 60 m (Lesser et al. 2009; Kahng et al. 2010, 2014; Lindfield et al. 2016; Fukunaga et al. 2016; Abdul Wahab 2018), including at other shoals of the north coast of Australia (Heyward et al. 2011 and ERM 2012). Benthic cover and morphological composition of hard corals at Glomar Shoal is reported to be a key influencing factor in fish community composition at Glomar Shoal, with coral reef-associated and herbivorous fish species associated with the occurrences of hard corals (Abdul Wahab 2018). The fish community structure at Glomar Shoal shows a strong relationship with habitat type, with a distinct difference in structure (species richness, abundance) in water depths <36.7 m (Abdul Wahab 2018). Surveys of the shoal have reported hard coral coverage to be limited and in water depths less than 40 m (Abdul Wahab 2018). Therefore, site-attached fish assemblages may be present at Glomar Shoals, principally in water depths less than 40 m.

Without appropriate control measures in place, noise emissions from the seismic source have the potential to impacts 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 7-7 presents the results of the acoustic modelling study for maximum predicted R_{max} distances to morality/PMI, recoverable injury and TTS thresholds in fishes in the Operational Area. Data are presented for both the maximum-over-depth (MDO) throughout the water column and for the seafloor. The results are further summarised in Table 7-8.

Table 7-7 Maximum Predicted Distances (R_{max}) to Mortality/PMI, injury and TTS Thresholds for Fish and Fish Eggs and Larvae for Single Pulse and SEL24h Modelled Scenarios, for Both Water Column and at the Seafloor

Marine Fauna Group	Potential Impact	Sound Exposure Threshold	Maximum-over-depth (MOD)	Seafloor
			R_{max} (km)	R_{max} (km)
I Fish: No swim bladder (incl. sharks)	Mortality/PMI	219 dB re 1 µPa²·s (SEL_{24h})	0.02	-
		213 dB re 1 µPa (PK)	0.10	0.09
	Recoverable injury	216 dB re 1 µPa²·s (SEL_{24h})	0.02	-
		213 dB re 1 µPa (PK)	0.10	0.09
	TTS	186 dB re 1 µPa²·s (SEL_{24h})	5.86	5.86
II Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality/PMI	210 dB re 1 µPa²·s (SEL_{24h})	0.04	0.04
		207 dB re 1 µPa (PK)	0.24	0.17
	Recoverable injury	203 dB re 1 µPa²·s (SEL_{24h})	0.10	0.1
		207 dB re 1 µPa (PK)	0.24	0.17
	TTS	186 dB re 1 µPa²·s (SEL_{24h})	5.86	5.86
III Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality/PMI	207 dB re 1 µPa²·s (SEL_{24h})	0.06	0.06
		207 dB re 1 µPa (PK)	0.24	0.17
	Recoverable injury	203 dB re 1 µPa²·s (SEL_{24h})	0.10	0.10
		207 dB re 1 µPa (PK)	0.24	0.17
	TTS	186 dB re 1 µPa²·s (SEL_{24h})	5.86	5.86

Marine Fauna Group	Potential Impact	Sound Exposure Threshold	Maximum-over-depth (MOD)	Seafloor
			R_{max} (km)	R_{max} (km)
Fish eggs and larvae	Mortality/PMI	210 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h})	0.04	0.04
		207 dB re 1 µPa (PK)	0.24	0.17
	Recoverable injury	Popper et al. (2014) relative risk criteria[#]	(N) Moderate; (I) Low; (F) Low	
	TTS		(N) Moderate; (I) Low; (F) Low	

*Not relevant. A dash indicates the threshold was not reached. [#]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).

Table 7-8 Summary of Maximum Distances to Injury and TTS Onset in Fish, Fish Eggs and Larvae for Single Pulse and SEL_{24h} Modelled Scenarios

Marine Fauna Group	Impact Criteria	Water Column		Seafloor	
		Metric associated with longest distance to impact criteria	R_{max} (km)	Metric associated with longest distance to impact criteria	R_{max} (km)
I - Fish: No swim bladder (incl. sharks)	Injury	PK	0.10	PK	0.09
	TTS	SEL_{24h}	5.86	SEL_{24h}	5.86
II - Fish: Swim bladder not involved in hearing and III – Fish: Swim bladder involved in hearing	Injury	PK	0.24	PK	0.17
	TTS	SEL_{24h}	5.86	SEL_{24h}	5.86
Fish eggs and larvae	Injury	PK	0.24	PK	0.17

The following fish types have been identified for this assessment:

- Site-attached fishes associated with the Glomar Shoals KEF;
- Demersal fish species, including key commercial indicator species such as tropical snappers and emperors (families Lutjanidae and Lethrinidae), including demersal fishes associated with the Ancient coastline at the 125 m depth contour KEF;
- Pelagic fish species, including key commercial indicator species such as Spanish mackerel; and
- Shark species, including *EPBC Act*-listed whale sharks.

<u>Site-Attached Fish Assemblages</u>

As shown in Table 7-7, the maximum predicted R_{max} distances to the injury thresholds of 213 dB re 1 µPa (PK) and 207 dB re 1 µPa (PK) at the seafloor for all hearing groups of fishes, and for fish eggs and larvae, range from 90-170 m. The maximum predicted R_{max} distance to the TTS threshold of 186 dB re 1 $\mu Pa^2 \cdot s$ (SEL_{24h}) at the seafloor for all hearing groups of fishes is 5.86 km.

As described above, the Operational Area overlaps with the Glomar Shoals KEF. However, the seismic source will not be operated within the KEF. The seismic source may be operated in water up to and adjacent to the KEF boundary during line run-outs and run-ins (during soft-starts). Therefore, at the closest point of approach to Glomar Shoal, the seismic source will be operated in water depths greater than 60 m, and generally at least 1 km from the nearest coralline habitat area in less than 40 m water depth where site-attached fishes are most likely to occur (refer to Figure 4.8 and Figure 4.9 in Section 4.5). Given the maximum predicted R_{max} distance for mortality/injury is 170 m, shallow habitat within the Glomar Shoal KEF that potentially supports site attached fishes is not expected to be exposed to mortality/injury effects. The maximum predicted R_{max} distance for TTS is 5.86 km. However, this R_{max} distance corresponds with the broadside sound propagations, which are significantly larger than propagations in the endfire directions. Given the east-west or north-east to south-west line orientation proposed, the sound exposure levels received at Glomar Shoal (and corresponding ranges to TTS in this direction) will be less. As illustrated in the acoustic modelling report (Appendix E), the distance to TTS on the seafloor at the end of modelled acquisition lines in the vicinity of Glomar Shoal, resulting from received cumulative sound exposures (SEL_{24h}) in either the endfire direction or at an angle of 45 degrees from the sail lines is approximately 1 km. There is limited overlap with the Glomar Shoals KEF and no overlap of these exposures with the site-attached fish habitats in water depths less than 40 m. Therefore, site-attached fish assemblages in water depths less than 40 m are unlikely to experience TTS effects. If site-attached fishes are present in deeper parts of the shoal (up to approximately 60 m water depth), it is possible that some fishes may experience TTS.

The potential for TTS to occur is not the same for all fish species. The Popper et al. (2014) threshold is based on exposure experiments to different types of fish including sensitive fishes with a swim bladder mechanism involved in hearing. Most marine fish species do not have this hearing mechanism and are less sensitive to sound pressure. Therefore, some types of fish may not begin to experience TTS until sound exposure levels are higher. As Popper (2018) summarises, if TTS takes place in site-attached fishes in the shallow parts of Glomar Shoal, its level is likely to be sufficiently low that it may not be possible to easily differentiate it from normal variations in hearing sensitivity, and recovery will start as soon as the most intense sounds end and is likely to occur within 24 hours. The potential for such effects to have significant implications on the fishes' fitness and survival is low. For example, fishes exposed during the Woodside Maxima 3D survey at Scott Reef were examined for evidence of TTS. This included four species of tropical reef fishes, including the pinecone soldierfish (a sound pressure-sensitive species which has a swim bladder connection with the inner ear). None of the four species experienced any TTS following close-range exposure to 190 dB re 1 $\mu Pa^2 \cdot s$ SELcum (Hastings et al. 2008; Hastings & Miksis-Olds 2012). No significant decreases were detected in the diversity and abundance of either sound pressure-sensitive or non-pressure sensitive fish species after the seismic survey compared to the long-term temporal trend before the survey (Woodside 2011; Miller & Cripps 2013). Therefore, while TTS effects in site-attached fishes at Glomar Shoal may occur, the potential for impacts to individuals' fitness and survival is limited and impacts to fish community structure at the shoal are not expected.

Any potential TTS effects to fishes within the KEF are not likely to be ecologically significant at a population level for the following reasons:

- Limited spatial overlap with the Glomar Shoals KEF – no operation of the seismic source within the KEF. The KEF is located approximately 5 km from the Acquisition Area boundary and operation of the seismic source will occur over 1 km from habitats that are most likely to support site-attached fishes.
- The sound exposure thresholds applied are likely to be conservative and the criteria predicting the largest impact ranges (across all of the modelled sites and scenarios) have been utilised where relevant, providing further conservatism in the impact assessment.
- The area of potential impact for the assessed fish assemblages is a low proportion of the overall area they are likely to inhabit at Glomar Shoal. 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) and Popper (2018) report that fish that showed TTS recovered to normal hearing levels within 18-24 hours.
- Popper (2018) in his expert review of TTS for the Santos Bethany 3D MSS, which considered similar fish species as present within and adjacent to the Capreolus-2 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.
  - Nothing is known about the behavioural implications of TTS in fishes in the wild. However, since the TTS is likely very transitory, the likelihood of it having a significant impact on fish fitness is very low.

Based on the qualitative approach applied in Popper et al. (2014) the likelihood of behavioural effects occurring is assessed as high within tens or hundreds of metres of the seismic source. Site-attached fish communities in water depths less than 40 m at Glomar Shoal are unlikely to exhibit significant behavioural impacts, although fishes in deeper waters within the wider Glomar Shoal KEF may exhibit some behavioural responses to noise emissions from the seismic source for short periods when it is operating near Glomar Shoal.

<u>Demersal Fish Species</u>

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 & Wodinsky 1963; Higgs et al. 2006; Braun & 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 seafloor for the hearing group of fishes with swim bladders (Group II and III, which would represent most demersal fish), is 170 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 240 m. Therefore, injury effects could occur to demersal fishes at or close to the seafloor 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 there 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 (~5.86 km in the water column and ~5.86 km at the seafloor; refer to Table 7-8) individuals in demersal fish communities at or close to the seafloor within the Acquisition Area could experience TTS effects. The radii that corresponds to SEL_{24hr} 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 a period of 24 hours. Therefore, this method is highly conservative and a reported radius of SEL_{24hr} 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 Caproelus-2 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 & 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 & Popper (2016) highlight that some responses to man-made 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 & Popper 2016).

Based on 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 the Ancient coastline at 125 m depth contour KEF 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.

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 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 without swim bladders (Group I) and with swim bladders (Groups II and III), is 90 m and 240 m respectively (refer to Table 7-8). The maximum predicted R_{max} distance to the TTS threshold in the water column for all fish hearing groups is ~5.86 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 5.86 km of the operating seismic source for several hours to be exposed to sound levels that could cause TTS. Pelagic fishes are most likely to exhibit behavioural responses (avoidance) by moving away from an operating seismic source that approaches within a few tens of metres of them.

Whale Sharks

The Operational Area overlaps with a foraging BIA for the whale shark, which extends northwards from Ningaloo along the 200 m isobath (refer to Figure 4.11). The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November).

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 (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 100 m. The maximum predicted R_{max} distance to the TTS threshold for this fish hearing group is ~5.86 km. It is important to appreciate that individual whale sharks would have to remain within a range of approximately 5.86 km of the operating seismic source (which is also moving) for several hours 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 the 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 or NMR (DSEWPaC 2012).

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to fishes and elasmobranchs is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Benthic Invertebrates

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 & 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 & Gason 2006; André et al. 2016; Roberts et al. 2016; Edmonds et al. 2016; Carroll et al. 2017; Popper & 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 seafloor, with larger arrays and shallower water being related to higher particle motion levels, thus more relevant to effects on crustaceans and molluscs (including bivalves) (Koessler et al. 2020; Appendix E).

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 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) 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 PK-PK, 186 to 190 dB re 1 μPa^2.s per-pulse SEL, and SEL_{cum} of 192 to 199 dB re 1μPa^2.s. Exposed lobsters and control lobsters were sampled up to a year post-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 & Gardner 2009; Kordjazi et al. 2015). Therefore, the levels of statocyst impairment reported in the Day et al. (2016a, 2016b) study appear to not 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.

Day et al. (2019) found that airgun exposure caused damage to the righting reflect and statocysts in rock lobsters (*Jasus edwardsii*). Following exposure equivalent to a full-scale commercial array (3,100 cui) passing within 100–500 m, lobsters showed impaired righting and significant damage to the sensory hairs of the statocyst. Reflex impairment and statocyst damage persisted up to 365 days post-exposure and did not improved following moulting. For this study, maximum measured received noise levels were 209-213 dB re 1 µPa (PK-PK).

Kosheleva (1992; cited in Parry & 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 1µPa at a distance of 0.5 m or greater from the source. Conversely, Matishov (1992; cited in Parry & Gason 2006) reported a single scallop shell splitting in a sample of three scallops, but this was located 2 m beneath a seismic source element and therefore exposed to maximum sources levels (which is not representative of a typical commercial seismic survey).

Recent Australian studies (Przeslawski et al. 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 PK-PK, 181 to 188 dB re 1 µPa^2.s per-pulse SEL, and SEL_{cum} of 188 to 198 dB re 1µPa^2.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 6-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) timescales post exposure. Exposures did not elicit energetically expensive behaviours (i.e. extensive swimming or long periods of valve closure), but scallops showed significant changes in some behavioural patterns during exposure (e.g. “flinch” response) and scallops showed an increase in recessing into sediment following exposure (Day et al. 2017).

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 PK-PK to 212 dB re 1 µPa PK-PK, based on the findings of the Payne et al. (2008) and Day et al. (2016a, 2016b) studies, were applied in the assessment. The Payne et al. (2008) 202 dB re 1 µPa 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 PK-PK thresholds could be associated with some level of sub-lethal effects in these animals (Koessler et al. 2020; Appendix E). A 213 dB re 1 µPa PK-PK level is considered as representative of levels that may result in sub-lethal effects and chronic mortality in molluscs and some other invertebrates based on Day et al. (2016b, 2017).

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

Impact Assessment

<u>Sound Pressure</u>

As described above, a range of sound exposure thresholds, from 202 dB re 1 µPa PK-PK to 213 dB re 1 µPa PK-PK, were applied in the acoustic modelling study for benthic crustaceans. Sound levels of 209-212 re 1 µPa 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 PK-PK, maximum predicted R_{max} distance was 255 m. The maximum predicted R_{max} distance associated with the 213 dB re 1 µPa PK-PK level for sub-lethal effects and chronic mortality (Day et al. 2016b, 2017) is 151 m.

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

Sound Exposure Threshold (PK-PK)	R_{max} (m)
213 dB re 1 µPa	151
212 dB re 1 µPa	176
210 dB re 1 µPa	211
209 dB re 1 µPa	225
202 dB re 1 µPa	588

The PK sound level at the seafloor directly underneath the seismic source was estimated for both single pulse modelling sites, and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018b). The sound level was reached within an 8 m horizontal range from the acoustic centre of the source at the shallowest modelled site only (47 m water depth). As the seismic source is not a point source, the sound level may only be exceeded directly beneath the source, if at all. Therefore the footprint of effects is negligible. In addition, the 226 dB re 1 µPa PK reported in Heyward et al. (2018b) is not a threshold above which impacts are expected to occur, but a level at which no short term or long term effects were observed. Impacts to corals and sponges are not expected until significantly higher levels are exceeded, which are not predicted to occur during this survey. Therefore, no measurable impacts to corals and sponges are expected.

As described in Section 4.5.2, the Operational Area overlaps with the Glomar Shoals KEF and the Ancient Coastline at 125 m Depth Contour KEF.

The benthic communities and fish assemblages at Glomar Shoal were surveyed during a study of Glomar Shoals and Rankin Bank conducted by AIMS. It was found that macro-benthic organisms represent just 9.5% of the total cover; macroalgae (4.8%), sponges (1.8%), soft corals (1.3%), hard corals (0.4%) and other organisms (1.1%). The remaining cover comprised abiotic substrates. Total cover of hard corals, soft coral, sponges and other organisms (including ascidians bryozoans and hydrozoans) was highest at <40 m and decreased with depth (Abdul Wahab 2018). Therefore, a variety of benthic invertebrate communities are expected to be present at the shoals. However, the seismic source will not be operated within the KEF or in water depths shallower than approximately 60 m in the vicinity of the shoal.

Preliminary data from the AIMS North West Shoals to Shore research program, which includes multibeam and towed video surveys of some areas of the Ancient Coastline at the 125 m Depth Contour KEF, has found that these depth contours are dominated by sandy habitats with limited areas of hard substrate filter feeder communities. Therefore, substantial benthic invertebrate communities are not necessarily present within the Acquisition Area.

The seismic source will not be operated in shallow water depths less than 50 m where benthic invertebrate communities are likely to be more abundant than in deeper waters. Given the maximum predicted R_{max} distance for impacts to crustaceans of 225 m, there is the potential for some crustaceans on the seafloor within these KEFs 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. However, it is unlikely that this would occur to the majority of individuals, therefore, impacts at a population level due to reduced fitness would be unlikely as there would be sufficient unaffected individuals to maintain the population. Chronic mortality may also occur in a small number of organisms within a maximum distance of 151 m from the source within the weeks and months following exposure (Day et al. 2016b, 2017).

At received noise levels of 209 dB re µPa (PK-PK) (Day et al. 2016a), lobsters 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.

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 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. (2016), 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 (Koessler et al. 2020).

As described above, 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. (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} (Koessler et al. 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 32 m, which only occurs at the shallowest site (Site 9, 47 m water depth) (refer Figure 7.4).

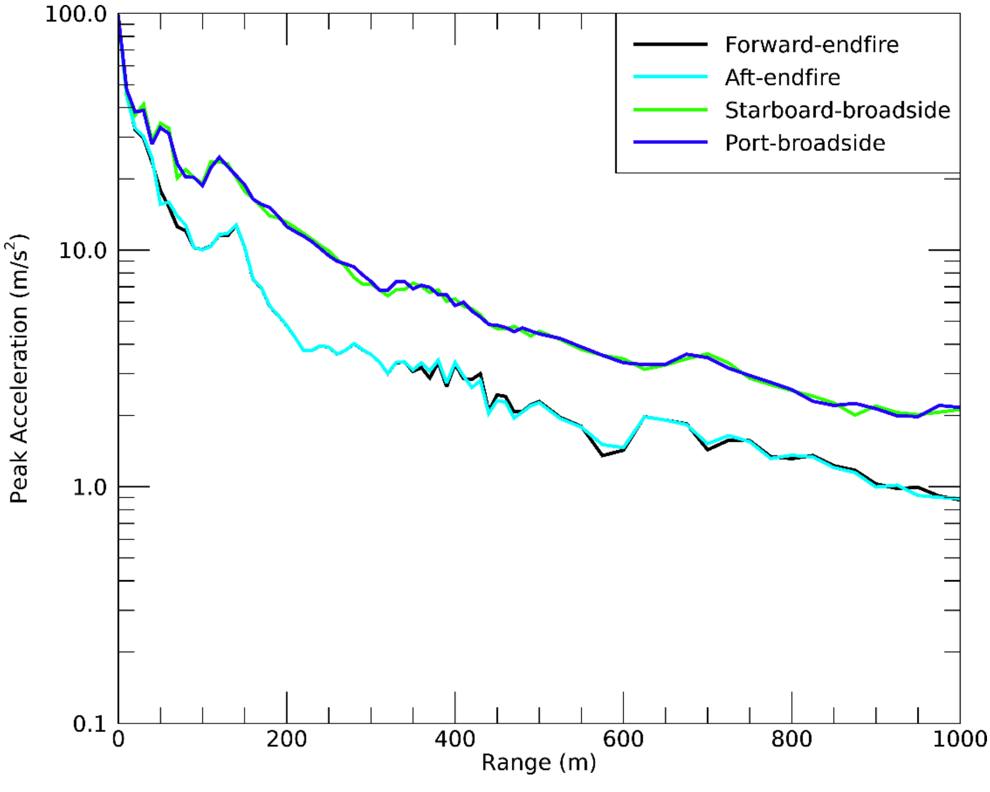


Figure 7.4 Maximum Particle Acceleration (top) and Velocity (bottom) at the Seafloor as a Function of Horizontal Range from the Centre of the 3,480 in^3 Array along Four Directions

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 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 (Koessler et al. 2020).

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 Capreolus-2 3D MSS, modelled peak acceleration at 10 m range was predicted to be between 21.8 and 47.5 ms^{-2} depending on the site; corresponding values at 100 m range was predicted to be between 11.4 and 19.2 ms^{-2}. At ~477 m, the modelling predicts acceleration ranging between 4.5–6.7 ms^{-2} in the broadside directions. These result aligns with the measurements reported in Day et al. (2016a) and Day et al. (2016b) thus represents what is likely to occur (Koessler et al. 2020).

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.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to benthic invertebrates is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Zooplankton

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 Capreolus-2 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 & Knutsen 1987; Holliday et al. 1987; Kosheleva 1992 cited in Parry et al. 2002; Pearson et al. 1994; Turnpenny & 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 Capreolus-2 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 (PK-PK; approximately 205 dB re 1 µPa 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 more conservative level of 178 dB re 1 µPa 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;
- the abundance of zooplankton estimated by net samples declined by 64%; and
- the 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 – 2 tows each sampling time x 3 distances from the gun (0 m, 200 m, 800 m) x 2 levels (Control, Exposed) x 2 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 Northwest 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 Northwest Shelf Integrated Marine and Coastal Regionalisation of Australia (IMCRA) Mesoscale Bioregion, of which the Capreolus-2 3D MSS is located mostly within, therefore the findings of this study are directly applicable in determining the potential impacts of the Capreolus-2 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 µPa^2.s and comparable to the far-field source levels predicted for the Capreolus-2 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 no sublethal effects of seismic exposure to the copepods. 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 other 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.

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 PK-PK threshold derived from the McCauley et al. (2017) study (refer to Table 7-7).

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 µPa^2·s (SEL_{24h})	<0.04
207 dB re 1 µPa (PK)	0.24
178 dB re 1 µPa PK-PK	14.0

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 (PK) threshold is 240 m. Based on the application of the McCauley et al. (2017) threshold of 178 dB re 1 µPa PK-PK, the maximum predicted R_{max} distance increases to approximately 14.0 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 & Hutchings 1996; Holliday et al. 2011; McKinnon et al. 2008; Pearce et al. 2000; Sutton & 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.

The potential impacts of noise emissions from the seismic source on plankton during the Capreolus-2 3D MSS are considered to be 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 Operational Area.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to fish eggs and larvae and zooplankton is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Fish Spawning

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 vocalisation, 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 relevant key indicator commercial fish species, which commercial fisheries stakeholders have raised as a concern during consultation.

Section 4.5.4, describes the key indicator species that are relevant to the Capreolus-2 3D MSS. Recent information obtained from DPIRD Fisheries (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 assessment considers the potential magnitude of effects to fish spawning behaviours, and therefore the potential influence of the survey on recruitment success and the sustainability of key indicator fish species. The assessment considers:

- Spatial-temporal analysis – to provide context on the proportion of the spawning biomass that may be exposed during the Capreolus-2 3D MSS;

- Consideration of the natural variability in fish distribution, spawning biomass and recruitment; and
- Consideration of the sustainability status of the fish stocks and fisheries.

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.

Spatial-Temporal Analysis

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

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

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

It is understood from DPIRD (2019c) that all of these species undergo group spawning throughout their ranges, 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 of the Acquisition Area are greater than 50 m. Therefore, the Capreolus-2 3D MSS is not expected to impact the spawning of the species.

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

- **Spatial overlap is based on a week (7 days) of acquisition lines with a 5 km buffer applied to the racetrack formation to account for possible uncertainty about the range to disturbance to fish.** This approach accounts for an area that will be encircled during a typical racetrack line acquisition and therefore subject to sound exposure from the seismic source. A week of racetrack was selected by TGS as this reflects an area where the seismic survey vessel will acquire consecutive, adjacent lines within proximity to the same general area of seabed and groups of demersal fishes. The 7-day timeframe is also precautionary in order to account for scientific uncertainty in relation to the duration and recovery of behavioural disturbances in fishes; it provides a conservative reflection of the longest duration changes in fish behaviour or fish distribution (approximately 5 days, as noted by Slotte et al. (2004); Engås et al. (1996); Engås & Løkkeborg (2002), noting that such changes are limited to studies that focused primarily on migrating sound pressure-sensitive types of fish with a swim bladder-ear connection (Clupeidae, Gadidae). Behavioural changes in demersal fish species typically return to normal within minutes or hours following exposure, although noting that during the racetrack formation, the same groups of fish may be exposed again when the seismic source returns to acquire an adjacent line nearby. Within any 7-day period, the seismic survey vessel (travelling at a speed of approximately 4.5 knots [8.3 km/hr]) will cover a distance of approximately 1,400 km.

It is also appropriate to consider a week of acquisition lines, given that over the duration of each survey, the seismic survey vessel would gradually move across the survey area; following a week, the racetrack would have progressed sufficiently far that it would no longer disturb the same areas and groups of demersal fishes as may be disturbed at the start of the racetrack. Therefore, this 7-day scenario already provides a highly conservative reflection of the spawning area that may be exposed at any time during the survey, and accounting for a larger area would significantly over-represent this area.

To apply an additional level of conservatism and account for possible uncertainty about the exact range over which fish may be disturbed, a 5 km buffer has been applied to the racetrack formation to account for potential variability in the hearing of different fish species and to broadly represent where some fishes may have some awareness of sound pressure changes, noting that the key indicator demersal fish species are primarily sensitive to particle motion effects more so than sound pressure and significant behavioural effects are more likely to be limited to within tens or hundreds of metres of the seismic source (Popper et al. 2014).. Overall, the 7-day scenario and 5 km sound exposure buffer would result in an area of disturbance of approximately 2,300 km^2.

- **The spatial extent of the spawning areas for each key indicator fish species has been estimated based on each species' depth range (as advised by DPIRD 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 survey depends on the duration of the egg and larval dispersion phase and the oceanographic currents; connectivity and recruitment in a single season may therefore occur within and well beyond the limits of the 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 TGS to provide a conservative indication of the proportion of the stocks that may be affected in a single spawning season. Referencing the fishery management units also allows the results to be considered in relation to the annual fish stock status assessments, which are also reported per fishery management area (an approach that is recognised as being a conservative approach for fishery management purposes [Gaughan et al. 2018]). As a result, the spatial overlaps accounted for in the spatial-temporal analysis are likely to significantly overestimate the percentage of spawning area available to each species.

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

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

Table 7-11 presents the spatial overlap 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 2.3% (red emperor) to 3.3% (goldband snapper).

Table 7-11 Spatial Overlap with Spawning Ranges of Key Indicator Fish Species

Fish Species	Principal Depth Range (m)	Spawning Area(km^2)*	Spatial Overlap with 7-days of Acquisition Lines + 5 km Buffer	
			Area (km^2)	%
Red Emperor	10 – 180	99,349	2,300	2.3%
Rankin Cod	10 – 150	92,568	2,300	2.5%
Goldband Snapper	50 – 200	68,748	2,300	3.3%
Bluespotted Emperor	5 – 110	77,903	2,300	3.0%
Giant Ruby Snapper	150 - 140	43,566	2,300	2.3%

*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.

A temporal (duration) analysis has been conducted to determine the maximum overlap between the timing of the Capreolus-2 3D MSS and the spawning times of key commercial indicator fish species (refer to Table 7-12). The temporal overlap ranges from 62% (red emperor) to 100% (ruby snapper).

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

Fish Species	Spawning Period	Maximum Temporal Overlap with the Capreolus-2 3D MSS*	
		Days	%
Red Emperor	September - June (303 days)	190	62.7%
Rankin Cod	June – December, March (245 days)	190	77.6%
Goldband Snapper	October – May (243 days)	190	78.2%
Bluespotted Emperor	July – March (274 days)	190	69.3%
Giant Ruby Snapper	December – April (151 days)	190	100%

*The temporal overlap is based on the number of days of acquisition coinciding with the days that each species is known to spawn. The temporal overlap does not take into consideration management controls adopted.

It is important to note 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 effected 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 spatial and temporal overlap of 7-days of acquisition with the spawning times and ranges of key commercial indicator fish species (refer to Table 7-13).

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

Fish Species	Spatial Overlap (%)	Temporal Overlap (%)	Combined Spatial-Temporal Overlap (%)
Red Emperor	2.3%	62.7%	**1.5%**
Rankin Cod	2.5%	77.6%	**1.9%**
Goldband Snapper	3.3%	78.2%	**2.6%**
Bluespotted Emperor	3.0%	69.3%	**2.1%**
Giant Ruby Snapper	2.3%	100%	**5.3%**

As shown in Table 7-13, the maximum spatial-temporal overlap (5.3%) is with the ruby snapper stock range and spawning period. The spatial-temporal overlap for other key indicator species ranges from 1.5%% (red emperor) to 2.6%% (goldband snapper). As noted above, a number of assumptions have been applied that make the spatial-temporal analysis results highly conservative.

<u>Natural Variability in Fish Distribution, Spawning Biomass and Recruitment</u>

In addition to the above spatial-temporal analysis, 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 7.2 presents CPUE data for the PFTIMF for red emperor, rankin cod, blue-spotted emperor and goldband snapper.

The spatial-temporal analysis accounts for disturbance to fish throughout the entire duration of the survey (up to 190 days), whereas the natural variability in the distribution of fish means that areas of high fish abundance may be exposed for a limited period of time, while the seismic survey vessel is operating in that area. At other times of the survey, while the seismic survey vessel is operating in areas of lower fish abundance, fewer fish may be exposed.

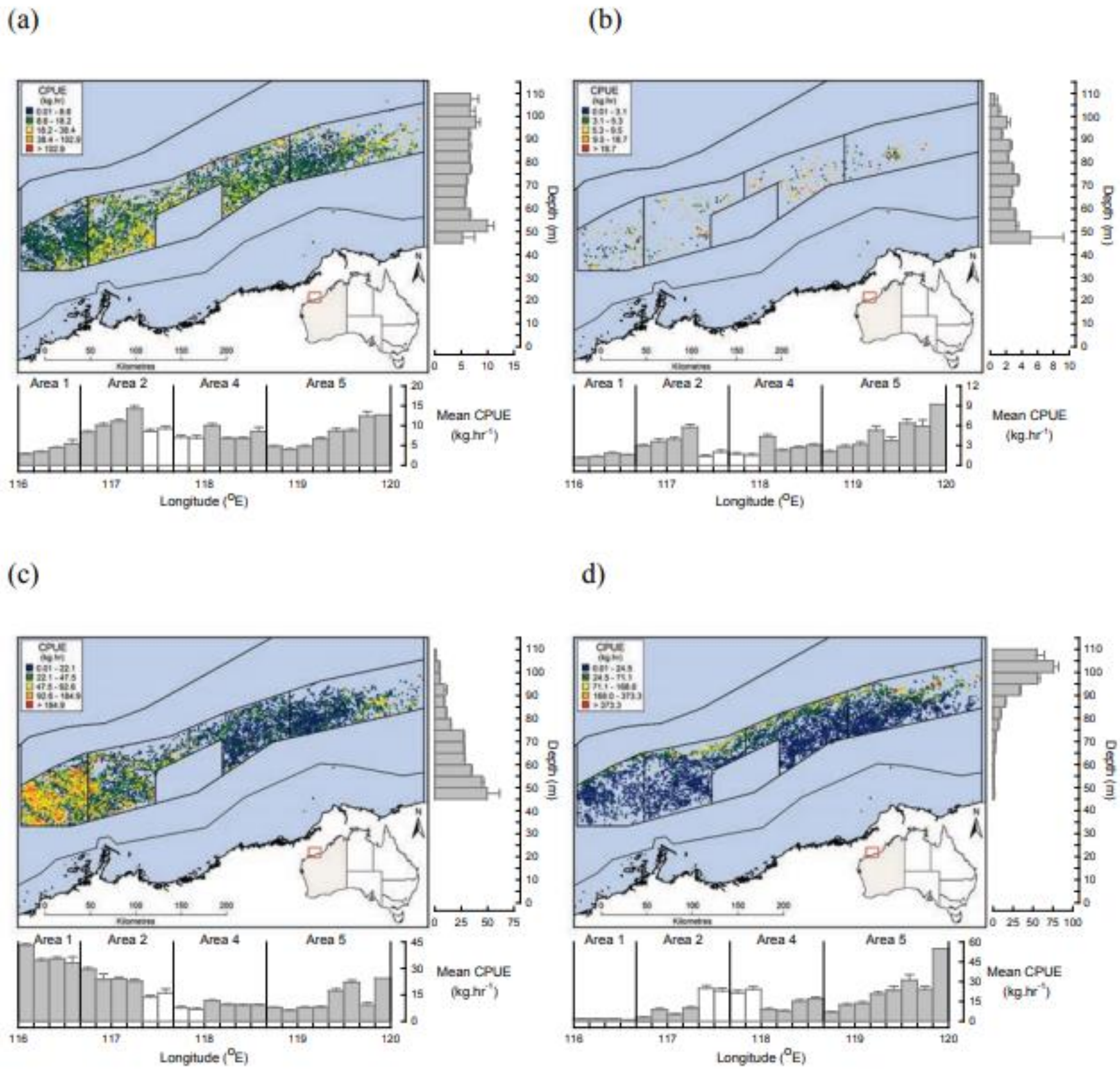


Figure 7.5 Spatial Distribution of CPUE for the PFTIMF from 2004-2008 for four Indicator Species (Gaughan et al. 2018)[4]

To provide further context, TGS 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 spawning's (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 7.6). 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 7.7). 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

[4] (a) Lutjanus sebae, (b) Epinephelus multinotatus and (c) Lethrinus punctulatus and (d) Pristipomoides multidens.

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 5.3% 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 survey are unlikely to be discernible from natural variation, given that it is only the groups of fishes exposed at a particular site and point in time that may be affected; spawning will continue undisturbed elsewhere throughout the stocks' ranges and the majority of spawning groups in the region at any point in time will be undisturbed. The affected groups of fishes will also spawn again at multiple other times during the spawning season and so discernible impacts to recruitment and populations are not expected.

The serial, broadcast spawning strategies of the indicator demersal fish species, by their very nature, offsets potential high natural embryo and larval mortality as a result of predation or other environmental factors and thereby spreads the risk or potential opportunity for larval settlement over large areas and long timeframes. Subsequent recruitment of fishes to the adult stock also occurs over extended timeframes and is ongoing. For example, with reference to goldband snapper stocks, the Australian Government's FRDC has previously noted that moderate or long-lived species such as goldband snapper are unlikely to be affected by "short-duration" environmental/climatic changes (of one or a few years), because adult stocks comprise fish that are recruited over many years (Martin et al. 2014). Therefore, in comparison, the occasional, short-term, transient and localised disturbances to groups of fish as a result of a seismic survey would have impacts many orders of magnitude smaller than regional scale environmental/climatic events that would affect entire stocks.

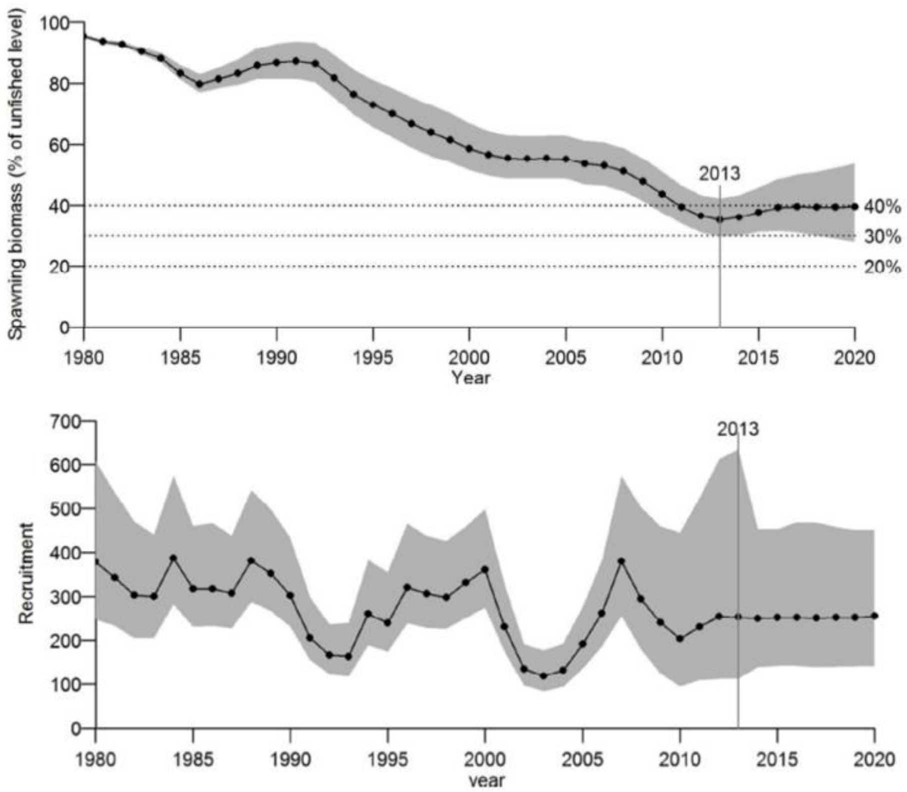


Figure 7.6 Red Emperor Spawning Biomass as a Percentage of Unfished Levels (top) and Recruitment (millions of fish) (bottom) (source: DoF 2015a)[5]

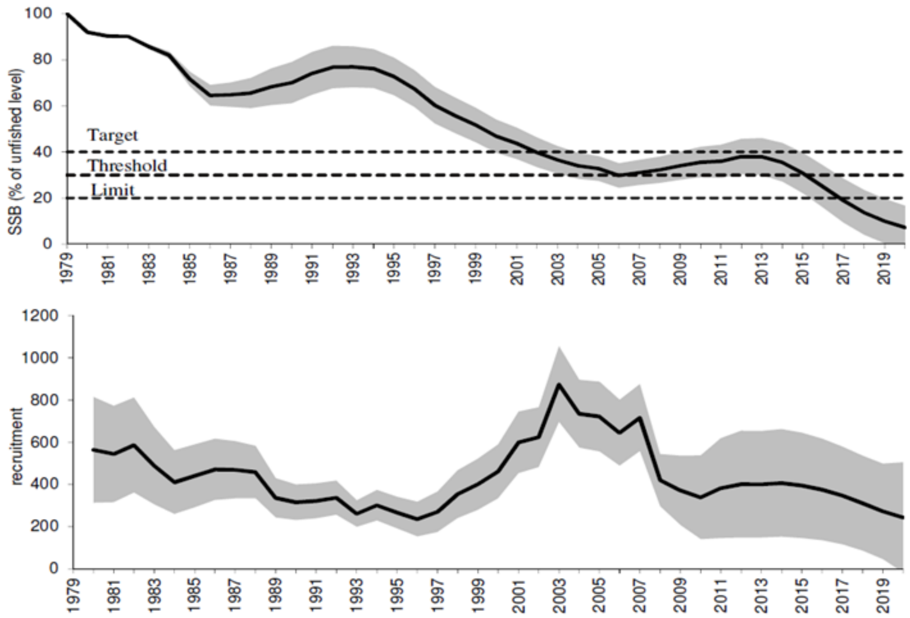


Figure 7.7 Goldband Snapper Spawning Biomass as a Percentage of Unfished Levels (top) and Recruitment (thousands of fish) (bottom) (source: DoF 2015a)[5]

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

Fish Stock Assessments and Sustainability Status

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

The main commercial fish species that are present and spawn within the Capreolus-2 3D MSS Acquisition Area are the suite of demersal scalefish targeted by the Pilbara Demersal Scalefish Fisheries. Assessment and management of the north coast demersal scalefish resource is undertaken by DPIRD for the Pilbara management unit. As outlined in the North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017), assessment of the sustainability of the fisheries and fish stocks is undertaken by DPIRD based on two assessment processes. The first is a formal resource-level review, which is undertaken every 3-5 years and assesses the current status of the resource (the overall stock abundance and spawning biomass, and fish mortalities from fishing catch) against defined biological reference levels (target, threshold and limit) to determine whether management arrangements are appropriate (DPIRD 2017).

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

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

Table 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 2017/18 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 7.2 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.
Goldband Snapper (Saunders et al. 2018)	Goldband snapper catches from the Pilbara management unit over the last 10 years (2008–17) have ranged from 113–208 t. The catch of goldband snapper in the unit has been consistent and stable for the past five years (2013–17), 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% 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 has been classified as a sustainable stock.

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

Fishing mortalities (which DPIRD considers to be acceptable and sustainable) and normal variability in the fish biomass and recruitment levels (250-350%) are provided in Figure 7.6 and Figure 7.7. The Capreolus-2 3D MSS is not expected to result in any direct reduction in the spawning biomass through fish mortalities. The potential spatial-temporal overlap of the survey with the spawning fish stocks (maximum of 5.3%) will be negligible. Therefore, the survey will not result in a serious or irreversible impact to the sustainability of key indicator commercial fish stocks.

The potential spatial-temporal overlap of the survey with the spawning fish stocks (⩽5.3%) 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 be 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 Table 7-8 (240 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 Capreolus-2 3D MSS with the spawning areas in the Pilbara management unit and spawning periods of key indicator fish species (maximum spatial-temporal overlap of 5.3%, based on highly conservative spatial-temporal analysis);
- The approach to assessing the spatial-temporal overlap of the survey includes a significant level of conservatism due to the assumptions outlined previously;
- The level of disturbance and spatial-temporal overlap (maximum of 5.3%) with the key fish stocks is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250 - 350%);
- Key indicator species in the 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 its Harvest Strategy is a conservative approach, 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 although there is a history of ongoing commercial fishing and seismic surveys across the fisheries, with evidence that fish abundance is increasing and stocks are rebuilding; and
- DPIRD Status of the Fisheries reports also considers other activities in the region, including oil and gas activities and seismic surveys. DPIRD consider the risk status of oil and gas activities to be ‘Low’ and states that ‘*While there are a number of specific oil and gas related offshore developments that are proposed in this region, at the overall ecosystem level there is only a low risk that the ecosystem will be altered measurably’* (Gaughan and Santoro 2018). 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.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to fish spawning is **Minor**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Commercial Fisheries

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 within the Capreolus-2 3D MSS Operational Area and in adjacent waters. 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 in Section 7.4.

As described in Section 4.6.7, there are a number of Commonwealth and WA commercial fisheries that operate in waters overlapping the Operational Area, as follows:

- North West Slope Trawl Fishery (NWSTF)
- Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)
- Pilbara Trap Managed Fishery (PTFMF)
- Pilbara Line Managed Fishery (PLMF)
- Mackerel Managed Fishery (MMF)

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 6-hour period (Peña et al. 2013). As fishing areas are large and commercial fish species are free-swimming, if fish are 'scared' temporarily from an area, based on evidence presented, it is likely they will be displaced temporarily to another area still within the fishing zone and so able to be caught.

There is little research undertaken on what effect seismic surveys have on fish catchability. Salgado Kent et al. (2016) 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.

Bruce et al. (2018) used a 2D seismic survey in the Gippsland Basin in April 2015 as an opportunity to quantify fish behaviour (field-based) and commercial fisheries catch desktop study) across the region before and after airgun operations. The catch rates in the six months following the survey indicated that six species (tiger flathead, goatfish, elephantfish, boarfish, broadnose shark and school shark) showing increases in catch following the seismic survey, and three species (gummy shark, red gurnard, and sawshark) showing reductions.

A critical review of the potential impacts of marine seismic surveys on fish and invertebrates (Carroll et al. 2017) found that other studies on fish have positive, inconsistent, or no effects from seismic surveys on catch rates or abundance. A desktop study of four species (gummy shark, tiger flathead, silver warehou, school whiting) in 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, goldband snapper, rankin cod, blue-spotted emperor and ruby snapper, which primarily detect particle motion, with limited, or no sensitivity to sound pressure changes at distance from a seismic source) will be limited to distances of a few hundreds of metres from the operating seismic source.

An analysis has been conducted to determine the area of overlap between the area 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	Area of Fishing Effort (km^2)*	Maximum Potential Spatial Overlap from the Capreolus-2 3D MSS**	
		Overlap (km^2)	%
North West Slope Trawl Fishery	126,082	10,000	7.9%
Pilbara Fish Trawl (Interim) Managed Fishery	25,922	9,387	36.2%
Pilbara Trap Managed Fishery	116,804	9,474	8.1%
Pilbara Line Managed Fishery	153,198	10,000	6.5%
Mackerel Managed Fishery	50,571	2,031	4.0%

*The area of fishing effort for WA managed fisheries is based on historic Fishcube data from 2014 to 2018. The area of fishing effort for Commonwealth managed fisheries is based on the information presented in the ABARES Fishery Status Report 2019 (data is based on 2017/2018 fishing season). Refer to Section 4.6.7.1 for more information.

**The spatial overlap is based on the area of fishing effort and a maximum of 10,000 km^2 representing the maximum area acquired in any given calendar year. The extent of overlap from the survey during a calendar year may not always be 10,000 km^2, as the Acquisition Area and extends beyond the areas where fishing effort typically occurs.

As shown in Table 7-15, the spatial overlap of the Acquisition Area with historic fishing effort ranges from 4% (Mackerel Managed Fishery) to a maximum 36.2% (Pilbara Fish Trawl (Interim) Managed Fishery). To calculate a spatial-temporal analysis, the PFTIMF has been used as the worst-case scenario. The PFTIMF operates throughout the year (365 days) and the Capreolus-2 3D MSS is estimated to take up to a maximum of 190 days to acquire 10,000 km^2. Therefore, the temporal overlap is approximately 52%, indicating a total spatial-temporal overlap of 18.8% with the PFTIMF. Additional detail on the interpretation of commercial fishing effort is provided in Section 7.4 in relation to potential physical interactions between the Capreolus-2 3D MSS and the various fisheries.

It is important to note that the spatial overlaps in Table 7-15 are highly conservative as this assumes disturbance across the entire Acquisition Area. In reality, the area that may be exposed to seismic sound at any one time during the survey will be significantly less. As described in the fish spawning assessment, it is more appropriate to consider a spatial overlap based on a week (7-days) of acquisition lines to represent an area within a fishery that may be occupied by the seismic survey vessel during the survey, with a 5 km buffer applied to the racetrack formation to account for possible uncertainty about the range to disturbance to fish. Over the duration of the survey, the seismic survey vessel will gradually move across the survey area; following a week, the racetrack would have progressed sufficiently far that it would no longer disturb the same fishing areas and groups of demersal fishes as may be disturbed at the start of the racetrack. Table 7-16 provides the spatial overlap of a week of acquisition lines (with a 5 km buffer applied to the racetrack formation) with historic fishing effort ranges. The spatial overlap ranges from 1.5% (PLMF) to 8.9% (PFTIMF). Therefore, it is concluded that up to a maximum of 8.9% of fishing grounds targeted by fisheries may be exposed to seismic sound during any week of the survey.

Table 7-16 Spatial Overlap of 7-Days of Acquisition Lines with Fishing Effort for Relevant Commercial Fisheries

Relevant Commercial Fisheries	Area of Fishing Effort (km^2)*	Maximum Potential Spatial Overlap of 7-days of Acquisition Lines + 5 km Buffer	
		Overlap (km^2)	%
North West Slope Trawl Fishery	126,082	2,300	1.8%
Pilbara Fish Trawl (Interim) Managed Fishery	25,922	2,300	8.9%
Pilbara Trap Managed Fishery	116,804	2,300	2.0%
Pilbara Line Managed Fishery	153,198	2,300	1.5%
Mackerel Managed Fishery	50,571	2,031	4.0%

It is 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 2017/18 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 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 cumulative effects of past seismic surveys on the commercial fisheries).

Potential impacts to commercial fish stocks and fishing catch rates are not likely to be significant based on the following reasons:

- 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).
- 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 2017/18 exceeding the acceptable catch tolerance range, indicating an increased level of fish abundance, as well as increased catch rates (CPUE).
- The stock assessment for key indicator commercial fish species (e.g. mackerel, red emperor) indicates adequate stock status, breeding stock and fishery catch levels (Gaughan and Santoro 2018).
- Fish recovery from TTS or behavioural effects is expected in hours or days. 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 effect for the assessed species is a low proportion of the area they are likely to inhabit and where they are targeted by commercial fishers..

However, it is noted that the Capreolus-2 3D MSS may undertake a “racetrack” of acquisition lines over a significant proportion of the Pilbara Demersal Scalefish Fisheries. The survey vessel may also be present at sites targeted by the MMF and NWSTF at the same time fishing vessels are in the area. While effects and disturbances to groups of target fishes may be localised and short term, and each of the fisheries has viable fishing grounds in locations outside of the Operational Area, the disruption to fishers as a result of fishing in the same area as the operating seismic vessel or as a result of moving to other locations outside of the area encompassed by the racetrack for potentially weeks at a time, is more significant. Further assessment of the disruption to fisheries as a result of physical interaction is provided in Section 7.4. TGS will communicate with fishers prior to and during the survey. The seismic survey vessel will change sail lines to accommodate commercial fisher’s requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel and providing TGS is afforded a reasonable opportunity to complete the survey in a timely and efficient manner. TGS is committed to working with relevant commercial fishers to enable fair and reasonable concurrent operations.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to the target species and catch rates of commercial fisheries is **Minor**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Tourism and Recreation

Impact Assessment

As described in Section 4.6.8, a range of recreational activities may take place within and or nearby to the Operational Area, including scuba diving, snorkelling and fishing charter trips. These activities are known to occur at nearby Bedout Island and within the Rowley Shoals State Marine Park.

The minimum separation distances from the Operational Area and Bedout Island and the Rowley Shoals are 12 km and 70 km, respectively. At these ranges, received sound levels 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 Capreolus-2 3D MSS will not result in any impact to recreational fishing charter trips to the Bedout Island and Rowley Shoals.

To assess the potential impacts from the operation of the seismic source in the Acquisition Area on recreational divers in the water at Bedout Island and the Rowley Shoals, 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 at Site 9, which is the closest modelling site to Bedout Island, the maximum predicted SPL received in water depths of 30 m or less surrounding Bedout Island is 130 dB re 1 µPa or less. For modelling at Site 4, which is the closest modelling site to Rowley Shoals, the maximum predicted SPL received is less than 120 dB re 1 µPa.

On this basis, divers at Bedout Island and Rowley Shoals will not be exposed to sound levels greater than 145 dB re 1 µPa (SPL) threshold. If diving activities occur in these areas during acquisition of the Capreolus-2 3D MSS, it is highly unlikely that individuals in the water would be impacted, although at Bedout Island, distant pulses from the seismic source when operating at the closest point of approach to the island may be audible above background ambient noise levels. It is noted that Bedout Island is 44 km from the Operational Area. TGS and so TGS will adopt mitigation control measures consistent with Diving Medical Advisory Committee (DMAC) guidance, as described in Section 7.1.3.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to tourism and recreation is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Marine Protected Areas

Impact Assessment

As described in Section 4.6.1 and 4.6.2, the Operational Area is located adjacent to a number of Commonwealth and State protected areas.

<u>Commonwealth Protected Areas</u>

Based on the sound level isopleths, maximum predicted received sound levels in the water column at the boundaries of the Australia Marine Parks within the EMBA, are as follows:

- Eighty Mile Beach Marine Park, Multiple Use Zone (0.1 km from the Operational Area) – approximately 180 dB re 1 µPa (SPL);
- Argo-Rowley Terrace Marine Park, Multiple Use Zone and Special Purpose Zone (45 km and 75 km from the Operational Area, respectively) – approximately 130 dB re 1 µPa (SPL);
- Montebello Marine Park, Multiple Use Zone (61 km from the Operational Area) - <120 dB re 1 µPa (SPL);
- Mermaid Reef Marine Park, National Park Zone (115 km from the Operational Area) - <120 dB re 1 µPa (SPL); and

- Gascoyne Marine Park, Multiple Use Zone (306 km from the Operational Area) - below modelled levels.

Consequently, with the exception of the Eighty Mile Beach AMP Multiple Use Zone, received sound levels in the water column or at the seafloor within the areas of these AMPs will not exceed any sound thresholds for cetaceans, marine reptiles, fishes/elasmobranchs, benthic invertebrates or zooplankton that may be present within the AMPs during acquisition of Capreolus-2 3D MSS.

The potential impacts to the natural values of the Eighty Mile Beach AMP are summarised as follows:

- Migrating humpback whales – When the seismic vessel and seismic source are operating in the Acquisition Area at the closest point of approach to the AMP, there is the potential for behavioural disturbance and TTS effects to migrating humpback whales within approximately 5 km and 13 km from the seismic source respectively. However, as described in the assessment of potential impacts to cetaceans above, the Capreolus-2 3D MSS will exclude all operation of the seismic source within the humpback whale migration BIA during the July to October peak migration period. The potential for impacts to migrating humpback whales, as a natural value of the AMP, is therefore very limited. As a result of the exclusion, during the humpback whale migration, the closest the seismic source may be operated in relation to the AMP is over 20 km away. Therefore, no discernible impacts are predicted to migrating humpback whales within the AMP itself.
- Internesting and nesting habitat for marine turtles – When the seismic vessel and seismic source are operating in the Acquisition Area at the closest point of approach to the AMP, there is the potential for behavioural disturbance and TTS effects to turtles within approximately 5 km and 520 m from the seismic source respectively. However, as described in the assessment of potential impacts to marine turtles above, the Capreolus-2 3D MSS will exclude all operation of the seismic source within turtle internesting habitat during the nesting and internesting period. The potential for impacts to nesting and internesting turtles, as a natural value of the AMP, is therefore negligible. As a result of the exclusion, during the internesting period, the closest the seismic source may be operated in relation to the AMP is over 35 km away. Therefore, no discernible impacts are predicted to nesting and internesting turtles within the AMP itself.
- Foraging, nursing and pupping habitat for sawfish – As described in Section 4.5, sawfish foraging, nursing and pupping habitat is concentrated in nearshore waters. Therefore, no impacts are expected to sawfish in these areas.
- Breeding, foraging and resting habitat for seabirds – As described in the assessment of potential impacts to marine birds above, only short-term and localised disturbances to diving birds may occur during foraging.

Given that the Eighty Mile Beach AMP is located outside of the Operational Area, no impacts to the marine habitats within the AMP are expected to occur. There

State Protected Areas

Based on the sound level isopleths, maximum predicted sound levels in the water column at the boundaries of the State Marine Parks, are as follows:

- Rowley Shoals Marine Park (70 km from the Operational Area) – approximately 120 dB re 1 μPa (SPL); and
- Montebello Islands Marine Park (110 km from the Operational Area) - <120 dB re 1 μPa (SPL).

Consequently, sound levels will be well below all sound exposure thresholds and no impacts to the values of the State Marine Parks are expected.

Summary

Based on the assessment above and the implementation of the controls identified in Section 7.1.3, the consequence of occasional short-term and localised disturbance to marine protected areas is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

Submarine Cables

Impact Assessment

As described in Section 4.6.11.1, the Operational Area overlaps with two submarine telecommunication cables – the JASURAUS system (which was decommissioned in 2012 and no longer used) and the operating North West Cable System (NWCS).

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

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

The NWCS passes within the Acquisition Area in water depths greater than 50 m. In these water depths, the 226 dB re 1 µPa PK level is not predicted to be exceeded. Vocus Communications, as operator of the NWCS, were consulted during the preparation of the EP and have not raised any concerns regarding the cable.

Summary

Based on the assessment above, the consequence of potential disturbance to submarine cables is **Minor**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

Further information about the selected control measures, the ALARP evaluation, and the demonstration of Acceptability is provided in Section 7.1.3 and Section 7.1.4.

7.1.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Part A of EPBC Policy Statement 2.1 will be applied in full to mitigate potential impacts to whales, including: ■ 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 Observation ■ Soft-start Procedures ■ Start-up Delay Procedures ■ Operational Shut-down and Low-power Procedures ■ Night-time and Low Visibility Procedures ■ Sighting Reports	Yes	Part A of EPBC Policy Statement 2.1 are standard management procedures and will be implemented during the Capreolus-2 3D MSS. Legislative requirement.
Good Industry Practice		
Minimum source size selected (3,480 cui) to acquire survey data and meet the geophysical objectives of the survey.		The source size was intentionally selected during the pre-planning phase of the Capreolus-2 3D MSS as it is the minimum source size identified to meet the geophysical objectives of the survey, taking into account the depth of the seismic targets and the characteristics of the underlying geology.

Control Measure	Control Adopted	Justification
Vessel crews will complete an environmental induction covering the requirements for vessel interactions with marine fauna.	Yes	Crew survey personnel and MFOs will be briefed in marine fauna observations (i.e. identification), separation distance estimation, EP controls and EP reporting requirements. Good industry practice, environmental benefit outweighs the additional cost.
Notification to fisheries stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within 2 weeks of survey completion.	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 commercial fisheries. Good industry practice, socio-economic benefit outweighs the additional cost.
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Yes	AHS will be contacted 4 weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure that commercial fishers are aware of the survey. Implementation will reduce the likelihood of interactions with commercial fishing vessels. Good industry practice, socio-economic benefit outweighs the additional cost.
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Yes	The AMSA JRCC will be contacted 24-48 hrs before operations commence for issuing of radio-navigation warnings. This will ensure that commercial fishers are aware of the survey. Implementation will reduce the likelihood of interactions with commercial fishing vessels. Good industry practice, socio-economic benefit outweighs the additional cost.
Daily look-ahead reports will be provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Yes	TGS will provide fisheries stakeholders with a daily look-ahead report, detailing the upcoming activities and planned seismic survey location within the next 72 hours. As part of this report, TGS will request information from commercial fishers on upcoming fishing activities for the next 24-72 hours. This will allow the seismic survey vessel to consider alternative lines, where practicable. Good industry practice, socio-economic benefit outweighs the additional cost.
Alternatives/Substitute Considered		
No practicable alternatives or substitutes were identified.	N/A	N/A
Additional Controls Considered		
No operation of the seismic source within 24 km of the pygmy blue whale migration BIA during the	Yes	TGS considers it appropriate to not acquire within the migration BIA during peak migration periods. Implementation of this control will minimise the potential for disturbance to migrating

Control Measure	Control Adopted	Justification
migration period (April – August and October – December).		pygmy blue whales. The additional 24 km buffer has been selected to prevent TTS, and therefore potential for injury, to pygmy blue whales. Environmental benefit outweighs the additional cost.
No operation of the seismic source in the humpback whale migration BIA during the peak migration period (July to October).	Yes	TGS considers it appropriate to not acquire within the migration BIA during peak migration periods. Implementation of this control will minimise the potential for disturbance to migrating humpback whales. Environmental benefit outweighs the additional cost.
No operation of the seismic source in the flatback turtle internesting BIA during the internesting period (October – March).	Yes	TGS considers it appropriate to not acquire within the internesting BIA and habitat critical during peak nesting periods. Implementation of this control will minimise the potential for disturbance to nesting flatback turtles. Control is consistent with the Recovery Plan for Marine Turtle in Australia (Commonwealth of Australia 2017). Environmental benefit outweighs the additional cost.
No operation of the seismic source in the designated Ancient Coastline at 125 m Depth Contour KEF.	No	Not justified. The KEF is not expected to support large numbers of site-attached species, therefore any impacts to individuals are not expected to lead to population or ecosystem level impacts. Implementation of this control would remove 2,808 km^2 from the overall Acquisition Area. TGS would not be able to obtain data for all hydrocarbon prospects being targeted. The costs are grossly disproportionate to any potential environmental benefit gained.
No operation of the seismic source in water depths less than 50 m.	Yes	Implementation of this control would minimise potential impacts to fish assemblages and benthic invertebrate communities in water depths less than 50 m. The minimum water depth within the Acquisition Area is 50 m. This approach provides a reduction in risk that is consistent with the risk profiles identified by DPIRD for water depths less than 50 m in their 2018 ecological risk assessment (Webster et al. 2018). Environmental benefit outweighs the additional cost.
No operation of the seismic source in the designated Glomar Shoals KEF.	Yes	Implementation of this control would minimise potential impacts to site-attached fish assemblages and benthic invertebrates associated with the Glomar Shoals KEF. Environmental benefit outweighs the additional cost.
The seismic survey vessel will not return to acquire adjacent lines within 5.86 km of the KEF within a 24 hour period to enable for recovery of TTS in fishes associated with Glomar Shoal.	Yes	Consideration has been given ensuring the seismic survey vessel will not return to acquire adjacent lines within 5.86 km of the KEF (the maximum predicted R_{max} to exceedance of the TTS threshold) within a 24 hour period to enable for recovery of TTS in fishes associated with Glomar Shoal. This is based on Popper et al. (2005) reporting that fish that showed TTS recovered to normal hearing levels within 18-24 hours.

Control Measure	Control Adopted	Justification
		Depending on the final line plan, it is likely that most, if not all, acquisition lines that abut the KEF boundary will be sufficiently long enough that the seismic source would not return to waters adjacent to the KEF within less than 24 hours. Environmental benefit outweighs the additional cost.
EPBC Act Policy Statement 2.1: Part B.1 – Marine Mammal Observers	Yes	Consistent with Part B.1 of EPBC Policy Statement 2.1, an MFO will be on board the seismic vessel and on duty during daylight hours during the survey.
EPBC Act Policy Statement 2.1: Part B.2 – Night-time/ Poor Visibility	No	Part B is intended to apply where cetaceans are expected to be encountered in moderate to high abundance. Given, no seismic acquisition will occur within designated BIAs for the Pygmy Blue Whale and Humpback Whale during peak migration periods, the survey is expected to have limited interaction with any significant habitats or life stages for cetaceans. The costs are grossly disproportionate to any potential environmental benefit gained.
EPBC Act Policy Statement 2.1 : Part B.3 - Use of spotter aircraft and vessels to detect presence of cetaceans	No	These control measures will not be implemented given the relatively low densities of whales expected in the Operational Area during survey acquisition. Additionally, survey acquisition is timed to avoid the humpback whale and pygmy blue whale peak migration periods. The costs are grossly disproportionate to any potential environmental benefit gained.
EPBC Act Policy Statement 2.1 : Part B.4 - Increased precaution/shut-down zones	Yes, in some instances.	Please refer to adaptive management controls below.
EPBC Act Policy Statement 2.1: Part B.5 - Passive Acoustic Monitoring (PAM) to detect presence of vocalising cetaceans	No	Consideration was given to the other controls provided for in Part B of the EPBC Policy Statement 2.1, including the use of PAM. The additional management measures described in Part B are designed to ensure that impacts and interference to whales are avoided/and or minimised for seismic surveys operating in areas where the likelihood of encountering whales is moderate to high. Although PAM can be used to supplement visual observations made by the MFO, the method is dependent upon animals vocalizing. Costs for engaging a trained PAM operator for the survey are approximately US$40,000. The significant additional cost of having a qualified PAM operator on board for the duration of the survey when few or no detections are expected was determined to outweigh any limited additional benefit that PAM might provide, particularly given the proposed soft-start, night time and low visibility procedures. MFOs may be trained in the operation of the PAM system on board the vessel, however, MFOs on board the vessel will be present to undertake

Control Measure	Control Adopted	Justification
		observational duties on deck and therefore additional MFOs would need to be engaged at a similar cost. Given that the survey is time to avoid migration peak periods for pygmy blue whales and humpback whales, and the limited detections expected from the use of PAM, the cost of this option is considered to outweigh the limited potential for any further reduction to an already low level of risk.
EPBC Act Policy Statement 2.1: Part B.6 - Adaptive Management Measures – Cetaceans: • <u>Relocating the seismic survey vessel to a different part of the survey area.</u>	No	Relocating is disruptive, time consuming and costly for the survey with limited certainty that whales will be less abundant in the new location. This is particularly the case if an entire survey phase is geographically restricted to being within or very close to a cetacean migration pathway or BIA (for example, the entire phase is limited to the southern portion of the Acquisition Area, within or in proximity to the humpback whale BIA). Given that: • the seismic source will not be operated within designated BIAs during peak migration periods for pygmy blue whales and humpback whales; • the waters surrounding the Acquisition Area and Operational Area are not areas that are recognised for significant life stages or activities such as breeding, calving, resting or foraging and, therefore, cetaceans will be migratory and generally transient; • only short-term and localised behavioural impacts are predicted from sound propagating from the seismic source into these areas at times when the seismic vessel is operating close to the BIA; population level impacts are unlikely to occur and the risk to whales is already low. It is also important to note, TGS will be providing fishers stakeholders (and other marine users) with daily reports detailing upcoming sail lines. If the vessel is required to relocate to another part of the survey without providing stakeholders with advanced notice this could interrupt commercial fishing activities to a greater extent than necessary. Therefore, relocation is not practicable or expected to provide a significant environmental benefit.
• <u>Increase shut-down zone to 2 km when whales are found in greater abundance.</u>	Yes	In order to reduce the potential risk to whales in the event that a greater abundance of whales is present (noting that the seismic source will not be operated within designated migratory BIAs during peak migration periods), TGS will increase the shut-down zone from 500 m (as per EPBC Policy Statement 2.1 Part A) to a horizontal distance of 2 km from the seismic source. Environmental benefit outweighs the additional cost.
• <u>Cease and delay operation of the seismic source to avoid periods when whales are found in greater abundance.</u>	Yes, in some instances	Ceasing acquisition can cost tens of thousands of dollars per day in survey down time and it is difficult to ascertain with certainty when whales may be less abundant and survey activities can recommence. Given, the seismic source will not be operated within designated BIAs during peak migration periods for pygmy blue whales and humpback whales, only short-term and localised behavioural impacts are predicted <u>from sound propagating from the seismic source</u>

Control Measure	Control Adopted	Justification
		into these areas at times when the seismic vessel is operating close to the BIA, and population level impacts are unlikely to occur. The risk to whales is already low. Therefore, the costs to implement the control measure is grossly disproportionate to any potential environmental benefit gained. As noted above, the seismic source will not be operated within 24 km of the pygmy blue whale migration BIA during the extended migration periods (April to August and October to December). Therefore, the seismic source will primarily be operated on the continental shelf during these periods, where it also has limited potential for behavioural disturbances to pygmy blue whales migrating in deeper and more distant waters on the continental slope. In addition, the above adaptive management control will be implemented, whereby the shut-down zone will be increased to 2 km if the survey is required to shutdown/power-down three or more times per day for three consecutive days as a result of sighting a whale. No further control measures are deemed practicable for pygmy blue whales given the already large area of avoidance by the survey and reduction in risk. The seismic source will also not be operated within the humpback whale migration BIA during the peak migration period (July to October). However, to account for the potential variation in the migration period for humpback whales, TGS will implement additional adaptive management measures within the humpback whale migration BIA outside of the peak migration period based on the number of sightings of humpback whales. The key indicator of an increase in the density of humpback whales in the Acquisition Area is an increase in the number of sightings within the power-down or shut-down zone. Ceasing survey operations within the migration BIA after a 24 hour duration of higher than 3 or more sightings within the power-down/ shut-down zone is a conservative approach to ensure no impacts to migrating humpback whales within the migration BIA. Environmental benefit outweighs the additional cost.
• No night time operations when whales are found in greater abundance.	No	No night time operations is disruptive and time consuming for the survey. The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of millions of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk to whales, it is not practicable or feasible to implement. Given, the seismic source will not be operated within designated BIAs during peak migration periods for pygmy blue whales and humpback whales, only short-term and localised behavioural impacts are predicted, population level impacts are not likely to occur and the risk to whales is already low. Therefore, the costs to implement the control measure is grossly disproportionate to any potential environmental benefit gained.

Control Measure	Control Adopted	Justification
A 100 m shut-down zone from the operating source will be applied to dolphins.	Yes	EPBC Act Policy Statement 2.1 was developed specifically to apply to baleen whales and large odontocete whales. Therefore, TGS has considered whether it is practicable to apply similar procedures to dolphins. Smaller dolphin species have peak hearing sensitivities in the mid to high frequency ranges and are likely to be less disturbed by low frequency seismic pulses and less vulnerable to acoustic trauma than large LF cetaceans. Accordingly, EPBC Act Policy Statement 2.1 does not normally apply to encounters with small dolphins. The potential for PTS/TTS impacts to occur to dolphins from a single seismic pulse is limited to within 20 m of the seismic source while the SEL_{24hr} thresholds for PTS and TTS impacts to dolphins are not predicted to be exceeded at any distance. The 20 m range to effect is taken from the centre of the seismic source, meaning that PTS and TTS effects are predicted to be possible only within the immediate area of the seismic source array. In addition, the offshore location of the 2D seismic survey is not sensitive habitat for dolphins. Dolphin species have been observed to approach seismic survey vessels and ride the bow wake for short periods before moving away again without apparent trauma. Depending on the size of the survey vessel, the bow may be slightly more or slightly less than 100 m of the towed seismic source, making it difficult to practically implement a shut-down zone. Dolphins are highly mobile creatures and are expected to avoid the seismic source at distances where received sound levels are high enough to result in significant hearing impairment. Soft-start procedures will be implemented and provide opportunity for dolphins to move away before the source is operated at full volume. Even so, as a precautionary measure to account for potential uncertainty and as a means of meeting the legislative requirement to not injure any cetacean within the Australian Whale Sanctuary, a shut-down zone of 100 m radius will be applied around the seismic source.
A 500 m shut-down zone from the operating source, as per the shut-down zone for whales in EPBC Act Policy Statement 2.1, will also be applied to dugongs.	Yes	In order to reduce the potential risks to dugongs, the 500 m shut-down zone is considered to be a practicable measure to implement given that precaution zones will already be established for whales. The seismic source will be shut down, or start-up will be delayed, if a dugong is observed within the shut-down zone. Operation of the seismic source using soft-start shall only resume after the dugong has been observed to move outside the shut-down zone or the survey vessel has proceeded more than 500 m from the last sighting (approximately 4 minutes sail time at 4.5 knots). Given that dugongs are slow swimming relative to the survey vessel and due to their limited sensitivity to sound, the shut-down and start-up delay is considered appropriate. Further start up delay is not considered practicable, as it could result in significant periods of shut-down when dugongs are not close enough to the seismic source to experience hearing impairment impacts. Multiple shut-downs and delays could extend the overall survey duration at significant cost (tens of thousands of dollars per day that the survey is extended).

Control Measure	Control Adopted	Justification
		Environmental benefit outweighs the additional cost.
A 250 m shut-down zone from the operating source, will be applied to turtles.	Yes	In order to reduce the potential risks to turtles, the 250 m shut-down zone is considered to be a practicable measure to implement. The seismic source will be shut down, or start-up will be delayed, if a turtle or dugong is observed within the shut-down zone. Operation of the seismic source using soft-start shall only resume after the turtle has been observed to move outside the shut-down zone or the survey vessel has proceeded more than 250 m from the last turtle sighting (approximately 4 minutes sail time at 4.5 knots). Given that turtles are slow swimming relative to the survey vessel and due to their limited sensitivity to sound (impairment impacts limited to <20 m form the seismic source), the shut-down and start-up delay is considered appropriate. Further start up delay is not considered practicable, as it could result in significant periods of shut-down when turtle are not close enough to the seismic source to experience hearing impairment impacts. Multiple shut-downs and delays could extend the overall survey duration at significant cost (tens of thousands of dollars per day that the survey is extended). Environmental benefit outweighs the additional cost.
A 250 m shut-down zone from the operating source, will be applied to whale sharks.	Yes	In order to reduce the potential risks to whale sharks, the 250 m shut-down zone is considered to be a practicable measure to implement given that precaution zones will already be established for whales. The seismic source will be shut down, or start-up will be delayed, if a whale shark is observed within the shut-down zone. Operation of the seismic source using soft-start shall only resume after the whale shark has been observed to move outside the shut-down zone or the survey vessel has proceeded more than 250 m from the last sighting (approximately 4 minutes sail time at 4.5 knots). Given whale sharks' limited sensitivity to sound (they are sensitive primarily to particle motion within close range to the seismic source), the shut-down and start-up delay is considered appropriate. Further start up delay is not considered practicable, as it could result in significant but unnecessary periods of shut-down when whale sharks are not close enough to the seismic source to experience hearing impairment or significant behavioural impacts. Multiple shut-downs and delays could extend the overall survey duration at significant cost (tens of thousands of dollars per day that the survey is extended). Environmental benefit outweighs the additional cost.
Two MFOs will be available on board the seismic survey vessel to manage shift duties during daylight hours. At least one MFO will have >12 months experience on a seismic survey vessel as an MFO in Australian waters.	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. Environmental benefit outweighs the additional cost.

Control Measure	Control Adopted	Justification
Pre-start visual observations to include observations for dolphins, marine turtles, dugongs and whale sharks, in addition to whales.	Yes	During pre-start observations, as prescribed for whales in the EPBC Act Policy Statement 2.1, MFOs will also observe for marine turtles, dugongs and whale sharks within the 500 m shut-down zone. Depending on the species and water depth, the diving times of marine turtles during foraging can vary from just a few minutes to more than an hour Houghton et al. 2000; Hays et al. 2001; Mast et al. 2008; Casey et al. 2010; Whittock 2017). Average dive times for green turtles and flatback turtles in water depths comparable to those within the Operational Area have been reported between approximately 10 and 30 minutes (Hays et al. 2001; Casey et al. 2010; Whittock 2017). Surface times may also range from momentary breaths for air, to a few minutes at the surface, or longer if resting at the surface (Hays et al. 2001; Casey et al. 2010). Therefore, the 30-minute pre-start visual observation period allows a reasonable amount of time to account for the immersion of turtles. Whale sharks may be present at the surface for brief periods when foraging, but because they are not air-breathing animals, surfacing intervals cannot be predicted. However, given that pre-start visual observations will already be undertaken, it is practicable to also observe for whale sharks within the 500 m shut-down zone during this period. The likelihood of being able to spot a turtle, dugong or whale shark at ranges further than 500 m is unlikely. In addition, turtles and whale sharks are less sensitive to low frequency seismic sound than whales and hearing impairment impacts are predicted to be limited to within close range of the seismic source (tens of metres from a single pulse). Therefore, the 30-minute pre-start observations will only apply within the 500 m shut-down zone. Environmental benefit outweighs the additional cost.
Adaptive Management Measures - Turtles	No	Adaptive management measures may include changes to the way in which a seismic survey is conducted if turtles are encountered in greater abundance than expected. An example is to increase the precaution zones or relocating to a different part of the survey area if more than three shut downs for turtles occurs within a single 24-hour period. TGS has considered the following adaptive management options: ■ Relocate the survey vessel and seismic source to a different part of the survey area: Relocating is disruptive and time consuming for the survey with no certainty that the new location will be any better, with respect to the presence and abundance of turtles. Therefore, relocation is not practicable or expected to be provide a significant benefit. ■ Increase the precaution zone that applies to marine turtles: A 500 m precaution zone is proposed for turtles, which is already at the upper limit at which turtles can be seen during calm seas. It is highly unlikely that turtles can be spotted at distances greater than 500 m. A 500 m precaution zone is already highly precautionary given that physical impairment impacts (PTS or TTS) would be limited to within less than 20 m of the seismic source. The

Control Measure	Control Adopted	Justification
		500 m precaution zone would also provide some level of protection from significant behavioural responses (e.g. startling) that may occur near the seismic source. ■ Cease and delay operation of the seismic source to avoid periods when turtles are found foraging in greater abundance than expected: This option is not possible as turtle foraging activities may occur year-round. Shut-down costs tens of thousands of dollars per day and there is no way to determine with any certainty when fewer turtles may or may not be present. Therefore, delays are unlikely to provide any measurable environmental benefit. It is not practicable to adapt the timing of the survey to avoid turtle foraging. Given that only short-term and localised behavioural impacts are predicted in response to the transient seismic source, displacement from critical foraging habitat or population level impacts is not likely to occur and the risk to turtles is already low. Therefore, the costs to implement adaptive management measures are grossly disproportionate to any potential environmental benefit gained.
Increased shut-down / lower power zone implemented for turtles and dugongs.	No	The likelihood of being able to spot a turtle and/or dugong at ranges further than 500 m is unlikely, therefore, no further precaution zone is proposed and is not considered necessary given the already low level of risk.
Increased shut-down / lower power zone implemented for whale sharks.	No	The likelihood of being able to effectively spot a whale shark at ranges further than 500 m is unlikely, therefore, no further precaution zone is proposed and is not considered necessary given the already low level of risk.
Notification to divers that are undertaken diving activities within 45 km of the seismic source.	Yes	Guidance note DMAC 12 issued by the UK Diving Medical Advisory Committee (DMAC) “Safe Diving Distance from Seismic Surveying Operations” (DMAC 2019) recommends that where diving and seismic activity occur within 30 km of each other, a joint risk assessment should be conducted. Where diving and seismic activities occur within 45 km of each other, all parties should be made aware of the planned activity.
A joint risk assessment will be conducted, where diving and seismic activity occur within 30 km of each other.	Yes	Guidance note DMAC 12 issued by the UK Diving Medical Advisory Committee (DMAC) “Safe Diving Distance from Seismic Surveying Operations” (DMAC 2019) recommends that where diving and seismic activities occur within 45 km of each other, all parties should be made aware of the planned activity.
Acquisition will be limited to a maximum of 10,000 km^2 per calendar year.	Yes	Implementation of this control would minimise catch displacement for commercial fishing vessels, in particular vessels in the Pilbara Demersal Scalefish Fisheries. Socio-economic benefit outweighs the additional cost.
Conducting the survey during daylight hours only.	No	As identified in the Richardson et al. (2017) report, conducting survey activities during the day rather than the night might minimize impact on zooplankton, as fewer zooplankton may occur

Control Measure	Control Adopted	Justification
		near the surface during the day because zooplankton vertically migrate in the water column to balance food intake and predation risks, and are generally deeper during the day. However, such a control would put major scheduling constraints on the Capreolus-2 3D MSS resulting in a longer overall survey duration and additional time on the water with the potential for other impacts and risks.
Complete avoidance of spawning times for commercially targeted key indicator species.	No	Not justified. Combined spawning periods for the key indicator species covers all 12 months of the year, and therefore the survey could not be acquired. The costs are grossly disproportionate to any potential environmental benefit gained. The proposed survey plan was determined taking into account: ■ the timing of key environmental and socio-economic receptors; ■ the hearing ability and sensitivity of those receptors to sound from the seismic survey; ■ the proximity of sensitive habitat areas to seismic survey areas; ■ the species distribution and range; ■ the level of overlap (in space and time) by the survey with important habitats and life stages of sensitive species; ■ species vulnerability / conservation status; and ■ the potential for impacts to species at both an individual level and at a population level. 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 pygmy blue whale migration periods. It is important to note, the southern zone (water depth between 50 m to 80 m) of the Acquisition Area will be acquired during April to May, which reduces the number of days of acquisition during the peak spawning times for these species (within the species principal range). 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

Control Measure	Control Adopted	Justification
		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.
Reduce survey area to decrease area of overlap with commercial fisheries.	No	Not justified. TGS would not be able to obtain the data for the identified hydrocarbon prospects being targeted. As mentioned above, TGS has set an upper limit on the area (km^2) that can be acquired in any given calendar year. It is important to note, TGS has minimised the overlap of the survey with the seasonality of the Mackerel Managed Fishery (MMF) in nearshore waters. TGS will only acquire the southern zone (depths between 50m – 80m) between April and May, primarily outside of the main fishing period for the MMF. It is not possible to entirely avoid acquisition during the peak mackerel fishing period due to other environmental sensitivities (i.e. humpback whale peak migration period (July to October) and internesting period for flatback turtles (October to March)).
No acquisition in known fishing grounds for the Mackerel Managed Fishery (i.e. waters less than 70m) in peak mackerel fishing periods (May – November).	Partially	TGS will acquire the southern zone (depths between 50m – 80m, refer to Section 3.2) between April and May, primarily outside of the main fishing period for the MMF. It is not possible to entirely avoid acquisition during the peak mackerel fishing period due to other environmental sensitivities (i.e. humpback whale peak migration period (July to October) and internesting period for flatback turtles (October to March)). Avoiding the peak fishing period would prevent the objectives of the survey being met. Additional years of acquisition in the southern zone would be required to acquire the full area, meaning that data would not be available when required. The costs are grossly disproportionate to any potential environmental benefit gained.
No acquisition in known fishing grounds for the Pilbara Demersal Scalefish Fisheries (PFTIMF, PTMF and PLMF).	No	Fishing effort in the Pilbara Demersal Scalefish Fisheries is all-year round, with no identified peak periods to schedule the survey to avoid fishing operations. Avoiding the fishing grounds would prevent the objectives of the survey being met. Additional years of acquisition would be required to acquire the survey, meaning that data would not be available when required. The costs are grossly disproportionate to any potential environmental benefit gained.
Limit acquisition to one calendar year or including ‘down-time’ periods.	No	Implementation of this control would minimise consecutive years of potential interference with commercial fisheries catchability. It is not possible to acquire the entire Acquisition Area within one calendar year. To acquire the entire Acquisition Area, it would take a maximum of 510 days (including contingency time). Minimising acquisition to one calendar year, would prevent the objectives of the survey being met.

Control Measure	Control Adopted	Justification
		Introducing down-time periods would increase the number of years of acquisition required to acquire the entire survey, meaning that data would not be available when required. The costs are grossly disproportionate to any potential environmental benefit gained.
Payment of compensation to commercial fishers for loss of catch due to displacement or via seismic noise reducing the 'catchability' of fish.	No	Not justified. 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. If compensation is appropriate for the activity, an appropriate process should be developed in collaboration with stakeholders. TGS has determined that compensation for commercial fishers is not an appropriate control or mitigation measure for the Capreolus-2 3D MSS, given the nature and scale of the activity. As noted in the above risk assessment, potential impacts to commercial fish stocks and fishing catch rates are not likely to be significant based on the following reasons: ■ 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). ■ 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 2017/18 exceeding the acceptable catch tolerance range, indicating an increased level of fish abundance, as well as increased catch rates (CPUE). ■ The stock assessment for key indicator commercial fish species (e.g. mackerel, red emperor) indicates adequate stock status, breeding stock and fishery catch levels (Gaughan and Santoro 2018). ■ Fish recovery from TTS or behavioural effects is expected in hours or days. 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 effect for the assessed species is a low proportion of the area they are likely to inhabit and where they are targeted by commercial fishers. TGS is committed to working with relevant commercial fishers to enable fair and reasonable concurrent operations and to minimise potential displacement. TGS will implement a range of communications measures to mitigate the potential impacts on the commercial fishing industry, including advanced notifications, daily notifications, access to seismic survey vessel tracking information, notice to mariners and daily navigational warnings (as outlined above). In addition, the seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so, provided that there is open and advanced communication between the

Control Measure	Control Adopted	Justification
		seismic survey vessel and commercial fishing vessel. The implementation of these additional mitigation measures will result in additional costs to TGS, in the order of thousands of dollars.

ALARP Statement

The decision context has been assessed as Type B and the overall residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impact of noise emissions from the seismic source. As no reasonable additional or alternative controls were identified that would further reduce the impact, without jeopardising the objectives of the survey, the impacts are considered to be ALARP.

7.1.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing impacts from underwater noise emissions, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines The activity will be undertaken in a manner consistent with the applicable objectives and actions of the following species conservation or recovery plans, threat abatement plans, and conservation advice: ■ Conservation Management Plan for the Blue Whale: The Conservation Management Plan states that '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'. The Conservation Management Plan, with reference to EPBC Act Policy Statement 2.1, also advises that seismic surveys should not result in disturbance in biologically important areas at biologically important times. These requirements support a defined level of acceptable impact for seismic noise impacts to pygmy blue whales, whereby the seismic survey shall not injure a pygmy blue whale or displace it from a biologically important area. No seismic acquisition will occur within the defined migration BIA for the species during peak migration periods. Therefore, no disturbance or injury to pygmy blue whales is expected and the level of impact and risk to pygmy blue whales is considered to be acceptable. ■ Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale): The Conservation Advice states that all seismic surveys must be undertaken consistently with the EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales. As stated above, TGS has proposed control measures that meet and exceed the required standards and control measures set out in Part A of EPBC Policy Statement 2.1. No seismic acquisition will occur within the defined migration BIA for the species during peak migration periods (July to October). In addition, TGS will implement adaptive management measures to mitigate the risk to migrating humpback whales. Therefore, the level of impact and risk to humpback whales is considered to be acceptable.

Context	Factor	Demonstration
		■ 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 (although it is noted in the Conservation Advice that acoustic disturbance is of minor consequence for the species). No significant or long-term disturbance, or injury, to sei or fin whales is expected and the level of impact and risk is considered to be acceptable. ■ Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017): ▪ 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 nesting season. This supports a defined level of acceptable impact for seismic noise impacts to marine turtles, whereby the seismic survey shall not take place within internesting BIAs or habitats critical to the survival of turtle species during nesting/internesting periods. No seismic acquisition will occur within the defined Habitat Critical and internesting BIAs for the flatback turtle, during nesting periods. No disturbance to turtles in these areas is expected and the level of impact and risk to marine turtles is considered to be acceptable. ▪ The Recovery Plan states that in accordance with EPBC Act Policy Statement 2.1 – Interactions between Offshore Seismic Exploration and Whales, all seismic survey vessels operating in Australian waters must undertake a soft start during surveys irrespective of location and time of year of the survey. Soft-starts (as well as pre-start observations and shut-down procedures, which exceed this requirement) will be implemented during the Capreolus-2 3D MSS. Therefore, the level of impact and risk to marine turtles is considered to be acceptable. ▪ The Recovery Plan also recognises that activities resulting in impacts to foraging habitats may indirectly contribute to a decreased viability of multiple stocks by reducing food availability. The impacts of the Capreolus-2 3D MSS to the behaviours of marine turtles is expected to include short term, transient disturbances to marine turtles. The survey is not expected to result in the decreased availability of prey items and is not expected to result in the displacement of turtles from foraging BIAs. Therefore, the survey is not expected to indirectly impact the viability of any turtle stocks and the level of impact and risk to marine turtles is considered to be acceptable. ■ Conservation Advice for *Rhincodon typus* (Whale Shark) - The 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 shut-down procedures for whale sharks, no injury is expected and the potential for significant disturbance is limited.

Context	Factor	Demonstration
		■ Whale shark wildlife management program no. 57 (DPaW 2013). This management program is relevant to the management of whale sharks within the Ningaloo Marine Park (approximately 500 km from the Operational Area) and does not extend to seismic surveys. However, given the conservation status of whale sharks and that disturbance to whale sharks is a focus of the wildlife management program, TGS considers the level of impact and risk to whale sharks to be acceptable if practicable measures are put in place, to prevent injury and reduce the potential for disturbance to whale sharks. Control measures for the Capreolus-2 3D MSS include pre-start observation and shut-down procedures for whale sharks, therefore, no injury is expected, the potential for disturbance is limited and the level of impact and risk is considered to be acceptable.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs. The biological diversity and natural values of these AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological use of the AMPs.
	Relevant Persons Expectations	WAFIC raised concerns in regards to undertaking the Capreolus-2 3D MSS during peak spawning periods for commercially targeted key indicator species. The spawning times for these commercial fish species cover a 12-month period. Therefore, it is not possible for the survey to be scheduled entirely outside of all spawning periods. The southern zone (50m to 80m water depth) of the Acquisition Area will be acquired during April to May, which reduces the number of days of acquisition during the peak spawning times for these species (within the species principal range). TGS is committed to undertaking the survey in a manner that does not interfere with commercial fishing or the resources of the sea. All 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 WAFIC and individual licence holders. The impact is considered to be addressed and managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	The proposed control measures meet and exceed the required standards and control measures set out in Part A of EPBC Policy Statement 2.1 – Interactions between Offshore Seismic Exploration and Whales. Proposed control measures are proposed that meet the required standards set out in Part A and TGS has also specified standards for the use of an MFO on board the vessel, in accordance with Part B of the policy statement. Similar standards have also been extended to marine turtles, dolphins, dugongs and whale sharks. In addition, the survey will be undertaken in accordance with section 280 of the OPGGS Act, which requires for the activity to be carried out in a manner that does not interfere with fishing or the resources of the sea, to a greater extent than necessary. Undertaking the Capreolus-2 3D MSS in a manner that does not interfere with fishing or fish resources to a greater extent than necessary for the exercise of right conferred by the titles granted to carry out exploration activities is considered to be an acceptable level of impact. Based on the maximum spatial overlap (8.9%) of the Capreolus-2 3D MSS at any one time during the survey with historic fishing effort and the proposed control measures, TGS has determined that the level of impact is considered acceptable, given the survey will not interfere with fishing or fish resources to a greater extent that necessary.

Context	Factor	Demonstration
Industry Standards	Industry Best Practice	The control measures adopted are in accordance with industry standards and best practice, including: ■ IAGC Mitigation Measures for Cetaceans during Geophysical Operations: ▪ activities will not have a significant effect on a cetacean population and specific management measures have been implemented. ■ APPEA Code of Environmental Practice: ▪ reduce impacts on cetaceans and other marine life to ALARP and acceptable levels with evidence that appropriate management measures are implemented according to legislation and that further studies and new knowledge were considered.
Ecological Sustainable 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 underwater sound emission from the seismic source during the survey. The aspect and potential interactions are well understood and managed in accordance with applicable industry standards and industry good practice. Therefore, the impact is considered to be consistent with the principles of ESD.

Defined Acceptable Levels of Impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact	EPO #
Cetaceans Listed as Threatened or Migratory under the EPBC Act (Matters of NES)	■ 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.	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 pygmy blue whales, given: ■ Behavioural changes (e.g. avoidance) to pygmy blue whales are expected to be temporary and localised and affect transient individuals only. Potential TTS effects may also occur to a few individuals. ■ Predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean	**EPO 1.1** **EPO 1.3**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			that may be present within the Operational Area. ■ The seismic survey will be undertaken consistent with EPBC Act Policy Statement 2.1 Part A. ■ Adaptive management measures will be implemented in the event of 3 consecutive days with ⩾3 whale-instigated shutdowns. ■ No seismic acquisition will occur within 24 km of the defined migratory BIA for pygmy blue whales during the migration period.	
	■ Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale).	Seismic survey activities are undertaken in a manner consistent with the requirements of the Approved 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	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 humpback whales, given: ■ Behavioural changes (e.g. avoidance) to humpback whales are expected to be temporary and localised and affect transient individuals only. Potential TTS effects may also occur to a few individuals. ■ Predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean that may be present within the Operational Area. ■ Consistent with the Conservation advice for humpback whales, acoustic modelling has been undertaken to assess the potential	**EPO 1.1** **EPO 1.3**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
		Management Procedures) must also be applied.	single pulse and cumulative sound exposure impacts on humpback whales. ■ The seismic survey will be undertaken consistent with EPBC Act Policy Statement 2.1 Part A. ■ Adaptive management measures will be implemented in the event of 3 consecutive days with ⩾3 whale-instigated shutdowns. ■ No seismic acquisition will occur within the defined migratory BIA for humpback whales during the peak migration period.	
	■ Approved Conservation Advice for Balaenoptera borealis (sei whale) ■ Approved Conservation Advice for Balaenoptera physalus (fin whale)	Seismic survey activities are undertaken in a manner consistent with the requirements of Conservation Advice for Balaenoptera borealis (sei whale) and Conservation Advice for Balaenoptera physalus (fin whale).	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 sei and fin whales, given: ■ Behavioural changes (e.g. avoidance) to whales are expected to be temporary and localised and affect transient individuals only. Potential TTS effects may also occur to a few individuals. ■ Predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean that may be present within the Operational Area. ■ The seismic survey will be undertaken consistent with EPBC Act Policy Statement 2.1 Part A.	**EPO 1.1** **EPO 1.3**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			■ Adaptive management measures will be implemented in the event of 3 consecutive days with ⩾3 whale-instigated shutdowns.	
Marine Turtles Listed as Threatened or Migratory under the EPBC Act (Matters of NES)	■ Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017).	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 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 turtles, given: ■ Behavioural disturbances to turtles are expected to be temporary and localised and affect a relatively small number of the species. These disturbances are not expected to affect a significant proportion of populations in the Pilbara region or occur in habitat of any particular significance to key life stages. ■ The survey is not expected to result in the decreased availability of prey items and is not expected to result in the displacement of turtles from foraging BIAs. Therefore, the survey is not expected to indirectly impact the viability of any turtle stocks. ■ No seismic acquisition will occur within the defined internesting BIA and Habitat Critical area during the nesting period (October – March). ■ Soft-starts (as well as pre-start observations and shut-down procedures) will be implemented for marine turtles.	**EPO 1.1** **EPO 1.3**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
Whale Sharks Listed as Threatened and Migratory under the EPBC Act (Matters of NES)	■ Conservation Advice for *Rhincodon typus* (Whale Shark) ■ Whale Shark Wildlife Management Program no. 57 (DPaW 2013).	Seismic survey activities are undertaken in a manner consistent with the requirements of Conservation Advice for Rhincodon typus (Whale Shark).	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 whale sharks given: ■ Minor and temporary behavioural changes to whale sharks such as avoidance are expected to be temporary and localised and affect a relatively small number of the species. ■ Pre-start observations and shut-down procedures will be implemented for whale sharks. ■ 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 or previously in force Whale Shark Recovery Plan 2005 – 2010 (DEH 2005). Noise pollution is also not identified as a pressure to whale sharks in the Marine Bioregional Plan for the NWMR (DSEWPaC 2012).	**EPO 1.1** **EPO 1.3**
Other Marine Fauna or Ecological Communities Listed as Threatened or Migratory	■ EPBC Act Part 3 (18A and 20A). ■ EPBC Act Significant Impact Guidelines 1.1	Seismic survey activities are undertaken in a manner consistent with: ■ the EPBC Act Part 3 (18A and 20A) and Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013),	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:	**EPO 1.1**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
under the EPBC Act (Matters of NES)	(Commonwealth of Australia 2013).	whereby activities do not have a significant impact[6] on a listed threatened or migratory species population or a listed threatened ecological community; and ■ do not result in the mortality or physical injury of an individual of an EPBC listed (marine fauna) species.	■ 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.	
Marine Fauna or Ecological Communities not Listed as Threatened or Migratory under the EPBC Act (not matters of NES)	■ Principles of ESD, specifically no serious or irreversible damage.	No serious [7] 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; and ■ 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.	**EPO 1.2**

[6] The definition of 'significant impact' is as per the defined criteria in the 'Matters of National Environmental Significance: Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013)'.
[7] In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, TGS 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 'Massive' or greater.

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			population level) or irreversible impacts are predicted to occur. The structure and ecological function of the Ancient coastline at 125 m depth contour KEF and Glomar Shoal KEF are not predicted to be altered. ■ <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 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 and Glomar Shoal KEF are not predicted to be altered ■ <u>Fish communities</u> – 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 is expected to comprise occasional localised behavioural disturbances to spawning groups of fish, but	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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 and Glomar Shoal 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.	
Commercial Fisheries and Commercial Fish Stocks	Commercial fisheries stakeholders raised objections, claims and concerns regarding: ■ effects of seismic sound on key indicator commercially targeted finfish and invertebrate stocks, specifically spawning; and	Commercial Fisheries: 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; and	Commercial Fisheries 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 commercial fisheries given that:	**EPO 1.5**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
	■ effects of seismic sound on fish behaviour and commercial catch levels. Commercial fisheries and fish stocks 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 2014-2018 FishCube data); ■ DPIRD (2019c) key indicator fish species' spawning information; ■ Key indicator fish species' stock status and annual performance reviews, as reported by DPIRD in the annual Status of the Fisheries reports;	■ 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 annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts). <u>Commercial Fish Stocks:</u> Seismic activities are undertaken in a manner that does not result in serious[8] 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[9].	■ The level of interference TGS 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 scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017/18 exceeding the Department's defined acceptable catch range, 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 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).	

[8] In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, TGS 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 'Massive' or greater.

[9] It is a legislated function of DPIRD to annually report the status of the WA fisheries and fish stocks to WA Parliament and so the status and trends can be considered over time.

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
	■ Other DPIRD and FRDC publications and summaries (various, as referenced in this EP).		TGS acknowledges that localised and temporary disturbances to commercial fishing activities from seismic survey activities may occur. TGS recognises that clear and regular communication with fisheries stakeholders is required in order to facilitate better planning and resource sharing. However, the level of impact from the survey to commercial fisheries is considered to be acceptable. <u>Commercial Fish Stocks</u> 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 commercial fish stocks 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 Table 7-8 (240 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	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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 with the spawning areas in the Pilbara management unit and spawning periods of key indicator fish species (maximum spatial-temporal overlap of 5.3%); ■ 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 5.3%) with the key fish stocks is expected to be negligible in the context of natural annual 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; ■ 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	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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; and ■ The 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. ■ 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.	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
Tourism and Recreation	■ No stakeholder objections, claims or concerns were raised regarding recreation and tourism. ■ UK Diving Medical Advisory Committee (DMAC) Safe Diving Distance from Seismic Surveying Operations 2019.	Seismic activities are undertaken in a manner that does not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities.	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 tourism and recreation (including recreational fishing, diving and snorkelling). Divers at Bedout Island and Rowley Shoals will not be exposed to sound levels greater than 145 dB re 1 µPa (SPL) threshold. If diving activities occur in these areas during acquisition of the Capreolus-2 3D MSS, it is highly unlikely that individuals in the water would be impacted. While diving may occur at Bedout Island (44 km from the Operational Area), with the implementation of adopted controls, potential impacts to divers will be negligible.	**EPO 1.6**
Marine Protected Areas	■ North-west Marine Parks Management Plan 2018.	Seismic activities are undertaken in a manner consistent with the requirements of the North-west Marine Parks Management Plan 2018.	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.	**EPO 1.4**
Submarine Cables	■ ICPC Recommendation No. 8 Procedure to be followed whilst Offshore Seismic Survey Work is undertaken in the Vicinity of Active Submarine Cable Systems 2014.	Seismic activities are undertaken in a manner that does not interfere with operational submarine cables.	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 submarine cables. Based on the ICPC (2014) a +2 bar overpressure is not to be exceeded over operational marine subcables. The NWCS passes within the Acquisition Area in water depths greater than 50 m. In these water depths, the 226 dB re 1 µPa PK level (equivalence to +2 bar overpressure) is not	**EPO 1.7**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			predicted to be exceeded. Therefore, no impacts are predicted to submarine cables. Vocus Communications, as operator of the NWCS, were consulted during the preparation of the EP and have not raised any concerns regarding the cable.	

Acceptability Statement
Impacts and risks classified as '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. Based on the evaluation above, TGS considers the adopted control measures appropriate to manage the impacts of underwater noise emission from the seismic source to be of an acceptable level.

7.1.5 Environmental Performance Outcomes

<table>
<tr><th>Environmental Performance Outcomes</th><th>EPS #</th></tr>
<tr><td>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.</td><td rowspan="7">1.1
1.2
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1.23</td></tr>
<tr><td>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.</td></tr>
<tr><td>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.</td></tr>
<tr><td>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).</td></tr>
<tr><td>EPO 1.5
Seismic acquisition is 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 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 annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts); and
■ 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.</td></tr>
<tr><td>EPO 1.6
Seismic acquisition is undertaken in a manner that does not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities</td></tr>
<tr><td>EPO 1.7
Seismic acquisition is undertaken in a manner that does not interfere with operational submarine cables.</td></tr>
</table>

7.2 Cumulative: Seismic Sound & Interference with Commercial Fisheries

7.2.1 Assessment Summary

Source of Impact / Risk

Cumulative impacts from seismic surveys can potentially 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 Capreolus-2 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 Capreolus-2 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 seismic surveys overlap with the distribution of the same population of a marine species or with the same commercial fishery.

Receptors

- Marine fauna (cetaceans, reptiles, birds);
- Fishes and elasmobranchs;
- Benthic invertebrates;
- Zooplankton;
- Fish spawning; and
- Commercial fisheries

Summary of Impacts and Risks

Impacts to receptors from previous seismic surveys (completed in the last five years) are expected to have recovered, well in advance of the Capreolus-2 3D MSS commencing.
There is, however, the potential for cumulative impacts to occur in the event that other seismic surveys occur in the region concurrently. Most impacts are unlikely to be significant given the timing of the Capreolus-2 3D MSS around key environmental receptors and life stages, and given the minimum separation distance of 40 km between the Capreolus-2 3D MSS seismic source and other operating seismic sources. If one or more surveys were completed concurrently, it is noted that there may be occasional additional disturbances to different groups of spawning fishes within each of the separate survey areas and mild changes in fish abundance and distribution. It is also 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.

Decision Content

B	The decision context for cumulative impacts from seismic sound has been assessed as 'Type B', given there is interest from fisheries stakeholders regarding the effects of multiple seismic surveys. The timing of other future seismic surveys also cannot be confirmed exactly so there is some uncertainty regarding the potential cumulative impacts. The following assessment, therefore, provides a qualitative evaluation of the potential cumulative impacts, taking into account the acoustic modelling and assessment of potential impacts and risks from the Capreolus-2 3D MSS and other surveys that are planned in the region. Consideration has been given to the cost and benefit of control measures that can be practicably implemented to reduce the potential impacts and risks to ALARP.

Adopted Control Measures	EPS #

TGS will engage with proponents identified as having potential concurrent seismic activities within 40 km of the Capreolus-2 3D MSS.			2.1
A minimum separation distance of 40 km shall be maintained between the Capreolus-2 3D MSS seismic sources and other operating seismic sources.			2.2
TGS will not acquire the NWS Renaissance North 3D MSS and NWS Renaissance South 3D MSS concurrently with the Capreolus-2 3D MSS.			2.3
If a separate petroleum activity is undertaken concurrently with the Capreolus-2 3D MSS and within the Operational Area, a simultaneous operations (SIMOPs) Plan will be developed and implemented.			2.4
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Minor	Possible	**Medium**
Residual Risk	Minor	Unlikely	**Low**

7.2.2 Detailed Evaluation of Impacts / Risks

A review of seismic survey activities published on the NOPSEMA website has been undertaken to identify other marine seismic surveys that have been completed or are planned in the same region as the Capreolus-2 3D MSS.

This section assesses the potential for cumulative impacts associated with:

- Capreolus-2 3D MSS being undertaken in an area where other seismic surveys have occurred previously; and
- Capreolus-2 3D MSS being undertaken concurrently (at the same time) as other marine seismic surveys in the region.

This section does not assess cumulative impacts from seismic surveys that may occur after the Capreolus-2 3D MSS. It is not possible to anticipate what surveys will be planned after the Capreolus-2 3D MSS and it is the responsibility of future seismic survey proponents to assess the potential cumulative impacts in their respective EPs.

7.2.2.1 Previous Seismic Surveys

Ecological Receptors

Table 7-17 presents a summary of the marine seismic surveys that have been undertaken in the last five years within approximately 150 km of the Capreolus-2 3D MSS Acquisition Area. The footprint of any significant underwater noise effects resulting from the Capreolus-2 3D MSS has been assessed as being within approximately 24 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 has been selected as a conservative search criterion.

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 seismic surveys in the same areas can occur when the timing between the 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 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.

Given that the last seismic survey to be completed over the same area of seabed as the Capreolus-2 3D MSS was completed in early July 2019 (Santos Keraudren 3D MSS), ecological receptors are expected to have recovered.

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 Capreolus-2 3D MSS.

Table 7-17 Previous Seismic Surveys Completed within 150 km of the Capreolus-2 3D MSS in the Last 5 Years

Survey Name	Acquisition Period(s)	Spatial Overlap	Potential Cumulative Impacts to Ecological Receptors
Polarcus Capreolus 3D MSS	12/01/2015 - 16/04/2015 15/01/2015 - 06/05/2015 21/05/2015 - 21/07/2015 30/07/2015 - 13/11/2015	The Capreolus 3D MSS Operational Area, partially overlaps with the TGS Capreolus-2 3D MSS.	All three surveys were completed approximately 4 – 5 years prior to subsequent surveys and the earliest potential commencement date of the Capreolus-2 3D MSS, allowing all receptors to recover. Therefore, no cumulative impacts will occur as a result of the Capreolus-2 3D MSS
Searcher Seismic Bilby 2D MSS	10/03/2015 - 27/04/2015 08/06/2015 - 01/07/2015 19/05/2016 - 27/06/2016	The Bilby 2D MSS Acquisition Area, partially overlaps with the TGS Caprelous-2 3D MSS.	
TGS North West Shelf Renaissance 2D MSS	30/06/2016 - 27/09/2016	The TGS North West Shelf Renaissance 2D MSS Operational Area, partially overlaps the TGS Capreolus-2 3D MSS.	
Santos Keraudren 3D MSS	18/05/2019 - 15/07/2019	The Santos Keraudren 3D MSS, partially overlaps with the TGS Capreolus-2 3D MSS.	The Keraudren 3D MSS was completed approximately at least 14 months prior to the earliest potential commencement date of the Capreolus-2 3D MSS. Impacts to ecological receptors are expected to have recovered, including benthic communities. Some residual chronic and sub-lethal effects to some benthic invertebrates may persist, but differences in overall community composition and structure are unlikely to be discernible from natural levels.
Woodside North-West Australia 4D MSS	29/12/2019 – 23/04/2020	The EP covers acquisition within six defined areas. The closest Acquisition Area 'Harmony', is located approximately 150 km to the west of the Capreolus-2 3D MSS.	The Woodside NW 4D MSS was completed at least 6 months prior to the earliest possible commencement date of the Capreolus-2 3D MSS, Impacts to most receptors would have recovered. There is no spatial overlap. Therefore, no cumulative impacts are expected.

Commercial Fisheries

A separate and more detailed assessment has been undertaken on the potential cumulative impacts to 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. Therefore, to address these concerns, TGS has assessed the potential cumulative impacts to the Pilbara Demersal Scalefish Fisheries.

To assess the potential cumulative impacts of past surveys to the Pilbara Demersal Scalefish Fisheries, TGS has reviewed both historical surveys and available FishCube data for the period 2014-2018. The assessment focuses on the PFTIMF, as the fishery is the most relevant in terms of potential for marine user interactions and area of overlap with the fishery. 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 Pilbara Demersal Scalefish Fisheries.

Figure 7.8 to Figure 7.13 show the history of seismic surveys across the PFTIMF between 2014 and 2018 in relation to trawl fishing vessel presence within 10 nm CAES fishing blocks. 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 3 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. Figure 7.13 shows seismic surveys completed in 2019, however, 2019 FishCube data is not yet available for further analysis.

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

- Survey areas have been calculated based upon the acquisition areas, as these are the only areas available for all surveys. Operational areas, ramp-up zones and acquisition lines/racetracks 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 would 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 for the duration of the survey. 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 avoid of 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 (presented in Figure 7.9and Figure 7.10), 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.

Based on the spatial analysis presented in Table 7-18, the following conclusions are made regarding impacts to the fisheries from historic seismic surveys:

- The PFTIMF fished area has historically been subject to approximately 50% overlap from 2D and 3D seismic surveys in a single year (maximum occurring in 2015). This is comprised of approximately 19% overlap from 3D seismic surveys and 31% overlap from 2D seismic surveys.
- Overall, Figure 7.8 to Figure 7.13 show that fishing vessels continue to fish in similar areas each year with no obvious variations in fishing vessel distribution attributable to the presence of seismic surveys. 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, but these cannot be identified from the available data, which is presented at a coarser spatial and temporal resolution than disturbances may have occurred. 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 overall fishing activity and distribution of fishing effort in any year.
- Since 2014/15, total fish catch has increased each year despite the occurrence of large-scale seismic surveys.

The North Coast Demersal Scalefish Resource Harvest Strategy 2017 – 2021 (DPIRD 2017) also notes that the total annual catch in the Pilbara Demersal Scalefish Fisheries has remained relatively stable, with the PFTIMF averaging approximately 1,200 tonnes over a five year period (between 2012 and 2017). Again, this has occurred despite seismic surveys being undertaken most years. The most recent DPIRD Status of the Fisheries Report (Newman et al. 2019) further notes that the 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 since 2015 has increased despite having the same annual effort allocations, with catches in 2017/18 exceeding the Department's defined acceptable catch range. However, Newman et al. (2019) suggest that these increased catch rates (combined with fishing mortality spawning biomass estimates) indicate that effort reductions since 2008 have resulted in increased fish abundance and stock rebuilding in the PFTIMF, and so the fishery continues to be assessed as sustainable.

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 seismic surveys.

Table 7-18 Total 2D and 3D Survey Areas Completed or Proposed Overlapping the PFTIMF

Year	Total Area Fished (km^2)[10]	Total Fish Caught (tonnes)[11]	Total Fishing Days[11]	Total 3D Seismic Surveys Overlapping the Total Area Fished (km^2)[12]	Total 3D Seismic Surveys Overlapping the Total Area Fished (%)[12]	Total 2D Seismic Lines Overlapping the Total Area Fished (km)[13]	Total 2D Seismic Surveys Overlapping the Total Area Fished (km^2)[13]	Total 2D Seismic Surveys Overlapping the Total Area Fished (%)[13]	Total Seismic Survey Area Overlapping the Total Area Fished (%)
2014	25,922	1,105	591	1,663	7%	0	0	0%	**0%**
2015	25,922	1,172	NA[3]	4,830	19%	2,525	8,126	31%	**50%**
2016	25,922	1,529	NA	0	0%	1,516	6,482	25%	**25%**
2017	25,922	1,795	NA	0	0%	0	0	0%	**0%**
2018	25,922	1,975	649	770	3%	0	0	0%	**3%**
2019	25,922	NA	NA	3,502	14%	0	0	0%	**14%**

[10] The total area of all 10 nm CAES blocks with recorded fishing effort per year within PFTIMF.

[11] Fishing catch and days effort are derived from FishCube data which is only available up to and including 2018. Total fishing days are not available for some years due to FishCube data confidentiality.

[12] Survey areas have been calculated based upon the define acquisition areas, as these are the only areas available for all surveys. Operational areas and ramp-up zones could not be confirmed for most surveys. 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 in for each year.

[13] 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 survey 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 (presented in Figure 7.10 and Figure 7.11), it is still possible that a 2D seismic vessel could have been operating within the total fished area during each 2D seismic survey.

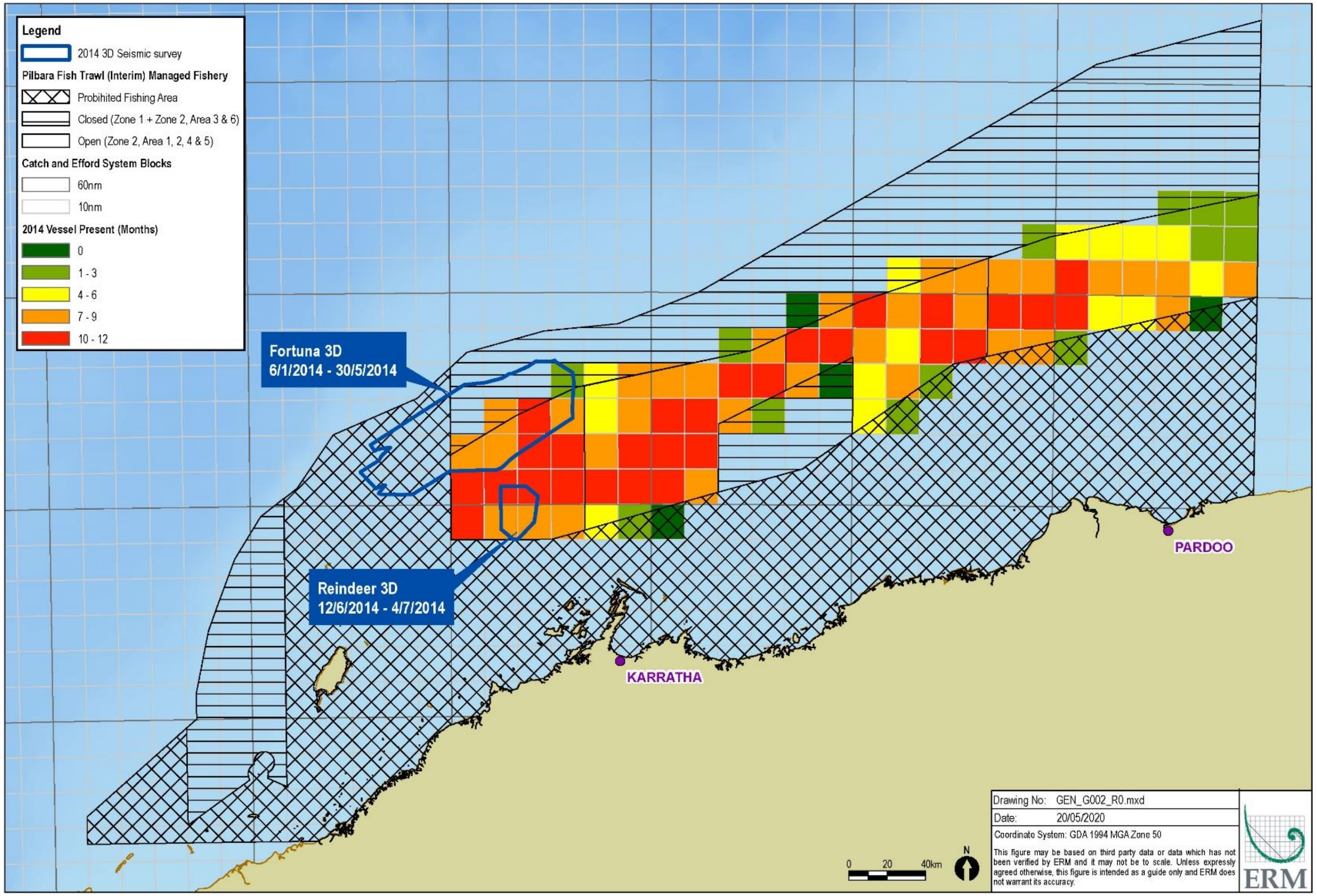

Figure 7.8 Seismic Surveys Completed in 2014 Overlapping the PFTIMF[14]

[14] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year).

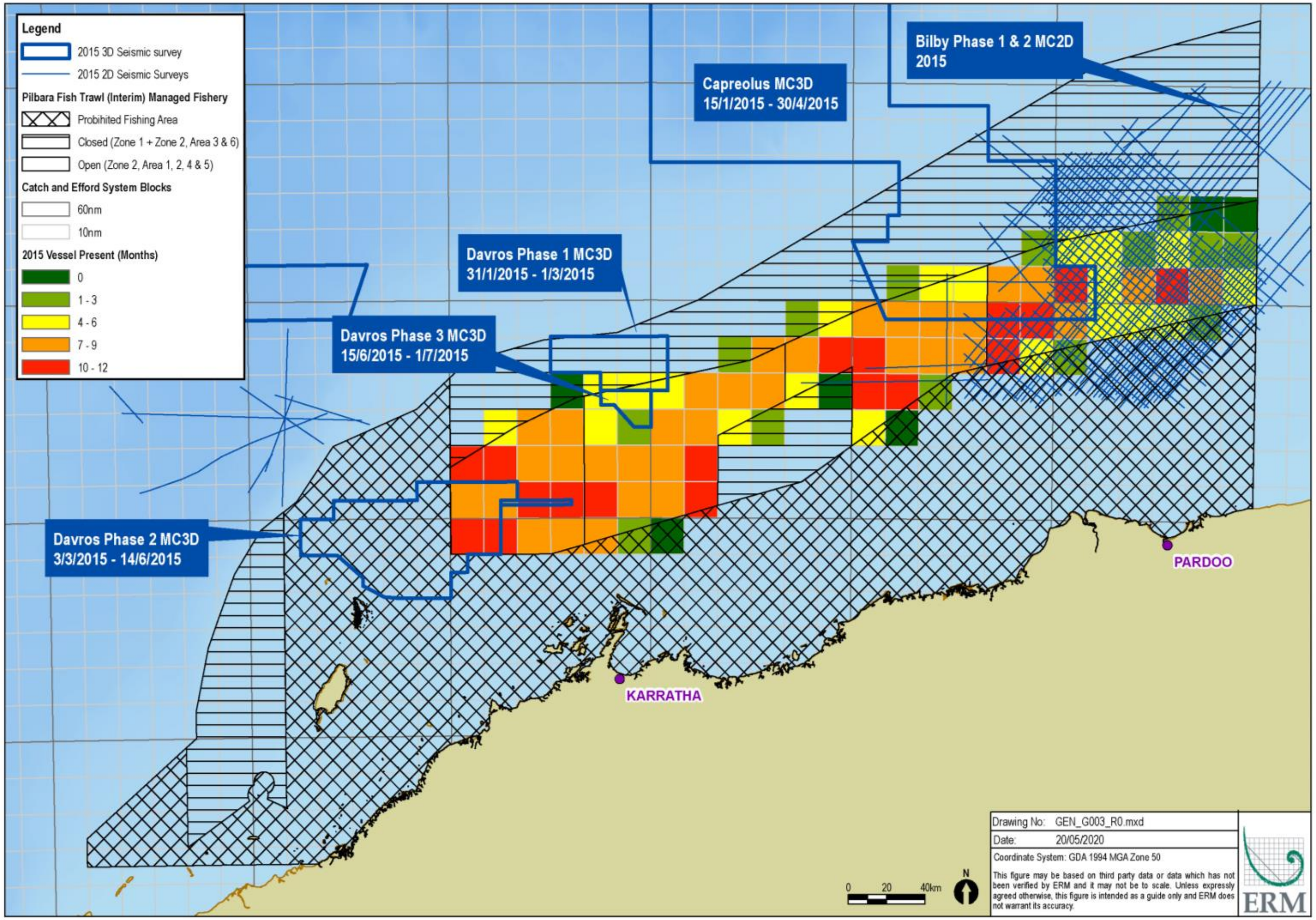

Figure 7.9 Seismic Surveys Completed in 2015 Overlapping the PFTIMF[15]

[15] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year).

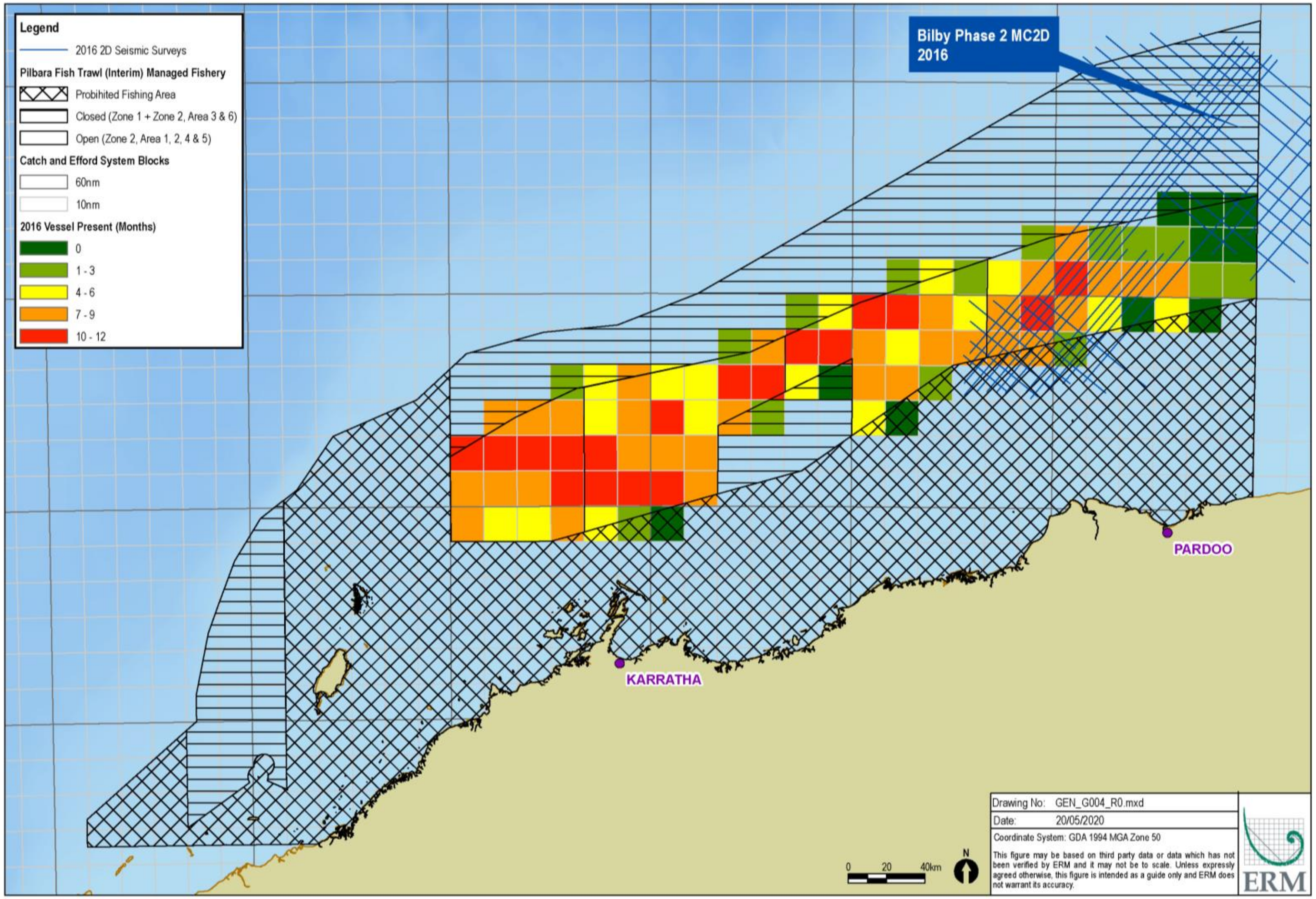

Figure 7.10 Seismic Surveys Completed in 2016 Overlapping the PFTIMF[16]

[16] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year).

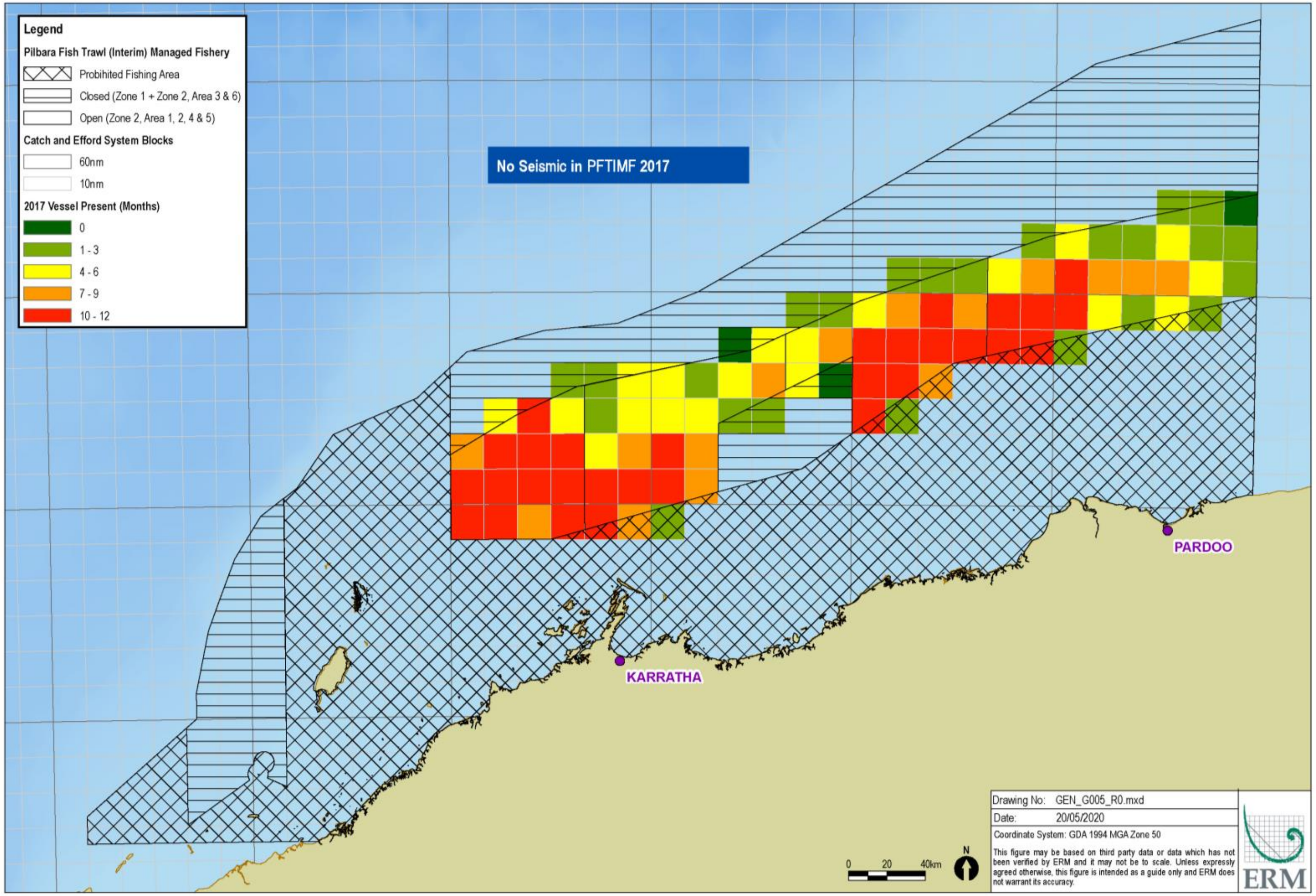

Figure 7.11 Seismic Surveys Completed in 2017 Overlapping the PFTIMF[17]

[17] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year).

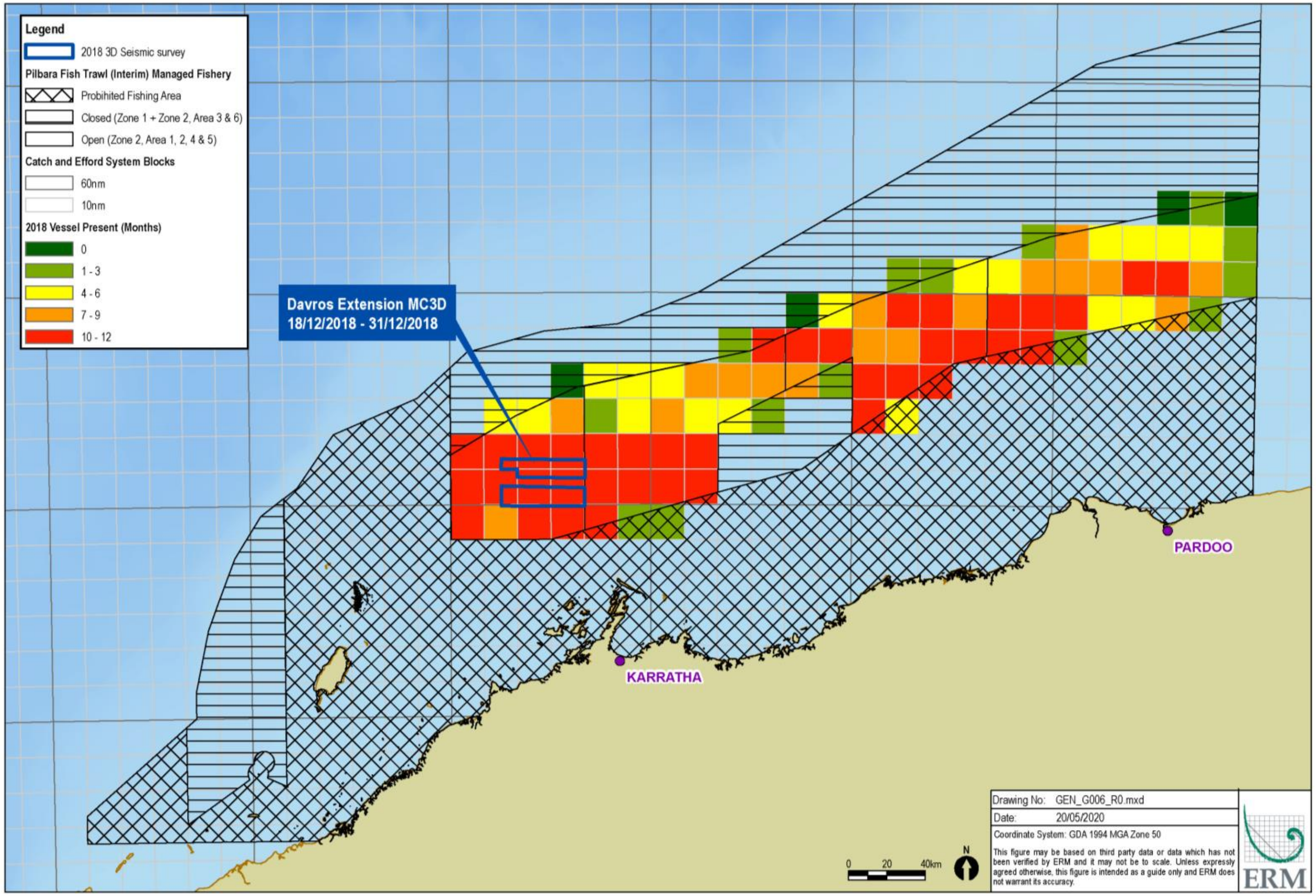

Figure 7.12 Seismic Surveys Completed in 2018 Overlapping the PFTIMF[18]

[18] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year).

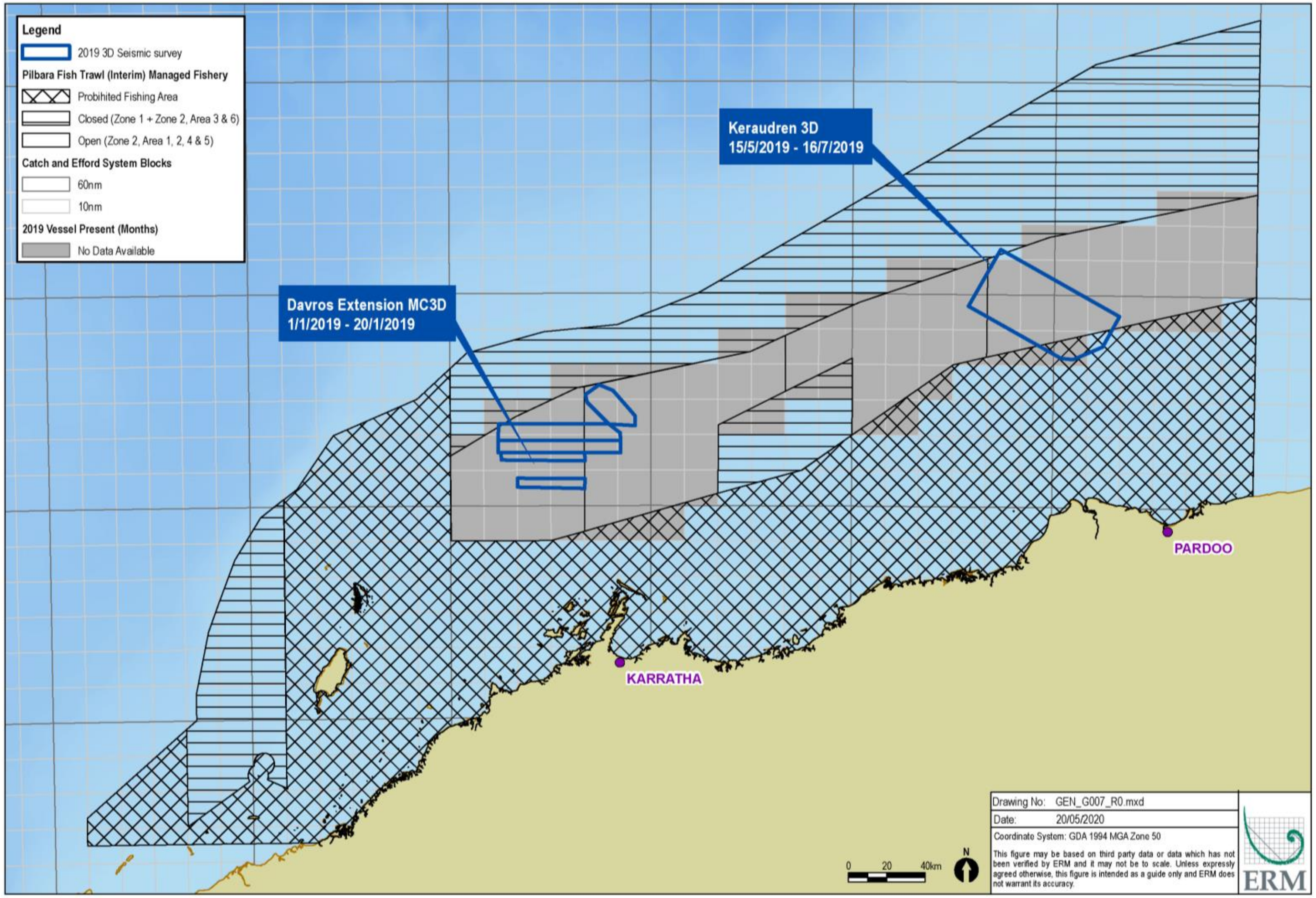

Figure 7.13 Seismic Surveys Completed in 2019 Overlapping the PFTIMF[19]

[19] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year).

Fish Spawning

In addition to the assessment of cumulative impacts to commercial fisheries, a detailed assessment has been undertaken on the potential cumulative impacts to commercial fish stocks. This assessment addresses concerns from fisheries stakeholders. 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 fish stock distribution. Therefore, to address these concerns, TGS has 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. Of the 5-year period between 2014 and 2018, 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 (refer to Figure 7.14).

As per the analysis undertaken on the spatial-temporal overlap of the Capreolus-2 3D MSS, as detailed in Section 7.1, a number of assumptions have been applied to the assessment. These assumptions 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 would 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. For example, 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 squared kilometres.
- Temporal overlap is based on the total duration of the surveys 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 has 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.
- It is conservatively assumed that fish spawning in the area and period of exposure would have been compromised. As indicated in Section 7.1, 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. 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 7-19. The following observations are made from the 2015 spatial-temporal analysis:

- The maximum spatial-temporal overlap with the spawning area and spawning period of 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.

The 1.87% to 8.73% spatial-temporal overlap is 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 (refer to Section 7.1).

It is important to note that from 2015 to 2018, the key indicator fish stocks and the Pilbara Demersal Scalefish Fisheries have maintained a classification of 'Sustainable' even with the occurrence of large-scale seismic surveys (DPIRD 2017; Gaughan et al. 2018; Newman et al. 2019). The most recent DPIRD Status of the Fisheries report (Newman et al. 2019) further notes that total annual trawl catches have increased between 2015 and 2015 despite having the same annual effort allocations, with catches in 2017/18 exceeding the Department's defined acceptable catch range. Newman et al. (2019) 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 7-19 Cumulative Spatial-Temporal Overlap of 2015 Seismic Surveys with Spawning Areas and Periods of Key Indicator Fish Species in the Pilbara

Fish Species	Depth Range (m)	Spawning Area (km^2)[20]	Spawning Period	Cumulative Spatial Overlap (%)[21]	Temporal Overlap (%)[22]	Cumulative Spatial-Temporal Overlap (%)[23]
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)
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)

[20] Spawning areas have been estimated based on each species' depth range and the FRDC (2019) stock assessment data and the 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.

[21] The cumulative spatial overlap is calculated based on the sum of all individual survey areas. Survey areas have been calculated based upon the define acquisition areas, as these are the only areas available for all surveys. 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.

[22] 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.

[23] The total cumulative spatial-temporal overlap with each species is calculated based on the spatial-temporal overlap of each individual survey summed together.

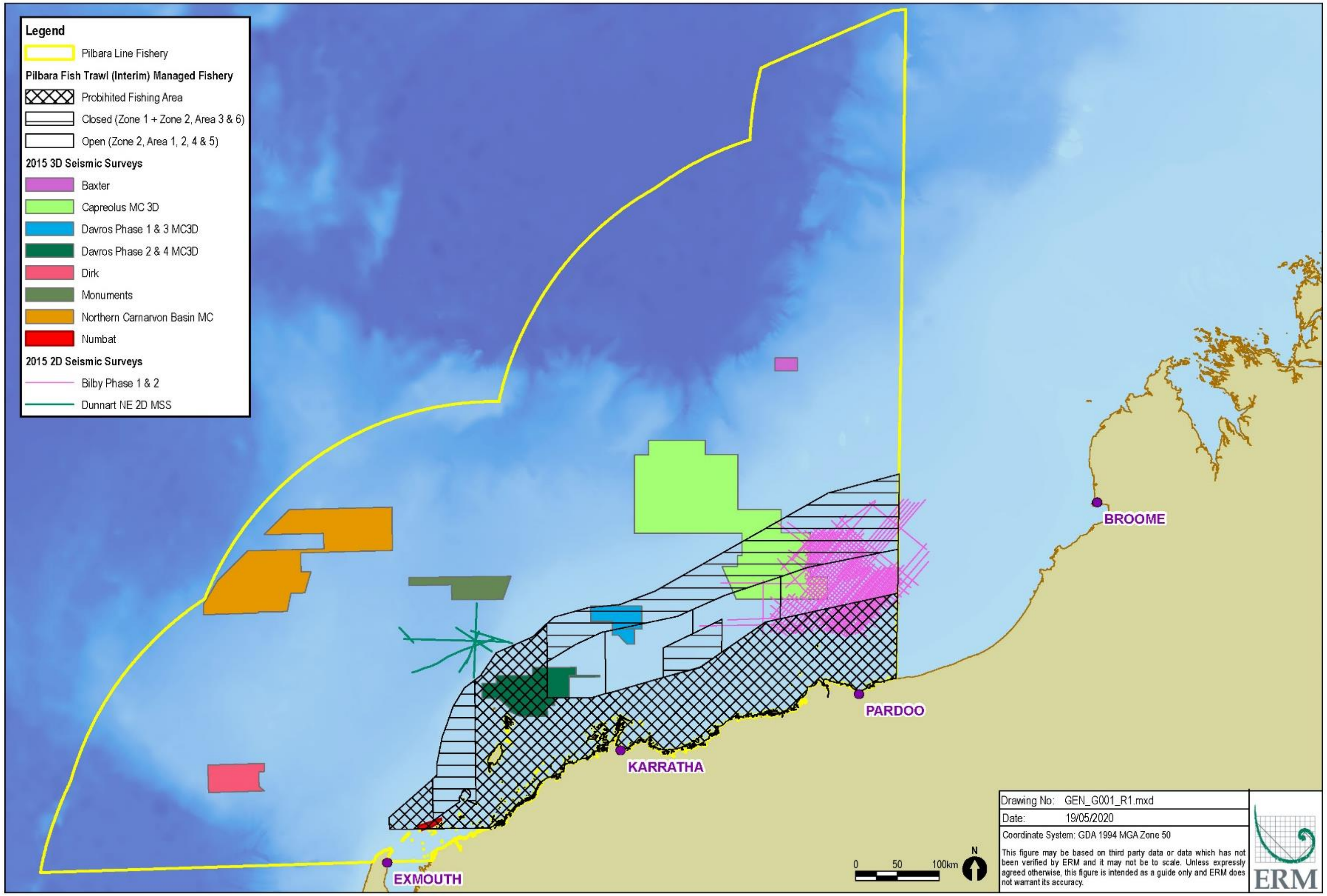

Figure 7.14 Completed 2D and 3D Seismic Surveys Overlapping the Pilbara Demersal Scalefish Fisheries in 2015

7.2.2.2 Concurrent Seismic Surveys

Over the scheduled period of the Capreolus-2 3D MSS (2020-2024) other seismic surveys are proposed in the region. Table 7-20 presents the seismic surveys that:

- may occur within the same EP timeframes; and
- either have an EP accepted by NOPSEMA or have submitted an EP to NOPSEMA for public comment period or assessment.

It is important to note that, while some of these seismic surveys may go ahead and some have the potential to occur at the same time as the Capreolus-2 3D MSS, for commercial reasons, it is unlikely that all of the proposed seismic surveys will actually proceed in a single calendar year 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 (as is the case for the Capreolus-2 3D MSS). Some of the seismic surveys may not proceed at all.

For the purpose of providing a realistic but conservative assessment, TGS has undertaken additional consultation with the relevant petroleum titleholders and seismic acquisition companies, to determine a maximum credible cumulative acquisition scenario. Due to the competitive and commercially sensitive nature of some of this information, responses received by other petroleum titleholders and seismic companies are not presented here in the EP and it is not possible to provide all details on why certain surveys have or have not been included in the maximum credible acquisition scenario. Consultation responses have been provided to NOPSEMA in the Sensitive Matters Report for consideration in parallel with this EP submission.

The maximum credible scenario is based on the following surveys occurring in 2021:

- An indicative 10,000 km^2 phase of the TGS Capreolus-2 3D MSS that may be completed in 2021. This indicative phase area has been selected as it includes the Santos ‘Archer’ survey prospect, which is also noted by Santos in the Keraudren Extension 3D MSS EP (Santos 2020) as having the potential to go ahead. The indicative phase has also been selected to maximise the potential spatial overlap with the PFTIMF and spawning areas of key indicator fish species.
- The entire 3D Oil Sauropod 3D MSS (3,500 km^2).
- The entire Santos Keraudren Extension 3D MSS (8,620 km^2), noting that the survey may be completed in smaller phases in 2021 and 2022.

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. It is important to note that petroleum titleholders will only contract one multi-client geophysical company to collect seismic data over their permit areas. Therefore, the PGS Rollo MC MSS has not been included in the maximum credible cumulative scenario.

The Keraudren Extension 3D MSS will not take place at the same time as the proposed Santos ‘Archer’ survey. Santos has committed in its EP to reduce the area of acquisition of the Santos Keraudren Extension 3D MSS by 1,859 km^2 should the Archer prospect 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, it is considered credible that the TGS Capreolus-2 3D MSS could occur concurrently with the Sauropod 3D MSS. It is expected that the Santos Keraudren 3D MSS and TGS Capreolus-2 3D MSS will occur in succession (one after the other). For assessment purposes, TGS has accounted for the three surveys occurring concurrently.

TGS considers it highly unlikely that more three seismic surveys will take place across the Pilbara fisheries in 2021, 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, the following assessment does not assess cumulative impacts from seismic surveys in the region that occur after the Capreolus-2 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.

The individual sound fields produced by separate concurrent seismic surveys has the potential to interact where sound waves from the separate seismic sources may be received either in synchrony ("in synch") or out of synchrony ("out of synch"). How these sound waves might interact has previously been considered by JASCO Applied Sciences and ERM for the Santos Keraudren Extension 3D MSS EP (Santos 2020). An increase in sound levels may sometimes occur temporarily at locations where the received signals from each source occur in synch. However, in most instances, pulses will be out of synch and increased received per-pulse sound levels will not occur often.

Given that different seismic sources are unlikely to be discharged at exactly the same time, different surveys will have different source impulse intervals, and each pulse will be a few hundred milliseconds in duration with several seconds in between, pulses will generally be out of synch with one another. Pulses may still line up occasionally for a brief moment at some locations, and where they do, the amplitudes will then be too unequal for the sum level to differ much from the stronger of the two components. However, in the unlikely case that two pulses interact and are exactly synchronised with each other, then the combined SPL would be 3 dB higher than the individual SPL, which represents a doubling of sound energy. Further explanation is provided in Santos (2020).

TGS will endeavour to minimise the potential for interaction between any concurrent seismic surveys to minimise both potential disruptions to operations as well as potential cumulative sound impacts to the marine environment and impacts to other marine users.

For operational reasons (to prevent acoustic interference and preserve seismic data integrity) a minimum separation distance of at least 40 km will be maintained between the Capreolus-2 3D MSS seismic source and any other concurrently operating seismic sources during data acquisition activities. Given this separation distance, underwater sound from the seismic sources is not anticipated to combine to significantly raise the sound pressure levels to which receptors may be exposed. In the unlikely event that two pulses interact and are exactly synchronised with each other, a 3 dB increase in SPL (doubling) may occur. Modelling of the seismic source for the Capreolus-2 3D MSS (Koessler et al. 2020) demonstrates that sound levels will be below 150 dB re 1µPa at 20 km from the source (half way between two seismic sources at their minimum separation distance) and in many cases will be below 140 dB re 1µPa. A combination of seismic sound from two similar seismic sources at this distance would therefore be expected to result in an SPL of no greater than 153 dB re 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.

Table 7-20 Other Potential Seismic Surveys Occurring in the Region

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
TGS Renaissance South	The Operational Area is 300,000 km^2. No defined Acquisition Area in the EP.	The Renaissance South Operational Area, partially overlaps with the TGS Capreolus-2 3D MSS.	2016 - 2021 The specific commencement dates and durations of individual surveys has not been confirmed. Note - TGS will not acquire the Renaissance South survey at the same time as the TGS Capreolus-2 3D MSS. Therefore, the survey has been excluded from the cumulative impact assessment.	The EP is accepted and valid to 2021.
PGS Rollo MC MSS	The Operational Area is 117,833 km^2. No defined Acquisition Area in the EP. Note – based on restrictions in the EP, it has been assumed for assessment purposes that acquisition is limited to a maximum of 25,000 km^2 per calendar year.	The Beagle Acquisition Area overlaps with the TGS Capreolus-2 3D MSS.	2018 – 2023 The specific commencement dates and durations of individual surveys has not been confirmed. .	The EP is accepted and valid to 2023.
3D Oil Sauropod 3D MSS	The Acquisition Area is 3,500 km^2.	The Sauropod 3D MSS Acquisition Area, is located approximately 83 km west of the Capreolus-2 3D MSS.	January – April 2021. No seismic acquisition is planned for 2020. Maximum of 60 days of acquisition.	The EP is accepted and valid to 2021.
INPEX 2D Seismic Survey (WA-532-P, WA-533-P, WA-50-L)	The Acquisition Area is 65,138 km^2.	The INPEX 2D Acquisition Area is located approximately 190 km from the Capreolus-2 3D MSS.	1 November 2020 – 31 December 2021. No acquisition between 1 June – 31 October in 2020 or 2021.	The EP is accepted and valid to 2021.

Survey Name	Survey Area	Survey Location	Survey Timing and Duration	EP Status
			Maximum of 210 days of acquisition.	
Santos Keraudren Extension 3D MSS	The full-fold acquisition area is 8,620 km^2.	The Keraudren Extension 3D MSS full-power zone is located 2 km from the TGS Capreolus-2 3D MSS.	1 February – 31 July, 2020 – 2022. No seismic acquisition is planned for 2020. Maximum of 162 days of acquisition.	The EP is accepted and valid to 2022.

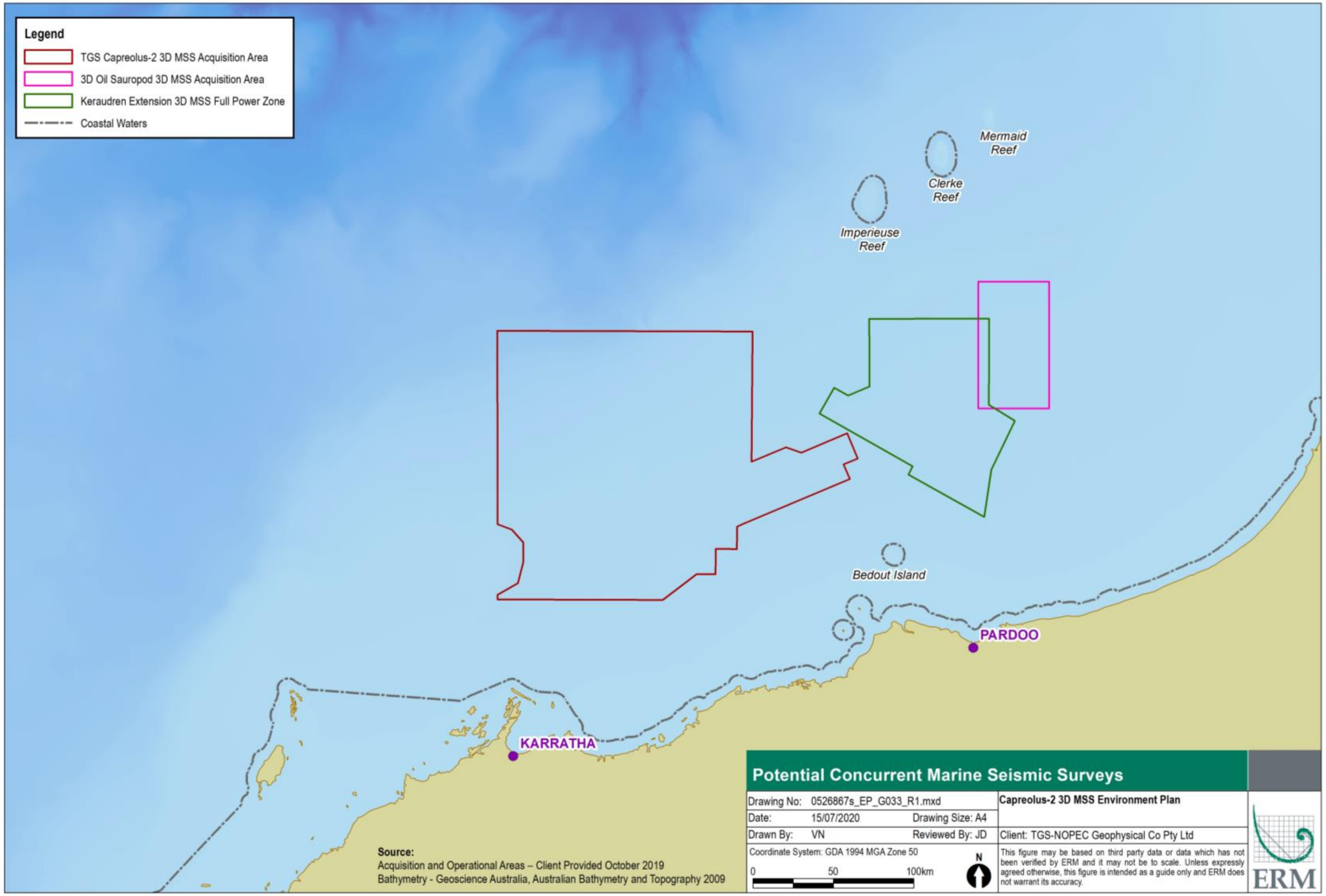

Figure 7.15 Other Potential Seismic Surveys Occurring in the Region

The following section provides a summary of the potential impacts that are predicted to occur from the maximum credible cumulative scenario identified above.

Cetaceans

No significant discernible cumulative impacts to cetaceans are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 (i.e. thousands of kilometres) over which cetaceans normally travel during their migrations.

Based on the evaluation provided in Table 7-21, no significant cumulative TTS or behavioural effects are expected to humpback whales or pygmy blue whales within the respective migration BIAs, as a result of multiple seismic surveys occurring in the region. The planned seismic surveys in the region do not constrain the migration route for any cetacean species. These species will be able to continue to utilise the migration routes/pathways without injury or displacement.

Other cetacean species are expected to be transient and no changes to migration or other important life stages are expected. Localised disturbances may occur when passing the concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.

Table 7-21 Evaluation of Cumulative Impacts to Migrating Cetaceans

	TGS Capreolus-2 3D MSS	Santos Keraudren Extension 3D MSS	3D Oil Sauropod 3D MSS	Cumulative Assessment
Pygmy Blue Whales	The Capreolus-2 3D MSS overlaps with the pygmy blue whale migration BIA. The seismic source will not be operated within 24 km of the pygmy blue whale migration BIA during migration periods for the species (April – August and October – December). Based on acoustic modelling, the maximum predicted distance to TTS thresholds for pygmy blue whales within the migration BIA is approximately 24 km. Therefore, no TTS effects are predicted to migrating whales. Short-term behavioural impacts are expected to occur up to a maximum of approximately 9.5 km from the operating seismic source (depending upon location and water depth). Therefore, short-term behavioural impacts to migrating pygmy blue whales are unlikely.	The Santos Keraudren Extension 3D MSS is located approximately 100 km from the pygmy blue whale migration BIA. Timing of the survey also only coincides with part of the northbound migration. Based on acoustic modelling, the maximum predicted distance to TTS thresholds for cetaceans is approximately 31 km. Therefore, no TTS effects are predicted to migrating whales. Short-term behavioural impacts are expected to occur up to a maximum of approximately 9 km from the operating seismic source (depending upon location and water depth). Therefore, no short-term behavioural impacts are predicted to migrating whales.	The 3D Oil Sauropod 3D MSS is located approximately 72 km from the pygmy blue whale migration BIA and the timing of the survey avoids the majority of the pygmy blue whale migration period. Based on acoustic modelling, the maximum predicted distance to TTS thresholds for cetaceans is approximately 15 km. Therefore, no TTS effects are predicted to migrating whales. Short-term behavioural impacts are expected to occur up to a maximum of approximately 8 km from the operating seismic source (depending upon location and water depth). Therefore, no short-term behavioural impacts are predicted to migrating whales.	No cumulative TTS or behavioural effects are predicted to arise to migrating pygmy blue whales, given: ■ the distance that the 3D Sauropod 3D MSS and the Keraudren Extension 3D MSS are located from the pygmy blue whale migration BIA: and ■ the TGS Capreolus-2 3D MSS seismic source will not be operated within 24 km of the pygmy blue whale migration BIA during migration periods for the species. Pygmy blue whales will be able to continue to utilise the migration BIA without injury or displacement from multiple surveys occurring the region. Therefore, no significant cumulative impacts are expected to occur to pygmy blue whales.
Humpback Whales	The Capreolus-2 3D MSS overlaps with the humpback whale migration BIA. The seismic source will not be operated within the humpback whale	The Santos Keraudren Extension 3D MSS overlaps with the humpback whale migration BIA. The survey will be acquired between 1 February to	The 3D Oil Sauropod 3D MSS is scheduled to occur between January and April 2021 and therefore avoids the humpback whale migration	A few migratory individuals may experience TTS and behavioural effects from individual surveys in the

	TGS Capreolus-2 3D MSS	Santos Keraudren Extension 3D MSS	3D Oil Sauropod 3D MSS	Cumulative Assessment
	migration BIA during the peak migration period (July to October). Based on acoustic modelling, the maximum predicted distance to TTS thresholds for humpback whales is approximately 15 km (based on survey lines in the southern portion of the Acquisition Area overlapping the migration BIA). Potential TTS effects may occur to a few individuals for a short-duration. Short-term behavioural impacts are expected to occur up to a maximum of approximately 9.5 km from the operating seismic source (depending upon location and water depth). Migrating humpback whales may deviate from their normal course by several kilometres to avoid the seismic sound source, however this distance does not constrain the migration path of humpback whales. Therefore, occasional and localised short-term behavioural impacts are predicted to migrating whales.	31 July (which extends into the northern migration period for the humpback whale species). Santos have a commitment in their EP to terminate the survey if there are 3 consecutive days of no seismic acquisition, due to the presence of migrating humpback whales (Santos 2020). Based on acoustic modelling, the maximum predicted distance to TTS thresholds for cetaceans is approximately 31 km. Potential TTS effects may occur to a few individuals for a short duration. Short-term behavioural impacts are expected to occur up to a maximum of approximately 9 km from the operating seismic source (depending upon location and water depth). Migrating humpback whales may deviate from their normal course by several kilometres to avoid the seismic sound source, however this distance does not constrain the migration path of humpback whales. Therefore, occasional and localised short-term behavioural impacts are predicted to migrating whales.	period. Therefore, no impacts to migrating humpback whales are expected.	region. However, effects are expected to be limited, given: ■ the 3D Sauropod 3D MSS will have no impact on humpback whales; ■ the adaptive management measures adopted by Santos for the Keraudren Extension 3D MSS (i.e. termination of the survey if there are three days of no seismic acquisition due to the presence of migrating humpback whales); and ■ the TGS Capreolus-2 3D MSS seismic source will not be operated within the humpback whale migration BIA during peak migration period for the species and adaptive management measures will be implemented at other times. Given the measures that will be implemented by both TGS and Santos, the potential for exposure to sound from these surveys will not occur when humpback whales are abundant in the region. Some humpback whale individuals may be exposed to sound from both the TGS and Santos surveys if they happen to

	TGS Capreolus-2 3D MSS	Santos Keraudren Extension 3D MSS	3D Oil Sauropod 3D MSS	Cumulative Assessment
				be passing along the coast in proximity to the survey when each survey vessel happens to be acquiring near their migration pathway. Such instances are likely to be limited to a few individuals or groups and not a large proportion of the population. These exposures may result in an increase in the potential for temporary effects such as TTS or behavioural responses that result in deviations from the animals intended course. However, these deviations are expected to be small relative to the long distances over which migration occurs. Humpback whales will be able to continue to utilise the migration BIA without injury or displacement. The surveys will not be undertaken near any areas that are recognised for significant life stages or activities such as breeding, calving, resting or foraging. Therefore, no significant cumulative impacts are expected to occur to humpback whales.

Marine Reptiles

No significant discernible cumulative impacts to marine turtles are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 marine turtles normally travel.

Short-term behavioural impacts are expected to occur up to a maximum of approximately 5 km from the TGS Capreolus-2 3D MSS operating seismic source for marine turtles (based on NMFS criterion of 166 dB re 1 µPa SPL) (refer to Section 7.1.2.3). No seismic acquisition will be undertaken within the flatback turtle internesting BIA during nesting seasons (October – March).

Given, the distance that the 3D Oil Sauropod 3D MSS is located from the nearest flatback turtle internesting BIA (15 km) and that no acquisition of the Santos Keraudren Extension 3D MSS will be undertaken within the flatback turtle internesting BIA during nesting seasons, no significant cumulative behavioural impacts are expected to marine turtles within turtle internesting BIAs. These species will be able to continue to utilise the BIAs without injury or displacement. Localised disturbances may occur when passing the concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.

Fishes and Elasmobranchs

Behavioural impacts in fish are expected to occur at distances of tens or hundreds of metres from the seismic source, returning to normal within minutes or hours. Potential changes in distribution of fishes are also expected to return to normal within hours or days (refer to Section 7.1.2.3).

No significant discernible cumulative impacts to fish are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 sources, but such changes are expected to return to normal within a few hours or days.

Whale sharks, may also experience localised disturbances when passing each of the seismic surveys. However, as the vessels will maintain the minimum separation distance of 40 km, separate isolated incidents of disturbance are not expected to result in significant impacts.

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 Capreolus-2 3D MSS, such impacts are expected to occur at close range to the seismic source (i.e. <225 m). In the context of natural mortality, recruitment and recovery rates, the impacts to overall benthic communities are expected to be negligible (refer to Section 7.1.2.3).

There is the potential for cumulative impacts to occur to benthic invertebrate communities in areas where the Capreolus-2 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.

Zooplankton

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, CSIRO (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 CSIRO (Richardson et al. 2017). Further, natural mortality rates can be as high as approximately 60%, and not entirely as a result of predation (refer to Section 7.1.2.3), therefore, limited impacts are expected relative to the natural variation in zooplankton concentrations and mortality rates.

No significant discernible cumulative impacts to zooplankton are expected, given the separation distances between the Capreolus-2 3D MSS seismic source and other operating seismic sources. Therefore, the cumulative impacts to plankton are expected to be negligible.

Fish Spawning

The spawning periods and ranges for a number of the key indicator species for the Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Managed Fishery and Pilbara Trap Managed Fishery overlap with the Capreolus-2 3D MSS and other planned seismic surveys (as mentioned above).

A combined spatial-temporal analysis has also been conducted to determine the maximum spatial and temporal overlap of concurrent seismic surveys with the spawning times and ranges of key commercial indicator fish species. The method and assumptions applied are the same as the analysis in Section 7.1.

The spatial analysis is based on a week (7 days) of acquisition lines with a 5 km buffer applied to the racetrack formation to account for possible uncertainty about the range to disturbance to fish. It is appropriate to consider a week of acquisition lines, given that over the duration of each survey, the seismic survey vessel would gradually move across the survey area; following a week, the racetrack would have progressed sufficiently far that it would no longer disturb the same areas and groups of demersal fishes as may be disturbed at the start of the racetrack.

Based on this approach, the estimated area of disturbance from each survey would be:

- TGS Capreolus-2 3D MSS: approximately 2,300 km^2;
- 3D Oil Sauropod 3D MSS: approximately 1,800 km^2; and
- Santos Keraudren Extension 3D MSS: approximately 2,500 km^2.

The combined spatial-temporal analysis is presented in Table 7-22.

Table 7-22 Cumulative Spatial-Temporal Overlap with Key Indicator Species Spawning Periods and Ranges[24] [25] [26]

Survey Name	Red Emperor	Rankin Cod	Goldband Snapper	Bluespotted Emperor	Ruby Snapper
TGS Capreolus-2 3D MSS	1.45%	1.93%	2.62%	2.05%	5.28%
3D Oil Sauropod 3D MSS	1.14%	1.51%	2.05%	0.22%	0.69%
Santos Keraudren Extension 3D MSS	1.58%	2.09%	2.84%	1.90%	0.46%
Total Overlap	**4.17%**	**5.53%**	**7.51%**	**4.17%**	**6.43%**

[24] The spatial analysis is based on a week (7 days) of acquisition lines with a 5 km buffer applied to the racetrack formation to account for possible uncertainty about the range to disturbance to fish. The racetrack formations have been calculated based upon the information presented in each surveys publically available EP.

[25] 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.

[26] The temporal overlap is based on the number of days of acquisition coinciding with the days that each species is known to spawn. The temporal overlap does not take into consideration management controls adopted.

Based on the maximum credible scenario (mentioned above), the cumulative spatial-temporal overlap for key indicator species ranges from 4.2% (red emperor) to 7.5% (goldband snapper). Therefore, it is concluded that up to 7.5% of the spawning ranges/periods of key indicator species may be exposed to seismic sound at any one time during the survey. As previously discussed in Section 7.1, the analysis is simply an indication of the area where potential spawning aggregations may be influenced.

It is acknowledged that in addition to natural factors and fishing catches, the proposed seismic surveys may contribute to some small, localised reduction in spawning success in disturbed areas. However, these effects are considered to be temporary, and relatively minor compared with normal variations in spawning success and fish recruitment, which have fluctuated by approximately 250% and 350% respectively, as a result of fishing and natural factors (refer to Section 7.1.6.6).

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 (<7.5%) with the key fish stocks during any spawning season is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250 ‑ 350%);
- Key indicator species in the 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; and
- 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.

Commercial Fisheries

Cumulative impacts to commercial fisheries may occur if multiple seismic surveys occur concurrently or in quick succession within an area, resulting in increased avoidance by target fish species (refer to Section 7.1.2.3). The expected range and duration of impacts to fish abundance, distribution and catch rates is relatively small compared to wider areas within which the fisheries operate.

An analysis has been conducted to determine the area of overlap of potential seismic surveys (based on the maximum credible scenario discussed above) and commercial fisheries. As per the analysis undertaken in Section 7.1, the assessment focuses 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.

As mentioned above, the Santos Keraudren Extension 3D MSS will not take place at the same time as the proposed Santos ‘Archer’ survey. Santos have committed in their EP that they will reduce the area of acquisition of the Santos Keraudren Extension 3D MSS by 1,859 km^2 should the ‘Archer’ prospect 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, it is considered credible that the TGS Capreolus-2 3D MSS could occur concurrently with the Sauropod 3D MSS and it is expected that the Santos Keraudren Extension 3D MSS and TGS Capreolus-2 3D MSS will occur in succession (one after the other).

The spatial overlap of these surveys with the PFTIMF is presented in Table 7-23. Up to approximately 46% of the PFTIMF fished area may be subject to seismic surveys at some point in 2021.

Table 7-23 Spatial Overlap of Potential Seismic Surveys with the PFTIMF

Seismic Survey	Pilbara Fish Trawl (Interim) Managed Fishery
TGS Capreolus-2 3D MSS (indicative 10,000 km^2 phase)	21.54%
3D Oil Sauropod 3D MSS	6.97%
Santos Keraudren Extension 3D MSS	15.95% [10.76%]
Maximum Total Overlap (Sauropod + Keraudren Extension [reduced] + Capreolus-2)	**46.24%**

* Numbers in brackets indicate survey reductions already committed to by Santos in the Keraudren Extension 3D MSS EP (Santos 2020).

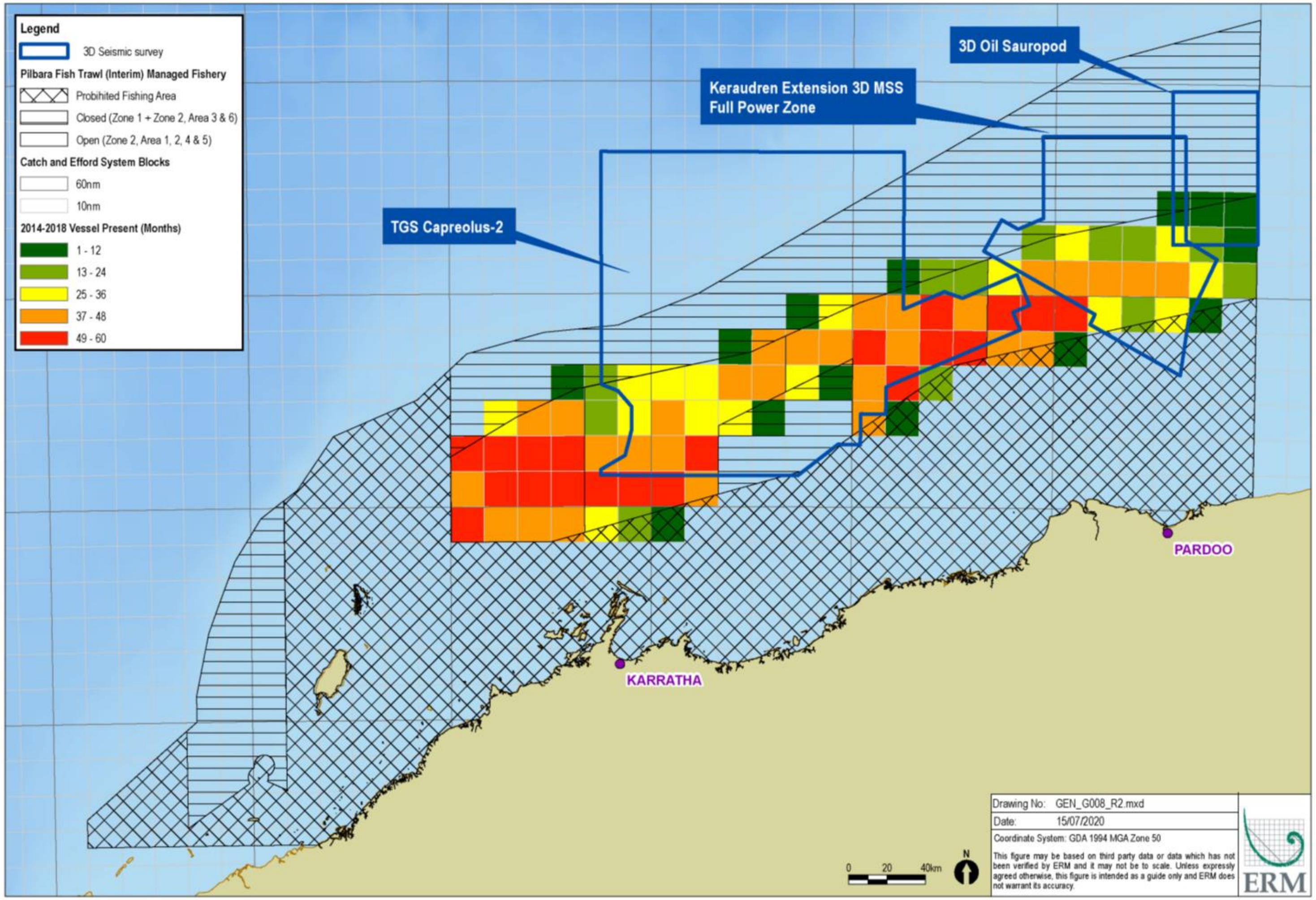

Figure 7.16 Potential Seismic Surveys Overlapping the PFTIMF[27]

[27] PFTIMF fishing effort is represented by the number of months where a fishing vessel was recorded as fishing in a 10 nm CAES block (0 = no months of the year; 12 = 12 months of the year). Note, the entire TGS Capreolus-2 3D MSS Acquisition Area is displayed on the figure for representative purposes. TGS will only acquire up to a maximum of 10,000 km^2 per calendar year.

However, accounting for the entire acquisition areas of each survey simply provides an indication of the total area and duration that may be surveyed and where there is potential for interactions with fishers to occur. This is highly conservative and not representative of a real-life situation because the seismic survey vessel will only be operating in part of each survey area at any one time. Therefore, the spatial overlap significantly over-represents the actual spatial footprint of potential disturbance to commercial fishers. 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:

- TGS Capreolus-2 3D MSS: approximately 2,450 km^2, with a spatial overlap with the PFTIMF fished area of approximately 9.5%.
- Sauropod 3D MSS: approximately 1,950 km^2, with a spatial overlap with the PFTIMF fished area of approximately 2.0%; and
- Santos Keraudren Extension 3D MSS: approximately 2,700 km^2, with a spatial overlap with the PFTIMF fished area of approximately 6.5%.

Based on this more representative scenario, approximately 18%[28] of the PFTIMF fished area may be subject to interactions between seismic survey vessels and fishing vessels if all three surveys are conducted at the same time.

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.

Despite potential interactions with fishers resulting from 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 18% 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 the 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 7.1, 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.

TGS 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. TGS will notify fisheries stakeholders prior to the commencement of the survey and will provide regular updates to fishery licence holders during survey operations.

[28] Assumes that the TGS Capreolus-2 3D MSS occurs concurrently with the Sauropod 3D MSS.

7.2.2.3 Summary

Based on the assessment above and the implementation of the controls identified in Section 7.2.3, the consequence of occasional short-term and localised disturbance to receptors within the Operational Area is **Minor**, the likelihood of this consequence is **Unlikely** and the residual risk is considered to be **Low**.

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

7.2.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
No relevant legislation has been identified.	N/A	N/A
Good Industry Practice		
TGS will engage with proponents identified as having potential concurrent seismic activities within 40 km of the Capreolus-2 3D MSS.	Yes	TGS will engage with titleholder/operators of potential concurrent seismic activities prior to acquisition commencing, and will develop a concurrent operations plan or SIMOPs (if required). Good industry practice, environmental benefit outweighs additional cost.
A minimum separation distance of 40 km shall be maintained between the Capreolus-2 3D MSS seismic sources and other operating seismic sources.	Yes	The Bureau of Ocean Energy Management (BOEM 2014) published a final environmental review of geological and geophysical survey activities off the mid and South Atlantic coast. To minimise impacts to marine life by providing a 'corridor' between vessels, the environmental impact statement from this review included a requirement for a 40 km geographic separation distance (based on worst case scenarios) between the sources of simultaneous seismic surveys. As a precautionary approach, TGS has also adopted the 40 km separation distance. Implementation of this measure will reduce the risk of cumulative impacts occurring and also preserves seismic data quality. Good industry practice, environmental benefit outweighs additional cost.
If a separate petroleum activity is undertaken concurrently with the Capreolus-2 3D MSS and within the Operational Area, a simultaneous operations (SIMOPs) Plan will be developed and implemented.	Yes	A SIMOPs plan is a standard tool utilised in the petroleum industry to control vessel activities and minimise the risk of vessel collisions or other incidents, when multiple vessels/assets are operating in a manner in which their interactions require an increased degree of coordination and communication. Good industry practice, socio-economic benefit outweighs the additional cost.
Alternatives/Substitute Considered		
No practicable alternative or substitutes to the above controls have been identified.	N/A	N/A
Additional Controls Considered		

Control Measure	Control Adopted	Justification
TGS will not acquire the NWS Renaissance North 3D MSS and NWS Renaissance South 3D MSS concurrently with the Capreolus-2 3D MSS.	Yes	Implementation of this control would reduce the potential for cumulative impacts to occur as a result of multiple surveys being acquired by TGS. Environmental benefit outweighs additional cost.
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 Capreolus-2 3D MSS with the spawning areas and periods of commercial fish species is approximately 5.3% (based on a week of seismic acquisition). This represents the area that may be exposed to seismic sound at any one time during the survey. The total cumulative spatial-temporal overlap ranges from between 4.1% and 7.5% (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 survey plan for the Capreolus-2 3D MSS was determined taking into account: ■ the timing of key environmental and socio-economic receptors; ■ the hearing ability and sensitivity of those receptors to sound from the seismic survey; ■ the proximity of sensitive habitat areas to seismic survey areas; ■ the species distribution and range; ■ the level of overlap (in space and time) by the survey with important habitats and life stages of sensitive species; ■ species vulnerability / conservation status; and ■ the potential for impacts to species at both an individual level and at a population level; 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 pygmy blue whale migration periods.

Control Measure	Control Adopted	Justification
		It is important to note, the southern zone (water depth between 50 m to 80 m) of the Acquisition Area will be acquired during April to May, which reduces the number of days of acquisition during the peak spawning times for these species (within the species principal range). 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. The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of millions of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement.
Reduce temporal overlap with commercial fishing operations	No	Not justified. TGS would not be able to obtain the data for the identified hydrocarbon prospects being targeted. The Pilbara Demersal Scalefish Fisheries 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. It is important to note, TGS has minimised the overlap of the survey with the seasonality of the Mackerel Managed Fishery (MMF) in nearshore waters. TGS will only acquire the southern zone (depths between 50m – 80m) between April and May, primarily outside of the main fishing period for the MMF. The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of millions of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement.
Reduce survey area to decrease area of overlap with commercial fisheries.	No	Not justified. TGS would not be able to obtain the data for the identified hydrocarbon prospects being targeted. TGS has set an upper limit on the area (km^2) that can be acquired in any given calendar year.

Control Measure	Control Adopted	Justification
		It is important to note, TGS has minimised the overlap of the survey with the seasonality of the Mackerel Managed Fishery (MMF) in nearshore waters. TGS will only acquire the southern zone (depths between 50m – 80m) between April and May, primarily outside of the main fishing period for the MMF. It is not possible to entirely avoid acquisition during the peak mackerel fishing period due to other environmental sensitivities (i.e. humpback whale peak migration period (July to October) and internesting period for flatback turtles (October to March)). The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of millions of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement.
ALARP Statement		
The decision context has been assessed as ‘Type B’ and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impacts of cumulative seismic sound. As no reasonable additional or alternative controls were identified that would further reduce the impacts, without jeopardising the objectives of the survey, the impacts area considered to be ALARP.		

7.2.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing impacts from cumulative seismic sound, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines As described in Section 7.3.4, the activity will be undertaken in a manner consistent with the applicable objectives and actions of Conservation Advice, Recovery Plans or Guidelines No specific Conservation Advice, Recovery Plans or Guidelines have been identified for managing cumulative impacts from seismic sound.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs. The biological diversity and natural values of these AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological use of the AMPs.
	Relevant Persons Expectations	WAFIC raised concerns in regards to cumulative impacts from multiple seismic surveys on the NWS on commercial fisheries and commercial fish stocks. TGS acknowledges that multiple seismic surveys are planned to occur on the North West Shelf, which overlap with the boundaries of the same fisheries and commercial fish stocks that occur within the TGS Capreolus-2 3D MSS Acquisition Area. TGS is committed to working collaboratively with fishers and other seismic survey operators in order to minimise the potential for interactions between commercial fishers and seismic surveys. All 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 WAFIC. The impact is considered to be addressed and managed to acceptable levels.

Context	Factor	Demonstration
Legislation, Conventions & Other	Legal Requirements	The survey will be undertaken in accordance with section 280 of the OPGGS Act, which requires for the activity to be carried out in a manner that does not interfere with fishing or the resources of the sea, to a greater extent than necessary. Undertaking the Capreolus-2 3D MSS in a manner that does not interfere with fishing or fish resources to a greater extent than necessary is considered to be an acceptable level of impact.
Industry Standards	Industry Best Practice	The control measures adopted are in accordance with industry standards and best practice, including: ■ <u>IAGC Mitigation Measures for Cetaceans during Geophysical Operations</u>: ▪ activities will not have a significant effect on a cetacean population and specific management measures have been implemented. ■ <u>APPEA Code of Environmental Practice</u>: ▪ reduce impacts on cetaceans and other marine life to ALARP and acceptable levels with evidence that appropriate management measures are implemented according to legislation and that further studies and new knowledge were considered.
Ecological Sustainable 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 sound emissions from the Capreolus-2 3D MSS. The aspect and potential interactions are well understood and managed in accordance with applicable industry standards and industry good practice. Therefore, the impact is considered to be consistent with the principles of ESD.

Defined Acceptable Levels of Impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact	EPO #
Cetaceans Listed as Threatened or Migratory under the EPBC Act (Matters of NES)	■ 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.	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 pygmy blue whales, given: ■ Behavioural changes (e.g. avoidance) to pygmy blue whales are expected to be temporary and localised and affect transient individuals only. Potential TTS effects may also occur to a few individuals.	**EPO 1.1** **EPO 1.3** **EPO 2**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			■ Predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean that may be present within the Operational Area. ■ The seismic survey will be undertaken consistent with EPBC Act Policy Statement 2.1 Part A. ■ Adaptive management measures will be implemented in the event of 3 consecutive days with ⩾3 whale-instigated shutdowns. ■ No seismic acquisition will occur within 24 km of the defined migratory BIA for pygmy blue whales during the migration period. No significant discernible cumulative impacts to cetaceans are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 cetaceans normally travel. Whales will be able to continue to utilise migration routes/pathways without injury or displacement. Localised disturbances may occur when passing concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
	■ Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale).	Seismic survey activities are undertaken in a manner consistent with the requirements of the Approved 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.	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 humpback whales, given: ■ Behavioural changes (e.g. avoidance) to humpback whales are expected to be temporary and localised and affect transient individuals only. Potential TTS effects may also occur to a few individuals. ■ Predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean that may be present within the Operational Area. ■ 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 be undertaken consistent with EPBC Act Policy Statement 2.1 Part A. ■ Adaptive management measures will be implemented in the event of 3 consecutive days with $\geqslant$3 whale-instigated shutdowns. ■ No seismic acquisition will occur within the defined migratory BIA for humpback whales during the peak migration period.	**EPO 1.1** **EPO 1.3** **EPO 2**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			No significant discernible cumulative impacts to cetaceans are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 cetaceans normally travel. Whales will be able to continue to utilise migration routes/pathways without injury or displacement. Localised disturbances may occur when passing concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.	
	■ Approved Conservation Advice for Balaenoptera borealis (sei whale) ■ Approved Conservation Advice for Balaenoptera physalus (fin whale)	Seismic survey activities are undertaken in a manner consistent with the requirements of Conservation Advice for Balaenoptera borealis (sei whale) and Conservation Advice for Balaenoptera physalus (fin whale).	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 sei and fin whales, given: ■ Behavioural changes (e.g. avoidance) to whales are expected to be temporary and localised and affect transient individuals only. Potential TTS effects may also occur to a few individuals. ■ Predicted noise levels are not considered likely to cause injury (PTS) effects, or any ecologically significant impacts at a population level for any species of cetacean that may be present within the Operational Area.	**EPO 1.1** **EPO 1.3** **EPO 2**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			■ The seismic survey will be undertaken consistent with EPBC Act Policy Statement 2.1 Part A. ■ Adaptive management measures will be implemented in the event of 3 consecutive days with ⩾3 whale-instigated shutdowns. No significant discernible cumulative impacts to cetaceans are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 cetaceans normally travel. Whales will be able to continue to utilise migration routes/pathways without injury or displacement. Localised disturbances may occur when passing concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.	
Marine Turtles Listed as Threatened or Migratory under the EPBC Act (Matters of NES)	■ Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017).	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	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 turtles, given: ■ Behavioural disturbances to turtles are expected to be temporary and localised and affect a relatively small number of the species. These disturbances are not	**EPO 1.1** **EPO 1.3** **EPO 2**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
		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.	expected to affect a significant proportion of populations in the Pilbara region or occur in habitat of any particular significance to key life stages. ■ The survey is not expected to result in the decreased availability of prey items and is not expected to result in the displacement of turtles from foraging BIAs. Therefore, the survey is not expected to indirectly impact the viability of any turtle stocks. ■ No seismic acquisition will occur within the defined internesting BIA and Habitat Critical area during the nesting period (October – March). ■ Soft-starts (as well as pre-start observations and shut-down procedures) will be implemented for marine turtles. No significant discernible cumulative impacts to marine turtles are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 turtles normally travel. Localised disturbances may occur when passing the concurrent seismic surveys, however these	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			isolated incidents of disturbance are not expected to result in significant impacts.	
Whale Sharks Listed as Threatened and Migratory under the EPBC Act (Matters of NES)	■ Conservation Advice for *Rhincodon typus* (Whale Shark) ■ Whale Shark Wildlife Management Program no. 57 (DPaW 2013).	Seismic survey activities are undertaken in a manner consistent with the requirements of Conservation Advice for Rhincodon typus (Whale Shark).	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 whale sharks given: ■ Minor and temporary behavioural changes to whale sharks such as avoidance are expected to be temporary and localised and affect a relatively small number of the species. ■ Pre-start observations and shut-down procedures will be implemented for whale sharks. ■ 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 or previously in force Whale Shark Recovery Plan 2005 – 2010 (DEH 2005). Noise pollution is also not identified as a pressure to whale sharks in the Marine Bioregional Plan for the NWMR (DSEWPaC 2012). No significant discernible cumulative impacts to whale sharks are expected, given the minimum separation distance of 40 km between the	**EPO 1.1** **EPO 1.3** **EPO 2**

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			Capreolus-2 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 turtles normally travel. Localised disturbances may occur when passing the concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.	
Other 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 a manner consistent 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[29] on a listed threatened or migratory species population or a listed threatened ecological community; and ■ 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 or more seismic surveys and their separate sound fields are acknowledged, however, no significant impacts, mortality or injury are expected.	**EPO 1.1** **EPO 2**

[29] The definition of 'significant impact' is as per the defined criteria in the 'Matters of National Environmental Significance: Significant Impact Guidelines 1.1 (Commonwealth of Australia 2013)'.

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			No significant discernible cumulative impacts to marine fauna are expected, given the minimum separation distance of 40 km between the Capreolus-2 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 turtles normally travel. Localised disturbances may occur when passing the concurrent seismic surveys, however these isolated incidents of disturbance are not expected to result in significant impacts.	
Marine Fauna or Ecological Communities not Listed as Threatened or Migratory under the EPBC Act (not matters of NES)	■ Principles of ESD, specifically no serious or irreversible damage.	No serious [30] 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; and ■ 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).	**EPO 1.2** **EPO 2**

[30] In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, TGS 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 'Massive' or greater.

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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 and Glomar Shoal KEF are not predicted to be altered. ■ 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 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 and Glomar Shoal 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	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			the seismic survey on the spawning biomass of the various stocks is 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 and Glomar Shoal 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 or more seismic surveys and their separate sound fields	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			are acknowledged, however, no serious or irreversible impacts are expected.	
Commercial Fisheries and Commercial Fish Stocks	Commercial fisheries stakeholders raised objections, claims and concerns regarding: ■ effects of seismic sound on key indicator commercially targeted finfish and invertebrate stocks, specifically spawning; and ■ effects of seismic sound on fish behaviour and commercial catch levels. Commercial fisheries and fish stocks 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 2014-2018 FishCube data);	<u>Commercial Fisheries:</u> 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; and ■ 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 annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts). <u>Commercial Fish Stocks:</u> Seismic activities are undertaken in a manner that does not result in serious[31] or irreversible impacts to key indicator commercial fish populations, such that sufficient spawning fish biomass and recruitment of the stocks may be	<u>Commercial Fisheries</u> 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 commercial fisheries given that: ■ The level of interference TGS 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 scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017/18 exceeding the Department's defined acceptable catch range, 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 fisheries management objectives for sustainability and consistent with the principles of ESD. ■ A maximum of 18% of the PFTIMF fished area may be subject to seismic survey activities at one time, based on the	**EPO 1.5** **EPO 2**

[31] In the absence of a definition for 'serious' environmental damage in relation to the Principles of ESD under the EPBC Act, TGS 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 'Massive' or greater.

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
	■ DPIRD (2019c) key indicator fish species ' spawning information; ■ Key indicator fish species ' stock status and annual performance reviews, as reported by DPIRD in the annual Status of the Fisheries reports; ■ Other DPIRD and FRDC publications and summaries (various, as referenced in this EP).	maintained and the stocks continue to be assessed by DPIRD as Sustainable[32].	maximum credible cumulative 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 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. ■ 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). <u>Commercial Fish Stocks</u> 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 commercial fish stocks given that: ■ The high fecundity and broadcast spawning characteristics of key demersal and pelagic	

[32] It is a legislated function of DPIRD to annually report the status of the WA fisheries and fish stocks to WA Parliament and so the status and trends can be considered over time.

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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 (<7.5%) with the key fish stocks during any spawning season is expected to be negligible in the context of natural variability in spawning biomass and recruitment (250 - 350%); ■ Key indicator species in the 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	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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; and ■ 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. The cumulative effects of seismic surveys is not expected to result in any direct reduction in the	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			spawning biomass through fish mortalities, and the potential spatial-temporal overlap of the survey with spawning fish stocks will be minor (<7.5%), 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. Therefore, the survey is not expected to result in a serious or irreversible impact to the sustainability of key indicator commercial fish stocks.	
Marine Protected Areas	■ North-west Marine Parks Management Plan 2018.	Seismic activities are undertaken in a manner consistent with the requirements of the North-west Marine Parks Management Plan 2018.	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. No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs, as a result of concurrent seismic surveys.	**EPO 1.4** **EPO 2**

Acceptability Statement
Impacts and risks classified as '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. Based on the evaluation above, TGS considers the adopted control measures appropriate to manage the impacts of underwater noise emission from the seismic source to be of an acceptable level.

7.2.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 2 Multiple seismic surveys do not occur concurrently in the same location, with a minimum separation distance of 40 km maintained between the Capreolus-2 3D MSS seismic source and other operating seismic sources.	**2.1** **2.2** **2.3** **2.4**

7.3 Noise Emissions: Vessels, Helicopter and Mechanical Equipment

7.3.1 Assessment Summary

Source of Impact / Risk	
Generation of noise emissions from vessels (seismic and support), helicopters and mechanical equipment during routine operations has the potential to cause disturbance to marine fauna and seabirds.	
Receptors	
■ Marine mammals; ■ Marine turtles; ■ Whale sharks; and ■ Marine birds.	
Summary of Impacts and Risks	
Given there are no high energy impulsive sound sources associated with the routine operation of helicopters and 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. Some transient marine fauna individuals may avoid the immediate proximity of a vessel, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations. Some minor behavioural disturbance may occur for short periods if marine fauna are present near the surface in the vicinity of helicopters landing on the seismic vessel. This would be limited to a temporary change in behaviour due to avoidance of the area, but is not expected to have any longer term impacts.	
Decision Content	
A	The decision context for noise emissions from vessels, helicopters and mechanical equipment has been assessed as 'Type A', given the impacts are well understood and uncertainty is minimal, with little or no stakeholder interest.

Adopted Control Measures	**EPS #**
Vessel activities will be undertaken in accordance 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; and ■ not exceeding a speed of 6 knots within the caution zone of a cetacean (300 m).	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; and ■ helicopters not to approach a cetacean from head on.	3.2
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 or dugong; and ■ not exceeding a speed of 6 knots within 300 m of a turtle or dugong.	3.3

Vessels (taking into account the limited manoeuvrability of a seismic vessel) will also adopt measures consistent with the DPaW Whale Shark Management Program (2013), including: ■ taking action to avoid approaching or drifting closer than 30 m of a whale shark; and ■ not exceeding 8 knots within 250 m of a whale shark.			3.4
Vessel engines and mechanical equipment maintained according to manufacturer's specifications.			3.5
Crew, survey personnel and MFOs will be briefed in the marine fauna observation, management controls and reporting requirements relevant to this EP.			3.6
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Slight	Unlikely	**Low**
Residual Risk	Slight	Unlikely	**Low**

7.3.2 Detailed Evaluation of Impacts / Risks

A seismic vessel and two support vessels (one supply and one chase) will be employed for the survey. Vessel noise comprises a combination of continuous noise generated by engine and machinery noise, and modulated, broadband noise produced by propeller rotation and cavitations (Richardson et al. 1995; Southall 2007; Jensen et al. 2009; Wales & Heitmeyer, 2002; Hildebrand, 2009). Vessel noise emissions varies with the size, speed, and engine type and the activity being undertaken. Noise levels for a range of vessels have been measured at 164-182 dB re µPa at 1 m (SPL) at dominant frequencies between 50 Hz and 7 kHz (Wyatt 2008; Simmonds et al. 2004).

In addition, a helicopter may be employed for the survey for the purpose of crew changes. Crew changes are expected to occur every 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.

As described in Section 7.1, 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); and
- Through disturbance leading to behavioural changes or displacement from important areas.

Given there are no high energy impulsive sound sources associated with the routine operation of vessels, physiological effects on marine fauna are not anticipated.

There may be some localised behavioural disturbance of marine fauna in the immediate vicinity of vessels during operations. 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). Some transient marine fauna individuals may 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.

Any avoidance or attraction behaviours displayed are expected to be localised and temporary, based on the limited duration of the survey. 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 helicopters landing on the seismic vessel. This would be limited to a temporary change in behaviour due to avoidance of the area, but is not expected to have any longer term impacts.

7.3.2.1 Marine Mammals

As described in Section 4.5.7, five threatened and migratory, and seven migratory marine mammals were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the Operational Area. In addition, the Operational Area overlaps with the humpback whale migration BIA and pygmy blue whale migration and distribution BIAs. Therefore, marine mammals may be present within the Operational Area during the survey.

No seismic acquisition will occur within the pygmy blue whale migration BIA during migration periods (April – August and October – December), and no seismic acquisition will occur within the humpback whale migration BIA during peak migration periods (July – October).

Noise generated by vessels would not exceed levels that could cause permanent or temporary injury to protected migratory whale species or other marine species (refer to Section 7.1.2 for injury thresholds).

Marine mammals are expected to exhibit avoidance or attraction behaviours in the immediate vicinity of vessel operations. This would be a limited and temporary change in behaviours, but is not expected to have any longer term impacts. Some transient individuals may avoid the immediate proximity of a vessel, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations.

7.3.2.2 Marine Turtles

As described in Section 4.5.6, 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. There are several BIAs for turtle species in the region. The Operational Area overlaps with an internesting BIA and habitat critical area for the flatback turtle species.

No seismic operations will occur with the flatback turtle internesting BIA and habitat critical area, during nesting season (October – March).

Marine turtles are expected to exhibit avoidance or attraction behaviours in the immediate vicinity of vessel operations. This would be a limited and temporary change in behaviours, but is not expected to have any longer term impacts. Some transient individuals may choose to avoid the immediate proximity of a vessel, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations.

7.3.2.3 Whale Sharks

As described in Section 4.5.6, the Operational Area overlaps with the whale shark foraging BIA, which extends northwards from Ningaloo along the 200 m isobath. The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November). Therefore, the species may be encountered within the Operational Area during the survey.

Whale sharks are expected to exhibit avoidance or attraction behaviours in the immediate vicinity of vessel operations. This would be a limited and temporary change in behaviours, but is not expected to have any longer term impacts. Some transient individuals may avoid the immediate proximity of a vessel, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations.

7.3.2.4 Marine Birds

As described in Section 4.5.9, five threatened, four threatened and migratory, and 25 migratory marine birds were identified by a search of the EPBC Act Protected Matters Database as potentially occurring in the Operational Area. In addition, several biologically important areas for marine bird species have been identified overlapping the Operational Area (refer to Section 4.5.9).

Impacts to foraging and migratory seabirds have not been observed previously during seismic surveys. Some minor behavioural disturbance may occur for short periods if seabirds are present in the vicinity of helicopters and/or vessels. 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. Some transient individuals to avoid the immediate proximity of a vessel, but this is not expected to have any widespread or longer-term impacts on their behaviour or populations.

7.3.2.5 Summary

Based on the assessment above and the implementation of the controls identified in Section 7.3.3, the consequence of occasional short-term and localised disturbance to marine fauna is **Slight**, the likelihood of this consequence occurring is **Unlikely** and the residual risk is considered to be **Low**.

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

7.3.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Vessel activities will be undertaken in accordance 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; and ■ not exceeding a speed of 6 knots within the caution zone of a cetacean (300 m).	Y	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 Regulations 2000.
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; and ■ helicopters not to approach a cetacean from head on.	Y	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 Regulations 2000.
Good Industry Practice		
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 or dugong; and ■ not exceeding a speed of 6 knots within 300 m of a turtle or dugong.	Y	In addition to implementing avoidance measures for cetaceans, TGS has considered extending the prescribed avoidance measures to turtles and dugong. Good industry practice, environmental benefit outweighs additional cost.

Control Measure	Control Adopted	Justification
Vessels (taking into account the limited manoeuvrability of the seismic vessel) will also adopt measures consistent with the DPaW Whale Shark Management Program (2013), including: ▪ taking action to avoid approaching or drifting closer than 30 m of a whale shark; and ▪ not exceeding 8 knots within 250 m of a whale shark.		In addition to implementing the EPBC Regulations 2000 for cetaceans, TGS has extended the avoidance measures to whale sharks. Good industry practice, environmental benefit outweighs additional cost.
Vessel engines and mechanical equipment maintained according to manufacturer's specifications.	Y	Maintaining engines and mechanical equipment to the manufacturer's specifications will ensure the relatability of the equipment and therefore reduce excess noise emissions. Good industry practice, environmental benefit outweighs additional cost.
Crew, survey personnel and MFOs will be briefed in the marine fauna observation, management controls and reporting requirements relevant to this EP.	Y	Crew survey personnel and MFOs will be briefed in marine fauna observations (i.e. identification), management controls and EP reporting requirements. Good industry practice, environmental benefit outweighs additional cost.
Alternatives/Substitute Considered		
No helicopter transfers.	N	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.
Additional Controls Considered		
Extend the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for helicopters to turtles, whale sharks and dugongs.	N	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.

Control Measure	Control Adopted	Justification
		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 marine fauna is impractical, unnecessary and disproportionate to the limited additional benefit it may provide to reducing the already low level of risk.
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impacts of noise emissions from vessels, helicopters and mechanical equipment. As 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.		

7.3.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk	The residual risk has been assessed to be low.
Internal	Company Policy	The risk management strategy for managing noise emissions from vessels, helicopters and mechanical equipment, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines The activity will be undertaken in a manner consistent with the applicable objectives and actions of the following species conservation or recovery plans, threat abatement plans, and conservation advice: ■ Conservation Management Plan for the Blue Whale - The Conservation Management Plan recognises noise interference (anthropogenic) as a threat to blue whales. With the implementation of EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') and restrictions on seismic operations within the pygmy blue whale migration BIA, no disturbance or injury to blue whales is expected and the level of impact is considered to be acceptable. ■ Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) – The Conservation Advices recognises noise interference (anthropogenic) as a threat to humpback whales. With the implementation of EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') and restrictions on seismic operations within the migration BIA (during migration periods), no disturbance or injury to humpback whales is expected and the level of impact is considered to be acceptable. ■ Conservation Advice for sei and fin whales - The Conservation Advices for both species does not specify required standards for managing vessel noise emissions. With the implementation of EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') and the lack of foraging, migration and distribution BIAs within the Operational Area, no disturbance or injury to sei and fin whales is expected and the level of impact is considered to be acceptable. ■ Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017): - 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 nesting season. This supports a defined level of acceptable impact

Context	Factor	Demonstration
		for vessel noise impacts to marine turtles, whereby the seismic survey shall not take place within internesting BIAs or habitats critical to the survival of turtle species during nesting/internesting periods. Given that the Capreolus-2 3D MSS will not be acquired within the flatback turtle internesting BIA during nesting periods (October – March), no disturbance to turtles in these areas is expected and the level of impact and risk to marine turtles is considered to be acceptable. - The Recovery Plan also recognises that activities resulting in impacts to foraging habitats may indirectly contribute to a decreased viability of multiple stocks by reducing food availability. The survey is not expected to result in the displacement of turtles from foraging BIAs. Therefore, the survey is not expected to indirectly impact the viability of any turtle stocks and the level of impact and risk to marine turtles is considered to be acceptable. ■ <u>Whale shark – wildlife management program no. 57 (DPaW 2013)</u> - The management plan identifies vessel noise as an existing and potential pressure facing whale sharks, however the management program does not extend to seismic surveys. Given the conservation status of whale sharks and that disturbance to whale sharks is a focus of the wildlife management program, TGS considers the level of impact and risk to whale sharks to be acceptable if practicable measures are put in place, to prevent injury and reduce the potential for disturbance. Control measures include speed and proximity restrictions, therefore, no injury is expected, the potential for disturbance is limited and the level of impact and risk is considered to be acceptable.
		<u>AMP Values, Management Prescriptions and IUCN Reserve Management Principles</u> No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs. The biological diversity and natural values of these AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological use of the AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to noise emissions from vessels, helicopters and mechanical equipment. The impact is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	The requirements of the EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') will be implemented.
Industry Standards	Industry Good Practice	Control measures adopted are complaint with industry standards and best practice: ■ <u>IAGC Environmental Manual for Worldwide Geophysical Operations:</u> ▪ Ensure vessel noise emissions are kept to appropriate levels.

Context	Factor	Demonstration
		■ APPEA Code of Environmental Practice: ▪ Reduce impacts on cetaceans and other marine life to ALARP and acceptable levels.
Ecological Sustainable 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 the vessels, helicopters and operation of mechanical equipment during the survey. The aspect and potential interactions are well understood and managed in accordance with applicable industry standards and industry good practice. Therefore, the impact is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impacts of noise emissions from vessels, helicopters and mechanical equipment to be of an acceptable level.		

7.3.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 3 Vessel and helicopter activities are undertaken in accordance with Part 8 of the EPBC Regulations 2000.	**3.1** **3.2** **3.3** **3.4** **3.5** **3.6**

7.4 Physical Presence: Interference with Commercial Fisheries

7.4.1 Assessment Summary

Source of Impact / Risk

Potential disruption/interference with commercial fisheries associated with the physical presence of the seismic survey vessel, in-water equipment and support vessel(s) in the Operational Area.

The seismic survey vessel will typically move along pre-determined sail lines at a constant speed of approximately 4.5 knots and will proactively and collaboratively manage operational information between the seismic survey vessel and commercial fishers located in the Operational Area. This section discusses the potential interference with commercial fisheries from the survey. Impacts to other marine users are discussed in Section 7.5.

Receptors

- Commercial Fishing.
  - Mackerel Managed Fishery (WA)
  - North West Slope Trawl Fishery (Cth)
  - Pilbara Fish Trawl Interim Managed Fishery (WA)
  - Pilbara Trap Managed Fishery (WA)
  - Pilbara Line Managed Fishery (WA)

Summary of Impacts and Risks

The limited manoeuvrability of the seismic survey vessel means that commercial fishing vessels may be asked to take measures to avoid the immediate vicinity of the seismic survey vessel and associated equipment. Typically, marine users are requested to provide a wide berth of 3.0 nm (5.5 km) ahead and on either side of the seismic vessel, and 6.0 nm (11 km) astern of the vessel.

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

Alternative fishing grounds are available to commercial fishers, including other sites near to the Operational Area (based on historic data). Commercial fishing vessels may be asked to deviate from intended fishing grounds, or remove fishing gear to accommodate seismic survey operations.

Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing ground within the Operational Area. However, such interactions are expected to be infrequent and short term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time. TGS will work collaboratively with fishers to ensure interactions offshore are minimised.

Decision Content

B	The decision context for physical presence: interference with commercial fisheries has been assessed as 'Type B', given the level of interest and nature of issues raised by fisheries stakeholders during consultation. The following assessment, therefore, provides a qualitative evaluation of the potential impacts. Consideration has been given to the cost and benefit of control measures that can be practicably implemented to reduce the potential impacts and risks to ALARP.

Adopted Control Measures	EPS #

Notification to fisheries stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within 2 weeks of survey completion.	4.1
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	4.2
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	4.3
Daily look-ahead reports will be provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	4.4
Access to seismic survey vessel tracking information via Google Earth for fisheries stakeholders who have registered for the service.	4.5
The seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel and providing TGS is afforded a reasonable opportunity to complete the survey in a timely and efficient manner.	4.6
All evidence-based compensation claims made by commercial fishing licence holders or vessel crews for equipment damage/loss will be assessed for merit in accordance with the TGS Fisheries Compensation Process (Appendix H).	4.7
Seismic survey vessel will adhere to the 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.	4.8
At least one support vessel (supply or chase vessel) will accompany the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods) to manage interactions with marine users.	4.9
No recreational fishing activities will occur from any activity vessels during survey operations.	4.10
Acquisition will be limited to a maximum of 10,000 km^2 per calendar year.	4.11
Streamers will be marked with tail buoys (fitted with virtual or installed AIS).	4.12

Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Minor	Possible	**Medium**
Residual Risk	Minor	Unlikely	**Low**

7.4.2 Detailed Evaluation of Impacts / Risks

The seismic survey vessel will typically move along pre-determined sail lines at a constant speed of approximately 4-5 knots and will proactively and collaboratively manage operational information between the seismic survey vessel and support vessel(s), and commercial fishers. The survey will adhere to the requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea Convention (SOLAS) as implemented in Commonwealth waters through the *Navigation Act 2012* and associated Marine Orders Parts 21, 27, 30, 58 - safety and emergency arrangements, prevention of collisions, safe management of vessels.

The likelihood of direct interactions between the seismic survey vessel and commercial fishing vessels in the Operational Area will be reduced through the required use of appropriate navigational lighting and shapes, communication channels and procedures, use of radar and implementation of 24/7 watch on board to keep other users of the area aware of the vessel's position.

The limited manoeuvrability of the seismic survey vessel means that commercial fishing vessels may be asked to take measures to avoid the immediate vicinity of the seismic survey vessel and associated equipment. In addition, commercial fishing vessels may be asked to remove fishing gear such as traps and lines to avoid interaction with the seismic survey vessel and in-water equipment. Typically, other users are requested to provide a wide berth of 3.0 nm (5.5 km) ahead and on either side of the seismic vessel, and 6.0 nm (11 km) astern of the vessel.

A support vessel will be employed for the survey to ensure that fishing vessels are informed and aware of the seismic activities.

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

There are a number of Commonwealth and WA managed commercial fisheries that have historically had catch effort within the Operational Area (refer to Section 4.6.7). An analysis has been conducted to determine the area of overlap with historic fishing activity (effort). Accounting for the entire Operational Area is a highly conservative approach and simply provides an indication of the total area that may be surveyed and where there is potential for interactions with fishers to occur. This is conservative because the seismic survey vessel will only be operating in part of the survey area at any one time. Therefore, the spatial overlap 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 (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 as result of the Capreolus-2 3D MSS is approximately 2,450 km^2.

Based on the approach mentioned above, an analysis has been conducted to determine the area of overlap of historic fishing activity (effort) and the extent of disturbance based on a week of seismic acquisition (refer to Table 7-24). The spatial overlap ranges from 1.6% (PLMF) to 9.5% (PFTIMF). It is concluded that up to a maximum 9.5% of the area of fishing effort for these fisheries may be occupied by seismic survey activities at any one time during the survey.

Table 7-24 Spatial of the 7-Days of Acquisition Lines with Fishing Effort for Relevant Commercial Fisheries

Relevant Commercial Fisheries	Area of Fishing Effort (km^2)*	Maximum Potential Spatial Overlap from the Capreolus-2 3D MSS**	
		Overlap (km^2)	%
North West Slope Trawl Fishery	126,082	2,450	1.9%
Pilbara Fish Trawl (Interim) Managed Fishery	25,922	2,450	9.5%
Pilbara Trap Managed Fishery	116,804	2,450	2.1%

Relevant Commercial Fisheries	Area of Fishing Effort (km^2)*	Maximum Potential Spatial Overlap from the Capreolus-2 3D MSS**	
		Overlap (km^2)	%
Pilbara Line Managed Fishery	153,198	2,450	1.6%
Mackerel Managed Fishery	50,571	2,031	4.0%

Assessment of potential impacts to each of the fisheries presented in Table 7-24 is provided in the sections below.

7.4.2.1 North West Slope Trawl Fishery

FishCube data is not available for Commonwealth-managed fisheries. Fishing effort in the fishery is known to occur along the northern edge of the Operational Area in water depths greater than 200 m. Typically, effort is concentrated along the slope offshore from the Pilbara region, in the Rowley Shoals area and north-east towards and around Scott Reef. The key target species, Australian scampi, is commonly associated with *Globigerina* ooze sediments at depths of approximately 420 m to 500 m depth (Holthuis 1991; Australian Faunal Directory 2008; AFMA 2019), consistent with the water depths within the Special Purpose (Trawl) Zone of the Argo-Rowley Terrace AMP located north-east of the Operational Area.

The Operational Area overlaps with approximately 16,552 km^2 (13.1%) of the area of fishing effort[33] in the 2017-18 fishing season. Fishing effort is based on the information presented in the ABARES Fishery Status Report 2019. 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 presented in the ABARES Fishery Status Report 2019.

A more realistic but conservative approach is to consider the area of overlap of fishing effort with the extent of disturbance based on a week of seismic acquisition (as presented in Table 7-24). Therefore, up to 1.9% of the NWSTF may be occupied by seismic survey activities at any one time during the survey.

The number of vessels involved in the fishery has been one or two vessels each year since 2008/2009. Two vessels were active in the fishery during the 2016-17 fishing season over 114 days of fishing effort. In the 2017-2018 fishing season, four vessels were active over 219 days of fishing effort. The total catch for the 2017-2018 fishing season was 79.7 tonnes.

Fishing effort occurs across the entire year with no identified peak periods.

Alternative fishing grounds are available to commercial fishers, including other sites near to the Operational Area (based on historic data). Vessels operating in the fishery predominately use demersal trawl gear and are restricted in their ability to manoeuvre. Vessels may be asked to deviate from intended fishing grounds to accommodate seismic survey operations.

Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from established fishing grounds (in the northern zone of the Acquisition Area). However, such interactions are expected to be infrequent and short term due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time. TGS will work collaboratively with fishers to ensure interactions offshore are minimised.

[33] The area of fishing effort is based on the information presented in the ABARES Fishery Status Report 2019.

7.4.2.2 Pilbara Demersal Scalefish Fisheries

Pilbara Fish Trawl Interim Managed Fishery

Analysis of FishCube data (refer to Section 4.6.7) shows that the area of fishing effort over the West Australian coast is 25,922 km^2 for the period between 2014 and 2018. The Operational Area overlaps with approximately 14,364 km^2 (55.4%) of the area of fishing effort.

A more realistic but conservative approach is to consider the area of overlap of fishing effort with the extent of disturbance based on a week of seismic acquisition (as presented in Table 7-24). Therefore, up to 9.5% of the PFTIMF may be occupied by seismic survey activities at any one time during the survey.

One or two vessels were active in the fishery in 2014, 2015 and 2017, three vessels were active in 2016 and four vessels were active in 2018. In 2018, the fishery accounted for approximately 75% of the total catch from the Pilbara Demersal Scalefish Fisheries (PFTIMF, PTMF and PLMF).

FishCube data showed that up to three vessels were active in this fishery in 2018. Two trawl fishing operators are understood to operate across the entire fishery.

FishCube data for annual fishing effort in blocks within the Operational Area (for blocks where at least three vessels have fished and data is available) ranges from 7 days to 123 days per year between 2014 and 2018, with an average of 36 days per 10 nm block per year (refer to Figure 4.28).

Fishing effort occurs relatively consistently across the year with no identified peak periods.

Alternative fishing grounds are available to commercial fishers, including other sites nearby to the Operational Area (based on historic data). Vessels operating in the fishery predominately use trawl gear and are restricted in their ability to manoeuvre. Commercial fishers may be asked to deviate from fishing grounds periodically to accommodate seismic survey operations.

Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time. TGS will work collaboratively with fishers to ensure interactions offshore are minimised.

Pilbara Trap Managed Fishery

Analysis of FishCube data (refer to Section 4.6.7) shows that the area of fishing effort over the West Australian coast was 116,804 km^2 for the period between 2014 and 2019. The Operational Area overlaps with 16,681 km^2 (14.3%) of the area of fishing effort. FishCube data for the Pilbara Trap Managed Fishery 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 CAES blocks.

A more realistic but conservative approach is to consider the area of overlap of fishing effort with the extent of disturbance based on a week of seismic acquisition (as presented in Table 7-24). Therefore, up to 2.1% of the PTMF may be occupied by seismic survey activities at any one time during the survey.

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 3 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 up to three vessels have typically operated in the Operational Area each year for the last 5 years (2014 - 2018), compared with greater fishing effort located to the south and south-west of the Operational Area, between Exmouth and Dampier (up to five vessels operating).

FishCube data for annual fishing effort in blocks within the Operational Area (for blocks where at least three vessels have fished and data is available) ranges from 19 days to 145 days per year between 2014 and 2018, with an average of 36 days per 60 nm block per year (refer to Figure 4.32).

Fishing effort occurs relatively consistently across the year with no identified peak periods.

Alternative fishing grounds are available to commercial fishers, including other sites nearby to the Operational Area (based on historic data). Vessels operating in the fishery predominately use demersal traps, which are set near or on the sea floor and marked with buoys. Commercial fishers may be asked to remove, alter locations or delay deployment of traps to accommodate seismic survey operations.

Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time. TGS will work collaboratively with fishers to ensure interactions offshore are minimised.

Pilbara Line Managed Fishery

Analysis of FishCube data (refer to Section 4.6.7) shows that the area of fishing effort over the West Australian coast is 153,198 km^2 for the period between 2014 and 2018. The Operational Area overlaps with 24,205 km^2 (15.8%) of the area of fishing effort. 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 CAES blocks.

A more realistic but conservative approach is to consider the area of overlap of fishing effort with the extent of disturbance based on a week of seismic acquisition (as presented in Table 7-24). Therefore, up to 1.6% of the PLMF may be occupied by seismic survey activities at any one time during the survey.

The available FishCube data indicates a low level of activity in relation to the trawl sector of the Pilbara Demersal Scalefish Fisheries (mentioned above), with less than 3 vessels typically active across the fishery. FishCube data shows that one or two vessels operated within the Operational Area over the last five years. In 2018, the PLMF accounted for 4% of the total catch for the Pilbara Demersal Scalefish Fisheries (refer to Section 4.6.7)

FishCube data reports that one or two vessels have operated in the Operational Area each year for the last 5 years (2014 to 2018), compared with greater fishing effort located to the west of the Operational Area, between Exmouth and Dampier. The available FishCube data indicates a low level of fishing activity in relation to the PFTIMF (mentioned above).

FishCube data for annual fishing effort in blocks within the Operational Area (for blocks where at least three vessels have fished and data is available) ranges from 4 days to 214 days per year between 2014 and 2018, with an average of 84 days per 60 nm block per year (refer to Figure 4.30).

Fishing effort occurs relatively consistently across the year with no identified peak periods.

Alternative fishing grounds are available to commercial fishers, including other sites nearby to the Operational Area (based on historic data). Vessels operating in the fishery predominately use demersal (bottom) longlines, which are set horizontally along the ocean floor (up to kilometres long) held in place with anchors and marked with buoys. Commercial fishers may be asked to remove, alter locations or delay deployment of the fishing gear to accommodate seismic survey operations.

Commercial fishing vessels may potentially experience operational inconvenience and temporary displacement from fishing grounds within the Operational Area. However, such interactions are expected to be infrequent and short term due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time. TGS will work collaboratively with fishers to ensure interactions offshore are minimised.

7.4.2.3 Mackerel Managed Fishery

Analysis of FishCube data (refer to Section 4.6.7) shows that the area of fishing effort in the Pilbara region of the MMS (Area 2) covers 50,571 km^2 for the five-year period between 2014 and 2018. The Operational Area overlaps with 5,110 km^2 (10.1%) of this fished area.

A more realistic but conservative approach is to consider the area of overlap of fishing effort with the extent of disturbance based on a week of seismic acquisition (as presented in Table 7-24). Therefore, up to 4.0% of the MMF may be occupied by seismic survey activities at any one time during the survey.

Fishing effort is restricted to the southern portion of the Operational Area in water depths less than 70 m. The FishCube data also shows that the number of fishing vessels operating in the 10 nm blocks overlapping the Operational Area in the last five years was typically limited to one or two vessels (with the exception of a single 10 nm block at Glomar Shoals).

It is noted that the MMF operate throughout the nearshore waters of the Pilbara and the vessel and gear types make them relatively mobile. Fishing effort is distributed along the Pilbara coast, with areas of significant effort located off Eighty Mile Beach, Port Hedland, Dampier, and near Barrow Island and the Montebello Islands. Alternative fishing grounds are available to MMF fishers, including other sites near to the Operational Area (based on historic fishing effort). Vessels operating in the fishery predominately use mobile fishing methods, trolling and handline. Commercial fishers may be asked to deviate from intended fishing grounds to accommodate seismic survey operations.

Fishing effort occurs year round, however typically takes place between May and November and is concentrated in waters less than 70 m. No seismic acquisition will occur within the southern zone (defined in Section 3.2) during June to March. Acquiring the southern zone in April and May minimise the temporal overlap with the peak fishing period for the MMF.

Based on a review of available data, MMF fishing vessels may potentially experience operational inconvenience and temporary displacement during the period when the seismic vessel is acquiring data in the southern zone of the Operational Area (during April and May). However, such interactions are expected to be infrequent and short-term, due to the transient nature of the seismic survey vessel and the small area occupied by the seismic survey vessel at any one time. TGS will work collaboratively with fishers to ensure interactions offshore are minimised.

7.4.2.4 Summary

There is a possibility that commercial fishing vessels will be displaced from the area, whilst the seismic vessel is conducting seismic acquisition. Disruptions to fishing operations are anticipated to be temporary and not significant for the following reasons:

- The fisheries overlapping the Operational Area typically cover wide spatial areas and alternative fishing grounds (including near the Operational Area) are available to commercial fishers.
- The transient nature of both the commercial fishing vessels and the seismic survey vessel means that an area is only temporarily unavailable to fishing. Only a small area (maximum of 9.5% of the area of historic fishing effort), will be temporarily unavailable to fishing operations at any one time during the survey.
- Notifications to fisheries licence holders via Notice to Mariners prior to survey commencement will enable pre-planning of fishing activities to avoid disruption.
- Radar detection systems and ongoing radio communications with licence holders will provide advanced and timely notice to fishers during operations.

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 2017/18 exceeding the Department's defined acceptable catch range. Given that the effort allocations are the same, Newman et al. (2019) suggests that the increased catch rates indicate that fishing effort reductions since 2008 have been effective and have resulted in increased fish abundance.

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).

It should be noted that the inherently broad nature of multi-client seismic acquisition programmes reduces the potential for future seismic acquisition to be required in areas actively targeted by commercial fisheries. This is because such multi-client surveys generate large, uniform datasets of geological information for access by oil and gas operators to further their understanding of the regional geology and support future petroleum exploration and production activity in the region over the medium to long term. Therefore, a multi-client survey approach reduces the long-term additional seismic activity in a given area by replacing the need for several seismic surveys to be conducted by individual petroleum titleholders.

Based on the assessment above and the implementation of the controls identified in Section 7.4.3, the consequence of localised and temporary disruptions to commercial fishers within the Operational Area is **Minor**, the likelihood of this consequence is **Unlikely** and the residual risk is considered to be **Low**.

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

7.4.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Seismic survey vessel will adhere to the 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 Capreolus-2 3D MSS are required to comply with the *Navigation Act 2012*. Tail buoys will be used to mark the ends of the streamers so that they can be detected by other vessels.
Good Industry Practice		
Notification to fisheries stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification will also be provided to fisheries stakeholders within 2 weeks of survey completion.	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 commercial fisheries. Good industry practice, socio-economic benefit outweighs the additional cost.
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Yes	AHS will be contacted 4 weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure that commercial fishers are aware of the survey. Implementation will reduce the likelihood of interactions with commercial fishing vessels. Good industry practice, socio-economic benefit outweighs the additional cost.
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Yes	The AMSA JRCC will be contacted 24-48 hrs before operations commence for issuing of radio-navigation warnings. This will ensure that commercial fishers are aware of the survey. Implementation will reduce the likelihood of interactions with commercial fishing vessels. Good industry practice, socio-economic benefit outweighs the additional cost.

Control Measure	Control Adopted	Justification
Daily look-ahead reports will be provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Yes	TGS will provide fisheries stakeholders with a daily look-ahead report, detailing the upcoming activities and planned seismic survey location within the next 72 hours. As part of this report, TGS will request information from commercial fishers on upcoming fishing activities for the next 24-72 hours. This will allow the seismic survey vessel to consider alternative lines, where practicable. Good industry practice, socio-economic benefit outweighs the additional cost.
At least one support vessel (supply or chase vessel) will accompany the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with marine users.	Yes	A support vessel will conduct advanced scouting when safe to do so (e.g. outside of inclement weather periods) to ensure that commercial fishers in the area are provided with advance notice of seismic activities. Good industry practice, socio-economic benefit outweighs the additional cost.
Streamers will be marked with tail buoys (fitted with virtual or installed AIS).	Yes	Tail buoys will be used to mark ends of the streamers, so that they are visible to other vessels. Implementation will reduce the likelihood of interactions with commercial fishing vessels. Good industry practice, socio-economic benefit outweighs the additional cost.
Alternatives/Substitute Considered		
No practicable alternative or substitutes to the acquisition or the good practice controls have been identified.	N/A	N/A
Additional Controls Considered		
Access to seismic survey vessel tracking information via Google Earth for fisheries stakeholders who have registered for the service.	Yes	TGS will provide commercial fishers with access to seismic survey tracking information via Google Earth. This will ensure that commercial fishers are aware of the exact location the seismic survey vessel in real time. Implementation will reduce the likelihood of interactions with commercial fishing vessels. Socio-economic benefit outweighs the additional cost.
The seismic survey vessel will change sail lines to accommodate commercial fishers requests, if it is feasible to do so, providing there is open and advanced communication between the seismic survey and commercial fishing vessel.	Yes	Implementation of this control will reduce the likelihood of interactions with commercial fishing vessels. The seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel and providing TGS is afforded a reasonable opportunity to complete the survey in a timely and efficient manner.

Control Measure	Control Adopted	Justification
		Implementation of this control measure will result in additional costs to TGS, in the order of thousands of dollars. It is acknowledged that this would provide a reduction in risk to the commercial fishing industry. Socio-economic benefit outweighs the additional cost.
All evidence-based compensation claims made by commercial fishing licence holders or vessel crews for equipment damage/loss will be assessed for merit in accordance with the TGS Fisheries Compensation Process (Appendix H).	Yes	All evidence-based compensation claims made by commercial fishing licence holders or vessel crews for equipment damage/loss will be assessed for merit by an independent third-party. All claims will be assessed in accordance with the TGS Fisheries Compensation Process (Appendix H). Socio-economic benefit outweighs the additional cost.
No acquisition in known fishing grounds for the Mackerel Managed Fishery (i.e. waters less than 70m) in peak mackerel fishing periods (May – November).	Partially	Implementation of this control would minimise operational inconvenience to MMF vessels. TGS will acquire the southern zone (depths between 50m – 80m, refer to Section 3.2) between April and May, primarily outside of the main fishing period for the MMF. It is not possible to entirely avoid acquisition during the peak mackerel fishing period due to other environmental sensitivities (i.e. humpback whale peak migration period (July to October) and internesting period for flatback turtles (October to March)). MMF vessels may potentially experience operational inconvenience when the seismic vessel is acquiring data in the southern zone. Interactions are expected to be infrequent and short-term. Avoiding the peak fishing period would prevent the objectives of the survey being met. Additional years of acquisition in the southern zone would be required to acquire the full area, meaning that data would not be available when required. The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of hundreds of thousands of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement.
No acquisition in known fishing grounds for the Pilbara Demersal Scalefish Fisheries (PFTIMF, PTMF and PLMF).	No	Implementation of this control would minimise operational inconvenience to commercial fishing vessels. Fishing effort in the Pilbara Demersal Scalefish Fisheries is all-year round, with no identified peak periods to schedule the survey to avoid fishing operations. Fishing vessels may potentially experience operational inconvenience. Interactions are expected to be infrequent and short-term.

Control Measure	Control Adopted	Justification
		Avoiding the fishing grounds would prevent the objectives of the survey being met. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement.
Limit acquisition to one calendar year or including 'down-time' periods.	No	Implementation of this control would minimise consecutive years of potential interference with commercial fisheries. It is not possible to acquire the entire Acquisition Area within one calendar year. To acquire the entire Acquisition Area, it would take a maximum of 510 days (including contingency time). Implementation of this control would significantly interrupt commercial fishing activities for more than an entire year. Minimising acquisition to one calendar year, would prevent the objectives of the survey being met. Introducing down-time periods would increase the number of years of acquisition required to acquire the entire survey, meaning that data would not be available when required. While it is acknowledged that this would provide a reduction in risk to the commercial fishing industry, it is not practicable or feasible to implement.
Limiting acquisition to a maximum of 10,000 km^2 per calendar year.	Yes	Implementation of this control would minimise operational inconvenience to commercial fishing vessels, in particular vessels in the Pilbara Demersal Scalefish Fisheries. The implementation of this control will result in additional costs to TGS. The additional costs would be in the order of hundreds of thousands of dollars to re-mobilise a seismic survey vessel the following calendar year. It is acknowledged that this would provide a reduction in risk to the commercial fishing industry. Socio-economic benefit outweighs the additional costs.
ALARP Statement		
The decision context has been assessed as 'Type B' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impacts of physical presence: interference with commercial fisheries. As 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.		

7.4.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing the physical presence of the seismic survey vessel and in-water equipment is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines N/A: No advice or guidelines have been identified that specifically address potential impacts to commercial fishers.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles The socio-economic values of the AMPs will not be impacted, and therefore, management measures are consistent with IUCN management prescriptions and the socio-economic use of the AMPs.
	Relevant Persons Expectations	WAFIC raised concerns in regards to the survey occurring within an area of high fishing activity and potentially disrupting commercial fishing activities over multiple years. WAFIC also raised concerns regarding the lack of a compensation process for displacement of commercial fishers and loss of catch as a result of the survey. In addition, a licence holder in the Pilbara Trap Managed Fishery raised concerns in regards to having clear access to fishing grounds during the survey and being compensated for equipment damage/loss, displacement and loss of catch. TGS is committed to undertaking the survey in a manner that does not interfere with commercial fishing or the resources of the sea. TGS will work collaboratively with fishers in order to minimise interactions offshore, including undertaking concurrent operational planning prior to each survey phase. TGS has agreed to change sail lines to accommodate commercial fisher's requests if it is feasible to do so and providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. TGS will ensure fisheries stakeholders are kept updated on the progress of the survey.

Context	Factor	Demonstration
		In addition, all evidence-based compensation claims made by commercial fishing licence holders or vessel crews for equipment damage/loss will be assessed for merit in accordance with the TGS Fisheries Compensation Process (Appendix H). TGS has determined that compensation for displacement and loss of catch is not an appropriate control or mitigation measure for the Capreolus-2 3D MSS, given the nature and scale of the activity, and the proposed control measures. TGS considers the level of impact to commercial fisheries to be of an acceptable level, given that any disruptions to commercial fishing operations are anticipated to be temporary and not significant, and the availability of alternative fishing grounds (including nearby to the Operational Area) to commercial fishers. All 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 WAFIC and individual licence holders. The impact is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	All requirements under the *Navigation Act 2012* and associated Marine Orders for navigation and collision are identified as control measures. In addition, the survey will be undertaken in accordance with section 280 of the OPGGS Act, which requires for the activity to be carried out in a manner that does not interfere with fishing or the resources of the sea, to a greater extent than necessary. Undertaking the Capreolus-2 3D MSS in a manner that does not interfere with fishing or fish resources to a greater extent than necessary for the exercise of right conferred by the titles granted to carry out exploration activities is considered to be an acceptable level of impact. Based on the maximum spatial overlap (30.5%) of the Capreolus-2 3D MSS with historic fishing effort and the proposed control measures (to mitigate and reduce operational inconvenience to commercial fishers), TGS has determined that the level of impact is considered acceptable, given the survey will not interfere with fishing or fish resources to a greater extent that necessary.

Industry Standards	Industry Best Practice	The control measures adopted are in accordance with industry standards and best practice, including:
		■ IAGC Environmental Manual for Worldwide Geophysical Operations:
		    ▪ minimise disturbance to fishing areas by restricting operations in specific commercial fishery license areas.
		■ APPEA Code of Environmental Practice:
		    ▪ reduce disturbance to fishing operations or other marine users to ALARP and acceptable levels and demonstrate adherence to agreed procedures.

Context	Factor	Demonstration
Ecological Sustainable Development (ESD)	ESD Application	There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity with disruption/interference with Commercial Fisheries during the Capreolus-2 3D MSS. The potential interactions between the seismic survey vessel and vessel(s) and commercial fishers are well understood. Ongoing consultation will be undertaken to communicate key updates and progress on the survey to fisheries stakeholders. There is no threat of serious or irreversible environmental damage or significant impact to biological diversity and ecological integrity associated with the disruption/interference with commercial fisheries during the Capreolus-2 3D MSS. Therefore, the impact is considered to be consistent with the principles of ESD.

Defined Acceptable Levels of Impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact	EPO #
Commercial Fisheries	Commercial fisheries stakeholders raised objections, claims and concerns regarding the effects of seismic sound on fish behaviour and commercial catch levels. 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; and ■ Spatial and temporal patterns in fisheries catch and effort distribution (based on DPIRD 2014-2018 FishCube data).	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; and ■ 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 annual fishing effort allocations, changes in active vessel numbers, environmental conditions, or market induced impacts).	<u>Commercial Fisheries</u> 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 commercial fisheries given that: ■ The level of interference TGS 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 scalefish catch in the Pilbara has consistently remained stable and within catch tolerance levels, with catches in 2017/18 exceeding the Department's defined acceptable catch range, 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	

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			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). TGS acknowledges that localised and temporary disturbances to commercial fishing activities from seismic survey activities may occur. TGS recognises that clear and regular communication with fisheries stakeholders is required in order to facilitate better planning and resource sharing. However, the level of impact from the survey to commercial fisheries is considered to be acceptable.	

Acceptability Statement
Impacts and risks classified as ‘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. Based on the evaluation above, TGS considers the adopted control measures appropriate to manage the impacts of physical presence: interference with commercial fisheries to be of an acceptable level.

7.4.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 4 No interference 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.	**4.1** **4.2** **4.3** **4.4** **4.6** **4.6** **4.7** **4.8** **4.9** **4.10** **4.11** **4.12**

7.5 Physical Presence: Interference with Other Marine Users

7.5.1 Assessment Summary

Source of Impact / Risk		
Potential disruption/interference with other marine users associated with the physical presence of the seismic survey vessel, in-water equipment and support vessel(s) in the Operational Area. The seismic survey vessel will typically move along pre-determined sail lines at a constant speed of approximately 4.5 knots and will proactively and collaboratively manage operational information between the seismic survey vessel and other marine users located in the Operational Area. The seismic survey 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 addresses the potential interference with other marine users from the survey. Potential interference with commercial fishers is assessed in Section 7.4.		
Receptors		
■ Tourism and recreational activities; ■ Commercial shipping; and ■ Petroleum activities.		
Summary of Impacts and Risks		
The limited manoeuvrability of the seismic survey vessel means that other marine users may be asked to take measures to avoid the immediate vicinity of the seismic survey vessel and associated equipment. Typically, other marine users are requested to provide a wide berth of 3.0 nm (5.5 km) ahead and on either side of the seismic vessel, and 6.0 nm (11 km) astern. Other marine users may potentially experience operational inconvenience, whilst the seismic vessel is conducting seismic acquisition at a particular location. Disruptions to other marine users are anticipated to be temporary and not significant.		
Decision Content		
A	The decision context for physical presence: interface with other marine uses has been assessed as ‘Type A’, given the impacts are well understood and uncertainty is minimal, with little or no stakeholder interest.	
Adopted Control Measures		**EPS #**
Notification to stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification will also be provided to stakeholders within 2 weeks of survey completion.		5.1
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.		5.2
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).		5.3
Daily look-ahead reports will be provided to stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.		5.4
Vessels will adhere to the 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		5.5

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.			
At least one support vessel (supply or chase vessel) will accompany the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with other marine users.			5.6
Adherence to the prohibition of vessel entry into designated petroleum safety zones surrounding petroleum wells, structures or equipment.			5.7
If a separate petroleum activity is undertaken concurrently with the Capreolus-2 3D MSS and within the Operational Area, a simultaneous operations (SIMOPs) Plan will be developed and implemented.			5.8
Streamers will be marked with tail buoys (fitted with virtual or installed AIS).			5.9
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Minor	Unlikely	**Low**
Residual Risk	Minor	High Unlikely	**Low**

7.5.2 Detailed Evaluation of Impacts / Risks

The seismic survey vessel will typically move along pre-determined sail lines at a constant speed of approximately 4-5 knots and will proactively and collaboratively manage operational information between the seismic survey vessel and support vessel(s), and other marine users. The survey will adhere to the requirements of the International Regulations for Preventing Collisions as Sea 1972 (COLREGS) and Chapter 5 of Safety of Life at Sea Convention (SOLAS) as implemented in Commonwealth waters through the *Navigation Act 2012* and associated Marine Orders Parts 21, 27, 30, 58 - safety and emergency arrangements, prevention of collisions, safe management of vessels.

The likelihood of direct interactions between the seismic survey vessel and other marine users transiting the Operational Area will be reduced through the required use of appropriate navigational lighting and shapes, communication channels and procedures, use of radar and implementation of 24/7 watch on board to keep other users of the area aware of the seismic survey vessel's position.

The limited manoeuvrability of the seismic survey vessel means that other marine users may be asked to take measures to avoid the immediate vicinity of the seismic survey vessel and associated equipment. Typically, other users are requested to provide a wide berth of 3.0 nm (5.5 km) ahead and on either side of the seismic vessel, and 6.0 nm (11 km) astern of the vessel.

A support vessel will be employed for the survey to manage interactions and communications with other marine users in the Operational Area.

Other marine users that may occur within or near the Operational Area include:

- Tourism and recreational activities– tourism and recreational sector operators may traverse through the Operational Area (refer to Section 4.6.8).
- Commercial shipping – there are numerous shipping fairways intersecting the Operational Area (refer to Section 4.6.10).
- Petroleum exploration and production activities, including associated vessel activities may overlap the Operational Area and surrounding areas (refer to 4.6.11).

7.5.2.1 Tourism and Recreation

Tourism and recreational activities such as recreational fishing are known to take place along the north-west coastline, however interactions with the Capreolus-2 3D MSS are considered unlikely due to the remoteness and predominantly deep waters of the Operational Area (refer to Section 4.6.8). Some tourism and recreational activities may occur in the shallow waters of the Operational Area at Glomar Shoals and the waters off nearby Bedout Island (44 km from the Operational Area). In the event that tourism/recreational fishing activities are present within the Operational Area, operational inconvenience would be minimal given the transient nature of the seismic activities. With controls adopted as identified below, no significant impacts are expected.

7.5.2.2 Commercial Shipping

Frequent vessel traffic is expected to be encountered within the Operational Area, due to vessels heading in and out of Port Hedland and Karratha (refer to Section 4.6.10). The Operational Area overlaps with seven shipping fairways, utilised by international bulk freighters/tankers and general cargo ships. Based on vessel traffic data obtained from AMSA for the last six months, between 70 and 641 vessels may be encountered within the Operational Area during the survey.

Twenty-four-hour radar and visual watch and open radio communications between vessels will occur during the seismic survey. Early communication allows for the speed and course of vessels to be ascertained in a timely manner and any necessary adjustment of course to be confirmed.

Some commercial vessels may need to deviate from their intended routes to avoid the seismic survey vessel and towed array. In the case of larger freighters/tankers, the seismic survey vessel will typically change course to avoid any interactions. Vessel encounters that occur in line with the seismic survey vessel will involve a minor deviation of course to give way to the vessel, which would likely be similar to the deviation given to any other vessel transiting the region. Vessels that are sailing crossways to the survey sail line will need to deviate a greater distance. As the Operational Area is in open waters with no grounding or navigational hazards, it is not likely that any such deviations would increase the potential for vessel collision or grounding in the area.

Commercial vessel masters are familiar with procedures for operating in the vicinity of a vessel restricted in its ability to manoeuvre and the seismic survey vessel and support vessel masters and crews operate in areas of the world with significantly higher vessel traffic without significant issue. Therefore, no significant navigational implications or long-term changes in shipping traffic patterns are expected.

7.5.2.3 Petroleum Exploration and Production Operations

The NWS is an established hydrocarbon province with a number of commercial operations operating off the coast of Karratha and Port Hedland (refer to Section 4.6.11). Vessels associated with nearby petroleum operations (i.e. Woodside Angel Platform) may be asked to deviate from intended routes to avoid the seismic vessel, in-water equipment and support vessel(s). Vessels will adhere to the prohibition of vessel entry into designated petroleum safety zones surrounding petroleum wells, structures or equipment.

Browse to NWS Project

As discussed in Section 4.6.11, Woodside, as Operator for and on behalf of the Browse Joint Venture (BJV), is proposing to develop the Brecknock, Calliance and Torosa fields located approximately 425 km north of Broome in the offshore Browse Basin.

The proposed Browse to NWS Project will comprise subsea infrastructure and two floating production storage offtake (FPSO) facilities, connected to existing NWS Project infrastructure via the ~900 km Browse Trunkline (BTL). The proposed route of the BTL intersects the northern portion of the Capreolus-2 3D MSS Acquisition Area. Installation of the BTL may commence as early as 2022, subject to all necessary joint venture and regulatory approvals being obtained and appropriate commercial arrangements being finalised.

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

7.5.2.4 Summary

Based on the assessment above and the implementation of the controls identified in Section 7.5.3, the consequence of localised and temporary disruptions to other marine users within the Operational Area is **Minor**, the likelihood of this consequence is **Unlikely** and the residual risk is considered to be **Low**.

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

7.5.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
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 Capreolus-2 3D MSS are required to comply with the *Navigation Act 2012 and* associated Marine Orders.
Adherence to the prohibition of vessel entry into designated petroleum safety zones surrounding petroleum wells, structures or equipment.	Yes	In compliance with the *OPGGS Act*, vessel(s) will adhere to vessel entry prohibitions into designated petroleum safety zones. Petroleum safety zones are specified areas surrounding petroleum wells, structures or equipment which vessels or classes of vessel are prohibited from entering or being present in.
Good Industry Practice		
Notification to stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification will also be provided to stakeholders within 2 weeks of survey completion.	Yes	Notification will be provided to stakeholders 4 weeks prior to the commencement of the survey and 2 weeks following completion of the survey. Implementation of the control will reduce the likelihood of interactions with other marine users. Good industry practice, socio-economic benefit outweighs the additional cost.
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Yes	AHS will be contacted 4 weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure that other marine users are aware of the survey. Implementation will reduce the likelihood of interactions with other marine users. Good industry practice, socio-economic benefit outweighs the additional cost.
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Yes	The AMSA JRCC will be contacted 24-48 hrs before operations commence for issuing of radio-navigation warnings. This will ensure that other marine users are aware of the survey. Implementation will reduce the likelihood of interactions with other marine users.

Control Measure	Control Adopted	Justification
		Good industry practice, socio-economic benefit outweighs the additional cost.
Daily look-ahead reports will be provided to stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Yes	TGS will provide stakeholders with a daily look-ahead report, detailing the upcoming activities and planned seismic survey location within the next 72 hours. As part of this report, TGS will request information from commercial fishers on upcoming fishing activities for the next 24-72 hours. This will allow the seismic survey vessel to consider alternative lines, where practicable. Good industry practice, socio-economic benefit outweighs the additional cost.
At least one support vessel (supply or chase vessel) will accompany the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods).	Yes	A support vessel will conduct advanced scouting when safe to do so (e.g. outside of inclement weather periods) to ensure other marine users in the area are provided with advance notice of seismic activities. A supply and chase vessel will be employed for the survey. Good industry practice, socio-economic benefit outweighs the additional cost.
If a separate petroleum activity is undertaken concurrently with the Capreolus-2 3D MSS and within the Operational Area, a simultaneous operations (SIMOPs) Plan will be developed and implemented.	Yes	A SIMOPs plan is a standard tool utilised in the petroleum industry to control vessel activities and minimise the risk of vessel collisions or other incidents, when multiple vessels/assets are operating in a manner in which their interactions require an increased degree of coordination and communication. Good industry practice, socio-economic benefit outweighs the additional cost.
Streamers will be marked with tail buoys (fitted with virtual or installed AIS).	Yes	Tail buoys will be used to mark ends of the streamers, so that they are visible to other vessels. Implementation will reduce the likelihood of interactions with other marine users. Good industry practice, socio-economic benefit outweighs the additional cost.
Alternatives/Substitute Considered		
No practicable alternative or substitutes to the acquisition or the good practice controls have been identified.	N/A	N/A
Additional Controls Considered		
Use of more than one support vessel to further reduce the potential for Collison or interference with other marine users.	No	Implementation of this control would minimise interactions with other marine users. An additional support vessel allows for communication and management of interactions, if there is an interaction with more than one approaching third party vessel.

Control Measure	Control Adopted	Justification
		The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of hundreds of thousands of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk, it is not practicable or feasible to implement.
No seismic acquisition within the seven shipping fairways.	No	Implementation of this control would minimise interactions with international freighters/tankers. However, avoiding the shipping fairways would prevent the objectives of the survey being met. The implementation of this control has the potential to result in additional costs to TGS. The additional costs would be in the order of hundreds of thousands of dollars, which would be detrimental to the commerciality of the survey. While it is acknowledged that this would provide a reduction in risk, it is not practicable or feasible to implement.
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impacts of physical presence: interference with other marine users. As 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.		

7.5.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing physical presence: interference with other marine users, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	EPBC Policy Statement 1.1. – Significant Guidelines The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines No advice or guidelines have been identified that specifically address potential impacts to other marine users.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles The socio-economic values of the AMPs will not be impacted, and therefore, management measures are consistent with IUCN management prescriptions and the socio-economic use of the AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to the interaction of the vessels and equipment with other marine users. This impacts is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	All requirements under the *Navigation Act 2012* and associated Marine Orders for navigation and collision are identified as control measures.
Industry Standards	Industry Best Practice	The control measures adopted are in accordance with industry standards and best practice, including: ■ APPEA Code of Environmental Practice: ▪ reduce disturbance to fishing operations or other marine users to ALARP and acceptable levels and demonstrate adherence to agreed procedures.

Context	Factor	Demonstration
Ecological Sustainable 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 Caprelous-2 3D MSS. Therefore, the impact is considered to be consistent with the principles of ESD.

Defined Acceptable Levels of Impact

Receptor Category	Relevant External Context	Defined Acceptable Level	Comparison with Predicted Levels of Impact	EPO #
Other Marine Users	No stakeholder objections, claims or concerns were raised regarding recreation and tourism.	Seismic activities are undertaken in a manner that does not interfere with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities.	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 other marine users given that: ■ The likelihood of direct interactions between the seismic survey vessel and other marine users is reduced through the required use of appropriate navigational lighting and shapes, communication channels and procedures, use of radar and implementation of 24/7 watch. ■ Some vessels may need to deviate from their intended routes to avoid the seismic survey vessel and towed array. However, it is not likely that any such deviations would increase the potential for vessel collision or grounding in the area. ■ Operational inconvenience would be minimal given the transient nature of the seismic activities. ■ No significant navigational implications or long-term changes in shipping traffic patterns are expected. Therefore, the level of interference TGS may have on other marine users is no greater than is necessary to exercise of right conferred by	5

Defined Acceptable Levels of Impact				
Receptor Category	**Relevant External Context**	**Defined Acceptable Level**	**Comparison with Predicted Levels of Impact**	**EPO #**
			the titles granted to carry out exploration activities.	
Acceptability Statement				
Based on the evaluation above, TGS considers the adopted control measures appropriate to manage the impacts of physical presence: interference with other marine users to be of an acceptable level.				

7.5.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 5 No interference with other marine users to a greater extent than is necessary for the exercise of right conferred by the titles granted to carry out exploration activities.	**5.1** **5.2** **5.3** **5.4** **5.5** **5.6** **5.7** **5.8** **5.9**

7.6 Routine Discharges: Liquid Waste Management

7.6.1 Assessment Summary

<table>
<tr><td colspan="3">Source of Impact / Risk</td></tr>
<tr><td colspan="3">The seismic vessel and support vessels used during the survey will generate liquid wastes associated with routine activities, including:
■ Domestic waste discharges (treated sewage, grey water and putrescible food waste); and
■ Deck drainage and bilge water.</td></tr>
<tr><td colspan="3">Receptors</td></tr>
<tr><td colspan="3">■ Water quality and marine biota.</td></tr>
<tr><td colspan="3">Summary of Impacts and Risks</td></tr>
<tr><td colspan="3">Routine discharges of domestic wastes have the potential for temporary and localised increases in nutrient levels resulting in localised, minor and temporary ecological impacts (e.g. changes in certain nutrients and/or dissolved oxygen).
The discharge from drains and bilge from each vessel also 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.</td></tr>
<tr><td colspan="3">Decision Content</td></tr>
<tr><td>A</td><td colspan="2">The decision context for routine discharges of liquid wastes has been assessed as ‘Type A’, given the impacts are well understood and uncertainty is minimal, with little or no stakeholder interest.</td></tr>
<tr><td colspan="2">Adopted Control Measures</td><td>EPS #</td></tr>
<tr><td colspan="2">Sewage will be managed in accordance with MARPOL Annex IV and AMSA Marine Order 96, using an IMO-approved sewage treatment plant, a sewage comminuting and disinfecting system or a sewage holding tank as applicable depending on vessel gross tonnage or people capacity (as evidenced by a current International Sewage Pollution Prevention (ISPP) Certificate).</td><td>6.1</td></tr>
<tr><td colspan="2">In accordance with MARPOL Annex IV and AMSA Marine Order 96:
■ 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 ≥ 4 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.</td><td>6.2</td></tr>
<tr><td colspan="2">In accordance with MARPOL Annex V and AMSA Marine Order 95:
■ Putrescible waste will be discharged while the vessel is moving and ⩾12 nm from the nearest land; or
■ Putrescible waste will pass through a comminuter or grinder with the capacity to screen waste to less than 25 mm in diameter prior to discharge and discharged while the vessel is moving and ⩾3 nm from the nearest land</td><td>6.3</td></tr>
</table>

Vessels >400 GRT 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.			6.4
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 are unavailable, bilge water mixtures will be retained on board for on shore disposal.			6.5
Oil discharge monitoring and control systems on board the vessels will be maintained and calibrated to ensure monitoring readings are accurate.			6.6
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Slight	Highly Unlikely	**Low**
Residual Risk	Slight	Highly Unlikely	**Low**

7.6.2 Detailed Evaluation of Impacts / Risks

The waters within and adjacent to the Operational Area are generally oligotrophic (i.e. low nutrient levels) except where localised, sporadic and short-lived upwellings occur in the region (e.g. at the shelf break, where deeper, cooler nutrient rich water is brought to the surface). Section 4.5 provides a detailed description of the ecological communities and marine fauna that may occur in the Operational Area, which could potentially be impacted.

7.6.2.1 Discharge of Domestic Waste

The seismic vessel will have up to 70 persons on board, resulting in up to approximately 9 m^3 of sewage and grey water discharges per day from domestic processes such as ablution, laundry and galley activities, and putrescible wastes primarily from food wastes. Discharges from the support vessels will be significantly less than that of the seismic vessel.

Routine discharges of domestic wastes has 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).

All domestic waste discharge streams will be managed in accordance with the requirements of MARPOL 73/78 and the AMSA Marine Orders made under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983, as follows:

- All vessels over 400 GRT to be used for the survey will hold a current International Sewage Pollution Prevention Certificate (ISPP Certificate);
- Sewage will be treated and discharged in accordance with MARPOL; using an International Maritime Organisation (IMO) approved sewage treatment plant, a sewage comminuting and disinfecting system or a sewage holding tank prior to discharge, as applicable depending on vessel gross tonnage or people capacity;
- Comminuted/disinfected sewage via an IMO-approved system will only be discharged when ≥3 nm from land and when the vessel is moving at ≥4 knots. 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; and
- For vessels greater than 100 GRT (or certified for >15 persons on board), a Waste Management Plan will be developed, and vessels greater than 400 GRT will have a waste management log book, in accordance with MARPOL 73/78.

Discharges will occur when vessels are moving, resulting in the discharges dispersing rapidly in the predominantly open oceanic location of the Operational Area. 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. The extent of impacts is expected to be localised to surface waters and in the immediate vicinity of the discharge location. Benthic communities are therefore not expected to be impacted.

7.6.2.2 Drains and Bilge Discharge

Liquids collected in the bilge consist of a mixture of water, oily residue, lubricants and cleaning fluids from various sources, including engines and machinery areas on board the vessel. The amount of bilge wastes accumulated on board is dependent on vessel characteristics, such as size, engine room design, and preventative maintenance schedule.

Rainwater and wash-down water from deck areas and other open drainage areas on-board the vessel may contain low concentration residues (e.g. oil, grease, detergent), and will require discharge. The volume of drain discharge required during the survey is dependent on the amount of rainfall received and the frequency of the deck washing activities. Discharges from open drain areas will be conducted directly overboard.

Routine discharge of deck drainage and bilge water, if not managed or treated, has the potential outcome of a temporary and localised reduction in water quality resulting in localised, minor and temporary toxicity impacts on marine biota. However, 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 treatment through an oil-in-water separator prior to discharge.

Deck drainage and bilge water discharges will be managed in accordance with the requirements of MARPOL 73/78 and the AMSA Marine Orders made under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983.

All vessels >400 GRT to be used for the survey 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 so that the bilge stream is treated to reduce hydrocarbon concentrations below 15 ppm in accordance with MARPOL 73/78 prior to discharge overboard.

In addition, oil discharge monitoring and control systems on board the vessels will be regularly calibrated to ensure monitoring readings are accurate.

7.6.2.3 Summary

Given the minor quantities of contaminants expected from the open drains, the expected rapid dispersal of both open drain and treated bilge discharges, the assimilative capacity of the open ocean environment, and the management measures to be implemented, no discernible impacts are expected.

Based on the assessment above and the implementation of the controls identified in Section 7.6.3, the consequence of a localised and temporary reduction in water quality is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

7.6.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Sewage will be managed in accordance with MARPOL Annex IV and AMSA Marine Order 96, using an IMO-approved sewage treatment plant, a sewage comminuting and disinfecting system or a sewage holding tank as applicable depending on vessel gross tonnage or people capacity (as evidenced by a current International Sewage Pollution Prevention (ISPP) Certificate).	Yes	Vessels used for the survey that are of 400 GRT or certified to carry more than 15 persons, will have an appropriate sewage treatment plant, sewage comminuting and disinfecting system or sewage holding tank on board (with related ISPP Certificate). It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.
In accordance with MARPOL Annex IV and AMSA Marine Order 96: ■ 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 ≥4 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 MARPOL and AMSA Marine Orders.
In accordance with MARPOL Annex V and AMSA Marine Order 95: ■ Putrescible waste will be discharged while the vessel is moving and ⩾ 12 nm from the nearest land; or ■ Putrescible waste will pass through a comminuter or grinder with the capacity to screen waste to less than 25 mm in diameter prior to discharge and discharged while the vessel is moving and ⩾3 nm from the nearest land.	Yes	Discharges of putrescible waste will be undertaken in accordance with the requirements of MARPOL Annex V and AMSA Marine Order 95. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.
Vessels >400 GRT will hold a current International Oil Pollution Prevention (IOPP) Certificate demonstrating that vessels are fitted with an oil discharge	Yes	Vessels used for the survey that are of 400 GRT will have an oil discharge monitoring and control system and oil filtering equipment on board (with related

Control Measure	Control Adopted	Justification
monitoring and control system and oil filtering equipment, which will be maintained and operated to 15 ppm standard.		IOPP Certificate) 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.
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 onshore disposal.	Yes	Bilge water discharges will be undertaken in accordance with the requirements of MARPOL Annex I and AMSA Marine Order 91 to ensure discharges to the marine environment are acceptable or otherwise retained on board for disposal. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.
Good Industry Practice		
Oil discharge monitoring and control systems on board the 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 as per the requirements of MARPOL and associated Marine Orders. Good industry practice, environmental benefit outweighs the additional cost.
Alternatives/Substitute Considered		
The alternative to the discharge of liquid wastes 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, IMO-standard oil discharge monitoring and control systems 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 sure 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

Control Measure	Control Adopted	Justification
		negligible reduction in risk that would be achieved and the already low level of risk.
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 cost of the survey, making it impractical to the nature and scale of the risk associated with sewage discharge on small vessels; as a result this additional control was determined to be impractical from an operational perspective.
ALARP Statement		
The decision context has been assessed as 'Type A' and residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impacts of routine liquid waste discharges during the survey. As 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.		

7.6.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing routine discharges of liquid waste, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines No species Recovery Plans or Conservation Advice set requirements relating to the management of routine liquid waste discharges.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs. Management of discharges in accordance with the requirements of MARPOL meets the management prescriptions for Multiple Use Zones. The biological diversity and natural values of AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological values of the AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to routine discharges of liquid waste during the survey. The impact is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	The proposed controls meet 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 Best Practice	Control measures adopted are compliant with industry standards and best practice for the management of routine liquid wastes, such as: ■ IAGC Environmental Manual for Worldwide Geophysical Operations:

Context	Factor	Demonstration
		▪ vessels to have a waste or garbage management plan to effectively manage waste in-line with the relevant MARPOL regulations as well as local legislation, contractor and client company requirements; ▪ sewage handled according to MARPOL; and ▪ bilge water and water from covered spaces aboard vessels are processed to remove oil to less than 15 parts per million before discharge. ■ APPEA Code of Environmental Practice: ▪ waste management practices are carried out based on the prevention, minimisation, recycling, treatment and disposal of wastes in accordance with statutory requirements and procedures.
Ecological Sustainable Development (ESD)	ESD Application	The residual risks to water quality and marine biota are low given the proposed controls meet the requirements of MARPOL 73/78. Impacts are expected to be negligible with no lasting, serious or irreversible ecological damage. The aspect and potential interactions are well understood and managed according to internationally adopted standards. Therefore, the impact is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impacts of routine discharge of liquid waste to be of an acceptable level.		

7.6.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 6 Liquid waste discharges to meet or exceed the requirements of MARPOL Annex I, IV, V and Marine Orders 91, 95, 96.	**6.1** **6.2** **6.3** **6.4** **6.5** **6.6**

7.7 Atmospheric Emissions: Vessels and Mechanical Equipment

7.7.1 Assessment Summary

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 vessel(s) 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 SO_2, NO_X, ozone depleting substances, CO_2, particulates and Volatile Organic Compounds (VOCs).

Receptors

- Air quality in the immediate vicinity of the vessel exhaust.
- Contribution of greenhouse gases (GHG) to the atmosphere.

Summary of Impacts and Risks

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 provide a minor contribution to Australian and global levels of GHG in the atmosphere.

Decision Content

A	The decision context for atmospheric emissions (vessels and mechanical equipment) has been assessed as 'Type A', given the impacts are well understood and uncertainty is minimal, with little or no stakeholder interest.

Adopted Control Measures	EPS #
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	7.1
The sulphur content of fuel oil used on board vessels for propulsion or operation will not exceed 0.50% m/m.	7.2
Vessel engines and incinerators maintained according to manufacturer's specification.	7.3

Risk Ranking	Consequence	Likelihood	Risk
Inherent Risk	Slight	Highly Unlikely	**Low**
Residual Risk	Slight	Highly Unlikely	**Low**

7.7.2 Detailed Evaluation of Impacts / Risks

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 provide a minor contribution to Australian and global levels of GHG in the atmosphere.

Overall emissions from the seismic survey vessel are expected to be low and vessels will comply with MARPOL 73/78 Annex VI (Prevention of Air Pollution from Ships) requirements.

Given the location of the survey activities offshore (approximately 50 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.

7.7.2.1 Summary

Based on the assessment above and the implementation of the controls identified in Section 7.7.3, the consequence of a localised and temporary reduction in air quality is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

7.7.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
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.
The sulphur content of fuel oil used on board vessels for propulsion or operation will not exceed 0.50% m/m.	Yes	Vessels will use low sulphur 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.
Good Industry Practice		
Vessel engines and incinerators maintained according to manufacturer's specification.	Yes	Vessel engines and 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.
Alternatives/Substitute Considered		
No practical alternative or substitute to the above controls have been identified.	N/A	N/A
Additional Controls Considered		

Control Measure	Control Adopted	Justification
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.
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.
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the impact of atmospheric emissions (vessel and mechanical equipment). As no reasonable additional or alternative controls were identified that would further reduce the impact, without jeopardising the objectives of the survey, the impacts are considered to be ALARP.		

7.7.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing atmospheric emissions (vessels and mechanical equipment), is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines No species Recovery Plans or Conservation Advice set requirements relating to the management of atmospheric emissions.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs. The management prescriptions for AMPs does not include information on atmospheric emissions from commercial vessels/operations. The biological diversity and natural values of AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological values of the AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to the discharge of atmospheric emissions during the survey. The impact is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & 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 Best Practice	Control measures are in accordance with industry standards and best practice, including: ■ IAGC Environmental Manual for Worldwide Geophysical Operations:

Context	Factor	Demonstration
		▪ regular service of exhaust systems to ensure that noise and emissions are kept to appropriate levels (no unburned fuels and exhaust gases to create localised pollution) ▪ vessels use low-sulphur MDO. ■ APPEA Code of Environmental Practice: ▪ reduce greenhouse gas emissions to ALARP and acceptable levels, with evidence of a structured assessment of greenhouse emission reduction.
Ecological Sustainable 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 Capreolus-2 3D MSS. Therefore, the impact is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impact of atmospheric emissions from vessels and mechanical equipment to be of an acceptable level.		

7.7.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 7 Atmospheric emissions to meet or exceed the requirements of MARPOL Annex VI and AMSA Marine Order 97.	**7.1** **7.2** **7.3**

7.8 Artificial Light Emissions: Vessels

7.8.1 Assessment Summary

<table>
<tr><td colspan="4">Source of Impact / Risk</td></tr>
<tr><td colspan="4">Navigational and safety lighting on the seismic and support vessels emit light emissions, which may disrupt normal marine fauna 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.</td></tr>
<tr><td colspan="4">Receptors</td></tr>
<tr><td colspan="4">■ Marine fauna sensitive to artificial lighting (i.e. turtles, fishes and seabirds).</td></tr>
<tr><td colspan="4">Summary of Impacts and Risks</td></tr>
<tr><td colspan="4">Impacts resulting from artificial lighting during the survey are expected to be negligible. Due to the size of the vessel and the height above sea level where lights will be positioned, it is expected that light emissions will be limited to localised offshore attraction/repulsion of marine fauna species, including marine turtles, fish and birds.

Artificial lighting has the potential to temporarily create an attraction/repulsion of marine fauna species, including marine turtles, fish and birds. The transient nature of the survey, the predominantly open oceanic location of the Operational Area, and the minimum distance to known turtle nesting (flatback turtle nesting at Eighty Mile Beach, 70 km south) and bird breeding colonies (Bedout Island, 44 km south) means that these are unlikely to be impacted. In addition, sound emissions from the seismic source are expected to act as a localised and temporary deterrent to approaching marine fauna. The survey will not generate light levels sufficient to disrupt natural behavioural patterns on a long-term basis that could result in significant effects to the marine fauna populations in the region.</td></tr>
<tr><td colspan="4">Decision Content</td></tr>
<tr><td>A</td><td colspan="3">The decision context for artificial light emissions (vessels) has been assessed as ‘Type A’, given the impacts are well understood and uncertainty is minimal, with little or no stakeholder interest.</td></tr>
<tr><td colspan="3">Adopted Control Measures</td><td>EPS #</td></tr>
<tr><td colspan="3">Vessel crews will be instructed at the pre-survey environmental induction to minimise unnecessary external lighting, where practicable during the survey.</td><td>8.1</td></tr>
<tr><td>Risk Ranking</td><td>Consequence</td><td>Likelihood</td><td>Risk</td></tr>
<tr><td>Inherent Risk</td><td>Slight</td><td>Highly Unlikely</td><td>Low</td></tr>
<tr><td>Residual Risk</td><td>Slight</td><td>Highly Unlikely</td><td>Low</td></tr>
</table>

7.8.2 Detailed Evaluation of Impacts / Risks

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; and
- ability of the fauna populations to return to their original state following the survey.

Due to the size of the 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. It is also notable that the Operational Area overlaps with frequent vessel traffic. Vessels associated with the survey will only result in a very small incremental increase in vessel lighting in the region.

7.8.2.1 Turtles

Artificial light has the potential to disrupt critical behaviours in turtles, particularly in relation to nesting at the shoreline. However, the Operational Area is approximately 70 km north from the closest known turtle nesting beach (flatback turtle nesting at Eighty Mile Beach), and impacts to nesting turtles are therefore not credible.

Limited information is available on the extent to which hatchlings use vision over wave direction and the earth's magnetic field for orientation once they enter the ocean (Lohmann 1992). However, Lohmann and Lohmann (1992) and Amos (2014) suggest that the vision of hatchlings is limited in the water and that other, more dominant navigational cues take over. Numerous studies have shown that hatchling dispersal offshore is heavily influenced by sea surface currents, particularly following the initial 24-hour swimming frenzy as swimming activity declines in duration and vigour (Frick 1976; Salmon and Wykenen 1987; Liew and Chan 1995; Witherington 1995; Okuyama et al. 2009). At 70 km from the nearest nesting beach, hatchlings in the vicinity of the Operational Area would be widely dispersed. It is also unlikely that metocean conditions in the open oceanic location of the Operational Area would be conducive for hatchlings to actively swim towards and remain in the vicinity of moving vessels should they be attracted by lighting.

Adult turtles that may be present within the Operational Area may be attracted to the seismic survey vessel and support vessel lighting. However, attraction of turtles to the vessels would be localised, short-term and affect a small proportion of the population due to:

- the transient nature of the survey (moving at 4.5 knots); and
- the limited distance of visible light from the seismic survey vessel.

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).

7.8.2.2 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).

7.8.2.3 Marine Birds

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 overlapping 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 on 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.

7.8.2.4 Summary

Given the transient nature of the survey, 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.

Based on the assessment above and the implementation of the controls identified in Section 7.8.3, the consequence of occasional short-term and localised disturbance to marine fauna is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

7.8.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
No legislative requirements were identified.	N/A	N/A
Good Industry Practice		
No additional good industry practice measures have been identified.	N/A	N/A
Alternatives/Substitute Considered		
No practicable alternative or substitutes to the above controls have been identified.	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.
Replacement of all lights or addition of light filters.	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 time and cost required to change lighting, this option was considered impractical and disproportionate to the limited benefit that would be gained.
Vessel crews will be instructed at the pre-survey environmental induction to minimise unnecessary external lighting, where practicable during the survey.	Yes	Survey crews will be instructed during the pre-survey environmental induction 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.
ALARP Statement		
The decision context has been assessed as ‘Type A’ and the residual risk has been determined to be low. TGS considers the adopted control measures appropriate to manage the impact of artificial light emissions from vessels. As no reasonable additional or alternative controls were identified that would further reduce the impact, without jeopardising the objectives of the survey, the impacts are considered to be ALARP.		

7.8.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing artificial light emissions (vessels), is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines *National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds* In January 2020, the Department of Agriculture, Water and the Environment released National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds (the Guidelines). The aim of the Guidelines is to manage artificial light so that wildlife is not disrupted, nor displaced from important habitat and is able to undertake critical behaviours such as foraging, reproduction and dispersal. Vessel crews will be instructed at the pre-survey environmental induction to minimise unnecessary external lighting, where practicable during the survey. TGS has reduced any adverse impacts of artificial lighting from the activities without compromising safety. *Recovery Plan for Marine Turtles in Australia* The Operational Area is located approximately 70 km from the nearest nesting beaches (i.e. Eighty Mile Beach) and no seismic acquisition will occur within the internesting BIA and Habitat Critical for flatback turtles, therefore, impacts to marine turtles from artificial lighting are not credible. Vessel crews will be instructed at the pre-survey environmental induction to minimise unnecessary external lighting, where practicable during the survey. TGS 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).
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No population-level impacts or serious or irreversible ecological implications are predicted to the values of AMPs. The management prescriptions for AMPs do not include information on artificial light emissions from commercial vessels. The biological diversity and natural values of AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological values of the AMPs.

Context	Factor	Demonstration
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to artificial light emissions during the survey. The impact is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & 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.
Industry Standards	Industry Best Practice	Control measures adopted are compliant with industry standards and best practice: ■ IAGC Environmental Manual for Worldwide Geophysical Operations: ▪ Ensure light emissions are kept to appropriate levels. ■ APPEA Code of Environmental Practice: ▪ Reduce light emissions to ALARP and acceptable levels.
Ecological Sustainable 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 Capreolus-2 3D MSS. Therefore, the impact is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impact of artificial light emissions from vessels to be of an acceptable level.		

7.8.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 8 Lighting reduced to levels required for navigational and safety purposes, so as to not disrupt behaviour patterns of marine fauna.	**8.1**

8. ENVIRONMENTAL RISKS AND MANAGEMENT – UNPLANNED

This section presents the evaluation of environmental impacts and risks completed for unplanned events associated with the Capreolus-2 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 Residual Environmental Impact and Risk Summary

Impact/Risk	EP Section No.	Residual Risk*		
		Consequence	Likelihood	Risk Ranking
Hydrocarbon Spill: Vessel Tank Failure	8.2	Major	Remote	**Low**
Hydrocarbon Spill: Vessel Refuelling Failure	8.3	Minor	Highly Unlikely	**Low**
Chemical Spill: Single Point Failure	8.4	Slight	Highly Unlikely	**Low**
Physical Presence: Collision / Entanglement with Marine Fauna	8.5	Moderate	Highly Unlikely	**Low**
Physical Presence: Loss of Equipment	8.6	Slight	Highly Unlikely	**Low**
Discharge: Loss of Hazardous or Non-Hazardous Solid Waste	8.7	Slight	Highly Unlikely	**Low**
Introduction of Invasive Marine Species: Biofouling and Ballast	8.8	Moderate	Highly Unlikely	**Low**

* The residual risk ranking is based on the ranking of the most sensitive receptor to the impact/risk.

8.1 Hydrocarbon and Chemical Spills Background

8.1.1 Properties

The following types of hydrocarbons and chemicals are likely to be present on the seismic and/or support vessels in varying quantities during the survey:

- Marine diesel oil (MDO) will be used to fuel the vessels;
- hydraulic fluids such as engine and synthetic oils required for equipment and engine use; and
- chemicals, such as for cleaning and maintenance purposes.

The characteristics and general behaviour of these hydrocarbons and chemicals in the event of a spill to the marine environment are provided below.

8.1.1.1 Marine Diesel Oil

Marine diesel oil (MDO) has a density of 829.1 kg/m^3 (API gravity of 37.6) and a dynamic viscosity of 4.0 cP at 25ºC, classifying it as a Group II light persistent oil according to the International Tankers Owners Pollution Federation (ITOPF, 2014) and USEPA/USCG classifications.

MDO is characterised by a high percentage of volatile components (95%), which will evaporate when on the sea surface. It also contains 5% persistent hydrocarbons, which will not evaporate and will breakdown over time. It is important to note that some heavy components contained in MDO have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but can re-float to the surface if these energies abate.

8.1.1.2 Hydraulic Fluid

Hydraulic fluid is likely to be present in small quantities on board the seismic survey vessel. A spill of hydraulic fluid resulting in less than 1 m^3 released to the marine environment is considered likely to disperse and weather very rapidly in the open ocean environment of the Operational Area.

8.1.1.3 Chemicals

Small quantities of chemicals may be used and stored on board (e.g. for cleaning and maintenance purposes). If spilled to the marine environment, the small volume (less than 1 m^3) is expected to rapidly disperse naturally and weather in the open ocean environment.

8.1.2 Credible Spill Scenarios

Credible hydrocarbon and chemical spill scenarios were identified during the environmental risk assessment undertaken for this EP (Section 6), 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); and
- 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
Single point failure	< 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 used on deck. Due to the low volumes involved, and the anticipated rapid dispersal in the marine environment, no modelling was undertaken.
Vessel refuelling failure	1.2 m^3 to 25 m^3 MDO	Vessel refuelling failure may result in the release of MDO 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 MDO transferred within a 15 minute period (AMSA 2013a), which represents the estimated time required to shut down refuelling operations following discovery of a spill. Based on the known transfer volume of 100 m^3/hr, this may result in a maximum credible spill volume of up to 25 m^3. Due to the low volumes involved, and the anticipated rapid dispersal in the marine environment, no modelling of this spill scenario was undertaken.
Vessel fuel tank rupture	1,062 m^3 of MDO	A collision between the seismic 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 result 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; and ■ floundering due to weather. If a collision involving the seismic vessel occurred, the worst case credible scenario would be the loss of the largest single fuel tank volume (consistent with AMSA [2013a] guidelines). A seismic contractor or specific vessel has not yet been selected for the TGS Capreolus-2 MSS, therefore, a fuel tank volume of 1,062 m^3 has been selected as the maximum credible release volume, based on the fuel tank configuration of a Ramform-class 3D seismic vessel. Ramform vessels are the largest available seismic vessels, with significantly larger

Scenario	Spilt Material and Volume	Description
		fuel tank capacities than other seismic vessels. By comparison, other 3D seismic vessels typically have fuel tank volumes of 300 m^3 or less.

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 less sensitive locations, shorter durations or smaller spill volumes were already captured through the assessment of the selected scenarios for consideration in this EP.

To understand the fate and trajectory of a potential spill associated with the Capreolus-2 3D MSS, hydrocarbon spill modelling was undertaken on the identified worst case credible scenario (refer to Section 8.1.3 and 8.1.3.4). 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/grounding scenario.

8.1.3 Spill Modelling Methodology

TGS commissioned RPS to undertake an oil spill modelling study for the Capreolus-2 3D MSS (RPS 2020; Appendix G). The study assessed the risk and potential exposure to the surrounding waters and contact to shorelines from a hypothetical hydrocarbon spill scenario due to a survey vessel tank rupture releasing 1,062 m^3 of marine diesel oil (MDO) over 6 hours on the sea surface.

Due to the size of the Operational Area, stochastic modelling was conducted at 3 possible release sites, which were carefully selected based on proximity to shorelines and sensitive receptors. Results are based on an annual assessment (combined seasons) (RPS 2020; Appendix G). Note, the modelling sites were selected based upon a previous iteration of the Operational Area (as presented in Version 0 and Version 1 of the EP, submitted to NOPSEMA on 26 February 2020 and 7 April 2020, respectively). Since these EP submissions, the eastern boundary of the Operational Area has been modified. All the modelling site locations remain on the border of the Operational Area, with the exception of Site 2 (refer to Table 8-4). This site is now located outside of the Operational Area. The modelling results from the site are considered conservative, given it is located closer to Bedout Island and Eighty Mile Beach AMP than the current Operational Area boundary.

Stochastic modelling was conducted which provides a combined summary of 300 possible spill trajectories to provide an understanding of a conservative 'outer envelope' of the potential area that may be affected in the unlikely event of a hydrocarbon release. It is important to note that the stochastic modelling output does not represent the extent of any one spill trajectory (which would be significantly smaller). Furthermore, the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that the released hydrocarbon may influence.

Modelling of the trajectory and fate of oil was performed using the Spill Impact Mapping Analysis Program (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 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. 300 simulations were modelled in total (100 simulations per release location). 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 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.

Inputs for the modelling are summarised in Table 8-3.

Table 8-3 Spill Modelling Inputs

Parameters	Modelling Inputs
Spill release locations	3 release locations along the perimeter of the Operational Area (refer to Appendix G).
Spill volume	1,062 m^3
Hydrocarbon type	MDO
Release type	Surface
Spill duration	6 hours
Simulation duration	40 days
No. of simulations	100 randomly selected trajectories at each release site using range of metocean conditions. A total of 300 spill trajectories were completed for the study.
Modelled seasons	Annual (range of conditions representative of all 12 months)

8.1.3.1 Release Location Selection

The release locations selected for the oil spill modelling study were based on the proximity to shoreline and sensitive receptors. The specific locations of the release sites are detailed in Table 8-4 and presented in Figure 8.1.

Table 8-4 Location of the Release Sites

Release Site	Latitude	Longitude	Water Depth (m)
#1	19° 56' 29.8998" S	116° 57' 26.517" E	~63
#2	19° 29' 56.241" S	119° 5' 46.3194" E	~38
#3	18° 8' 55.1328" S	118° 26' 31.095" E	~264

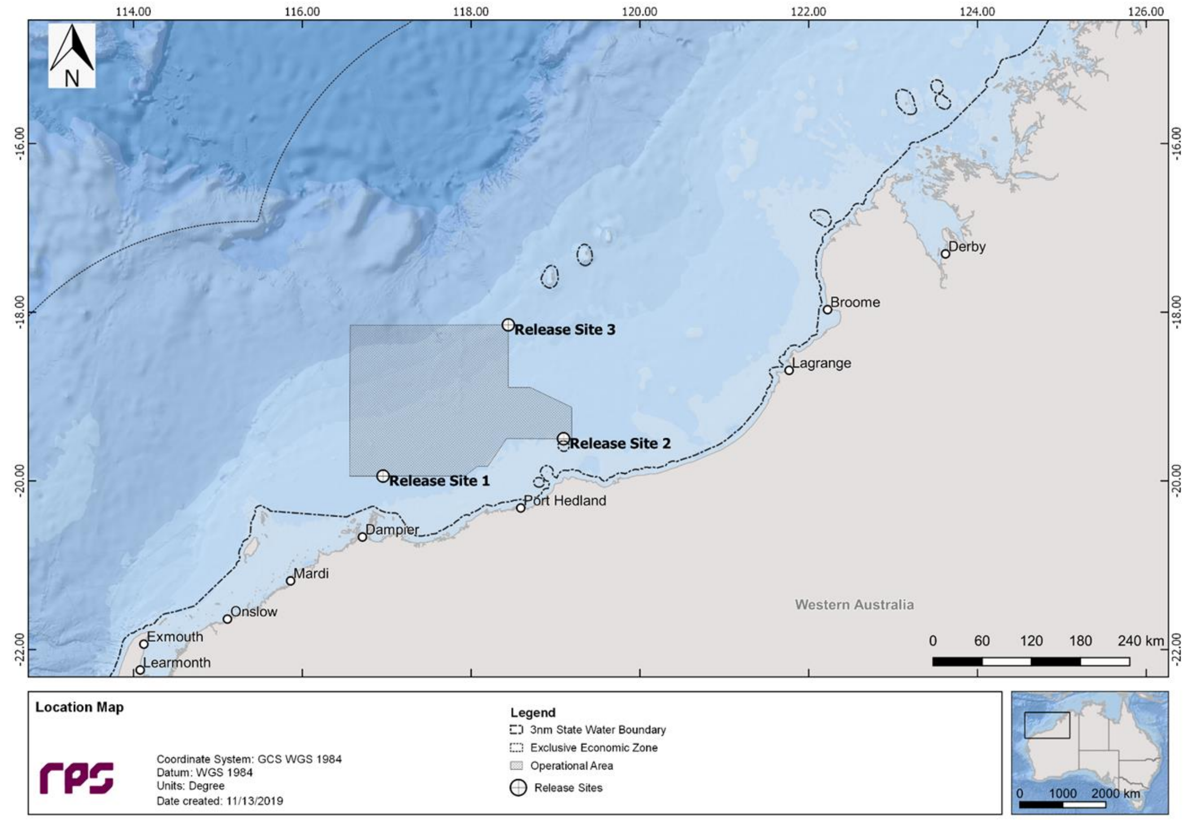

Figure 8.1 Location of the Release Sites

8.1.3.2 Hydrocarbon Exposure Levels

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 exposure levels were considered for the risk assessment as follows:

- Surface hydrocarbon exposure levels, to assess physical effects on sensitive receptors offshore;
- Shoreline accumulation levels, to assess physical effects on sensitive receptors onshore; and
- Water column exposure levels, to assess toxicity effects to sensitive receptors offshore from entrained and dissolved aromatic hydrocarbons.

The hydrocarbon exposure levels are summarised in Table 8-5.

These exposure levels are consistent with the exposure levels for floating, shoreline, dissolved and entrained hydrocarbons recommended by NOPSEMA in the Bulletin #1 “Oil spill modelling” April 2019 (NOPSEMA 2019a).

Refer to Appendix G, for supporting information on the justification of the adopted exposure levels.

Table 8-5 Hydrocarbon Exposure Levels

Exposure Type	Hydrocarbon Concentration	Potential Level of Exposure	Summary Description
Surface Exposure (g/m^2)	1	Low	Visible sheen on sea surface. Below levels which cause environmental harm. Indicative of perceived impacts and areas that may be temporarily closed as a precautionary measure.
	10	Moderate	Potential for ecological impacts, including impacts to birds, marine mammals and other marine fauna at the sea surface. Lowest “actionable” level where spill response may be possible.
	50	High	Approximates surface slick and informs spill response planning and prioritisation.
Shoreline Contact (g/m^2)	10	Low	Indicative of perceived impacts and shorelines that may be temporarily closed as a precautionary measure.
	100	Moderate	Potential for sub-lethal and lethal impacts to shorebirds, mammals and reptiles. Acceptable minimum thickness for effective shoreline clean-up efforts.
	1,000	High	Potential significant impacts to coastal vegetation, including mangroves and marshes. Likely to require intensive clean-up effort.
Dissolved Hydrocarbon Concentration (ppb)	10	Low	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.
	50	Moderate	Represents potential toxic effects, particularly sub-lethal effects to highly sensitive organisms and life stages of fish and invertebrates (e.g. larvae, plankton).
	400	High	Represents toxic effects including lethal effects to sensitive species.
Entrained Concentration (ppb)	10	Low	This value establishes the planning area for scientific monitoring based on potential for exceedance of water quality triggers.
	100	High	Represents potential toxic effects, particularly sub-lethal effects to highly sensitive organisms and life stages.

8.1.3.3 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.

It is important to note that diesel can contain some heavy components (or low volatile components) that have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves, but can re-float to the surface if these energies abate. In the event of a substantial diesel spill, the heavier components of diesel can remain on the sea surface for an extended period. As brightly coloured and silvery reflective sheens, which are highly visible, but below levels which could be responded to effectively and could cause any potential environmental harm.

Table 8-6 details the physical properties of MDO, while Table 8-7 presents the boiling point ranges of 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 (ºC)	-14
Wax content (%)	1
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light – Persistent Oil

Table 8-7 Boiling Point Ranges of MDO

Characteristic	Not Persistent			Persistent
	Volatile	Semi-volatile	Low volatility	Residual
Boiling point (ºC)	<180	180-265	265-380	>380
Percent (%)	6.0	34.6	54.4	5.0

Table 8-7 shows the weathering graphs for a 1,062 m^3 release of MDO over 6 hours (tracked for 40 days). 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.

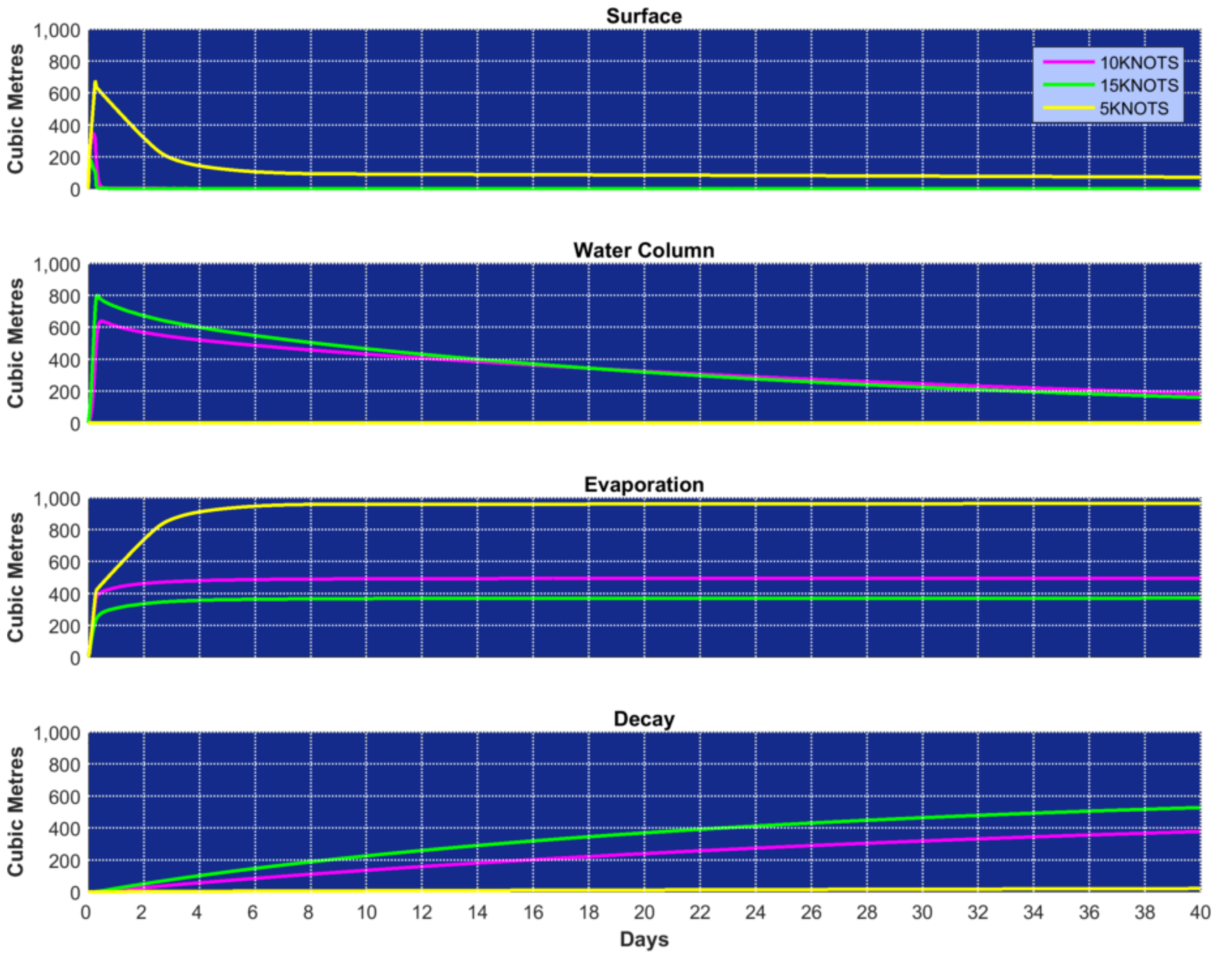

Figure 8.2 Weathering and fate graph, as a function of volume under 5, 10 and 15 knot static wind conditions. Results are based on a 1062m^3 surface release of MDO over 6 hours (tracked for 40 days)

8.1.3.4 EMBA Definition

For the purposes of this EP, and for the assessment of the potential impacts and risks associated with the worst-case credible hydrocarbon spill of 1,062 m^3 within the Operational Area, the environment that may be affected (EMBA) has been defined based on:

- the maximum extent of shoreline accumulation above the low exposure level (10 g/m^2);
- the maximum extent of sea surface exposure above the low exposure level (10 g/m^2);
- the maximum extent of dissolved hydrocarbons above the moderate exposure level (50 ppb): and
- the maximum extent of the entrained hydrocarbons above the high exposure level (<100 ppb).

Note that the zone of potential exposure to dissolved hydrocarbons above the low exposure level (10 ppb) falls within the defined EMBA.

The levels used to define the EMBA account for ecological impacts. However, the lower surface and shoreline exposure levels are also considered in the risk assessment in relation to perceived affects due to visible hydrocarbon sheens that may result in area closures of areas and potential socio-economic impacts. Refer to Figure 4.1 for a visual representation of the EMBA.

8.1.4 Spill Modelling Results

8.1.4.1 Sea Surface Exposure

Table 8-8 summarises the maximum sea surface exposures for the three release sites assessed by the stochastic modelling. Figure 8.3 shows the maximum areas of exposure on the sea surface produced by overlaying the results from all 300 simulations for release sites 1, 2 and 3.

The maximum distance from a release site to the low (1-10 g/m^2) surface exposure level was 35.7 km, 28.5 km and 115 km for release sites 1, 2 and 3, respectively. The maximum distance and direction from a release site to the moderate (10-50 g/m^2) surface exposure level (the lower limit for harmful surface exposures to birds and marine mammals) was 20.1 km, 23.5 km and 66.4 km for release sites 1, 2 and 3, respectively. Greater current speeds further offshore result in surface exposures from release site 3 being transported greater distances compared with release sites 1 and 2.

Surface exposures from release sites 1 and 3 occur only in offshore Commonwealth waters. Release site 2 is located approximately 9.3 km from the State waters boundary surrounding Bedout Island and just 115 m from the boundary of the Eighty Mile Beach AMP (note, the Operational Area is located 30 km from the boundary of the Eighty Mile Beach AMP). Consequently, low, moderate and high surface exposures were predicted to reach the Eighty Mile Beach AMP in all simulations, with a 35%, 15% and 5% probability of low, moderate and high surface exposures reaching State waters at Bedout Island, respectively.

The results represent the total exposed area resulting from all 300 simulations at each release site over the total 40-day model duration. At any one point in time, the sea surface area exposed during an actual spill would be significantly smaller. To provide an indication of the potential sea surface area that may affected at any point in time during a spill, deterministic modelling of a single spill trajectory was undertaken to assess the largest exposed area on the sea surface resulting across all 300 simulations, which resulted from release site 3.

The maximum area of coverage by surface hydrocarbons exceeding high exposure zones (>50 g/m^2) was predicted to occur 6 hours into the simulation and covered approximately 5.9 km^2. Note, no zones of high exposure (>50 g/m^2) remained on the sea surface after 18 hours. The maximum area of coverage by surface hydrocarbons exceeding moderate exposures (10 g/m^2) was predicted to occur between 6 hours and 1.5 days following the spill start and covered approximately 16 km^2 (Figure 8.4). After 2.75 days, as a result of evaporation and dispersion, no actionable surface hydrocarbons (exceeding the moderate exposure value [10 g/m^2]) remained. The maximum area of coverage of visible surface hydrocarbons (1 g/m^2) was predicted to occur between day 2.5 and 3.5 and covered approximately 50 km^2 (Figure 8.5). No visible surface hydrocarbons remained after 8.75 days after the release.

Table 8-8 Maximum Distances from each Release Site to Zones of Potential Oil Exposure on the Sea Surface

Release site	Distance and direction	Zones of potential sea surface exposure		
		Low (1-10 g/m^2)	Moderate (10-50 g/m^2)	High (>50 g/m^2)
1	Maximum distance from release site (km)	35.7	20.1	12.4
	Direction	Southeast	West-Northwest	West-Northwest
2	Maximum distance from release site (km)	28.5	23.5	19.0
	Direction	Northwest	Northwest	West-Northwest

3	Maximum distance from release site (km)	115.0	66.4	18.5
	Direction	West-Northwest	South-Southwest	West-Southwest

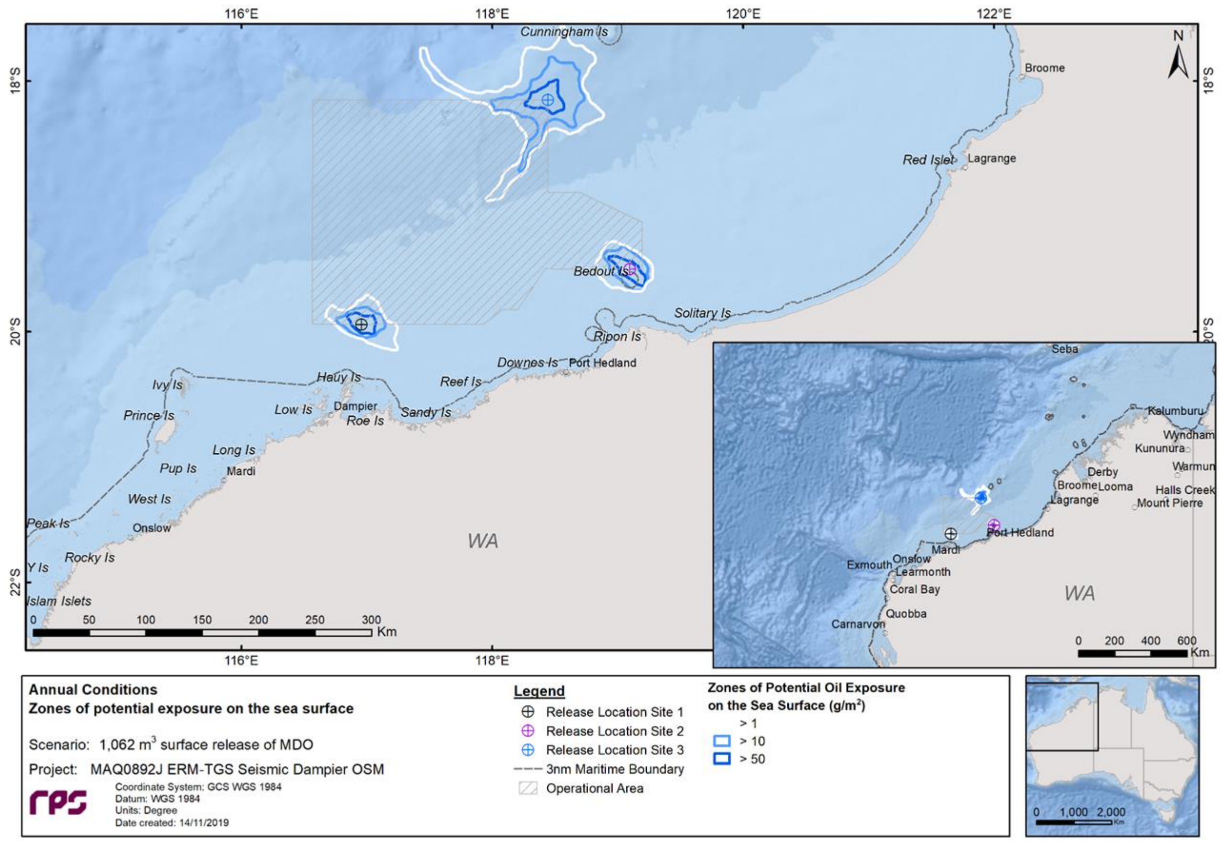

Figure 8.3 Maximum Areas of Sea Surface Exposures Produced from all 300 Simulations for Release Sites 1, 2 and 3, Tracked for 40 Days

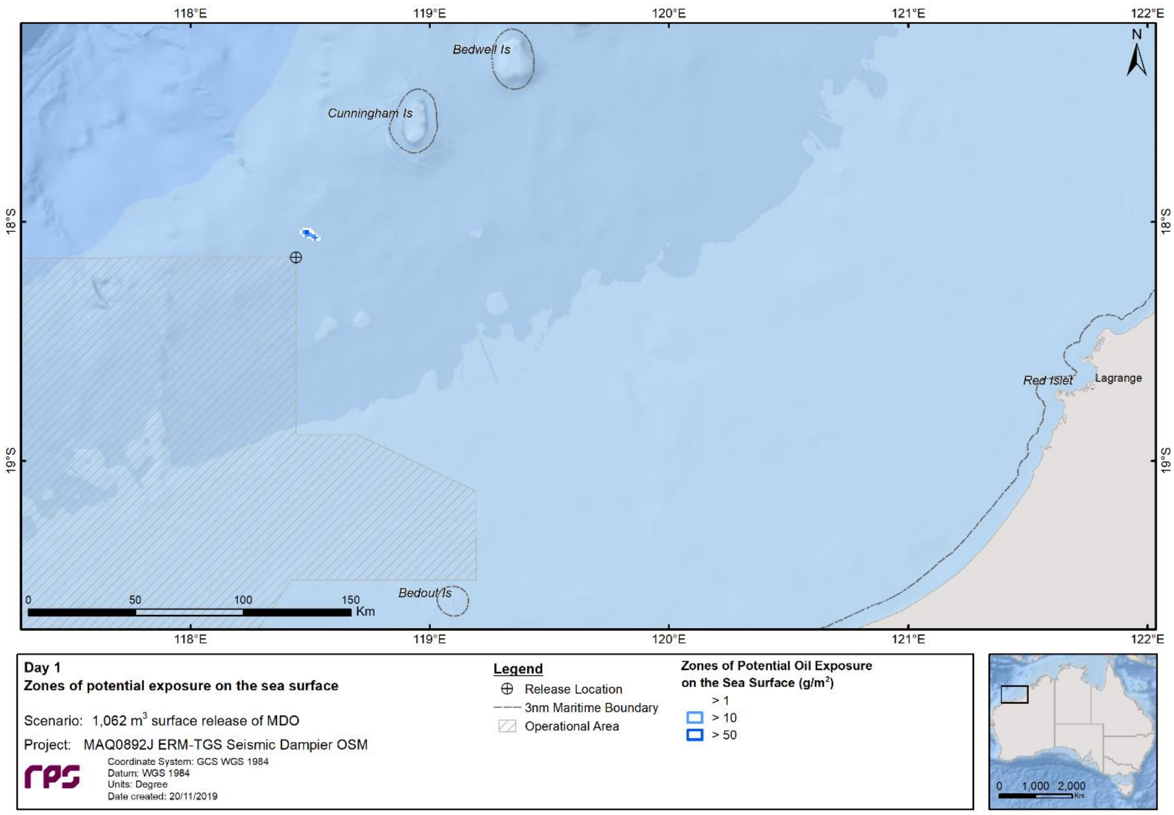

Figure 8.4 Maximum Potential Area of Exposure on the Sea Surface (>10 g/m^2) on Day 1 of the Deterministic Model Simulation

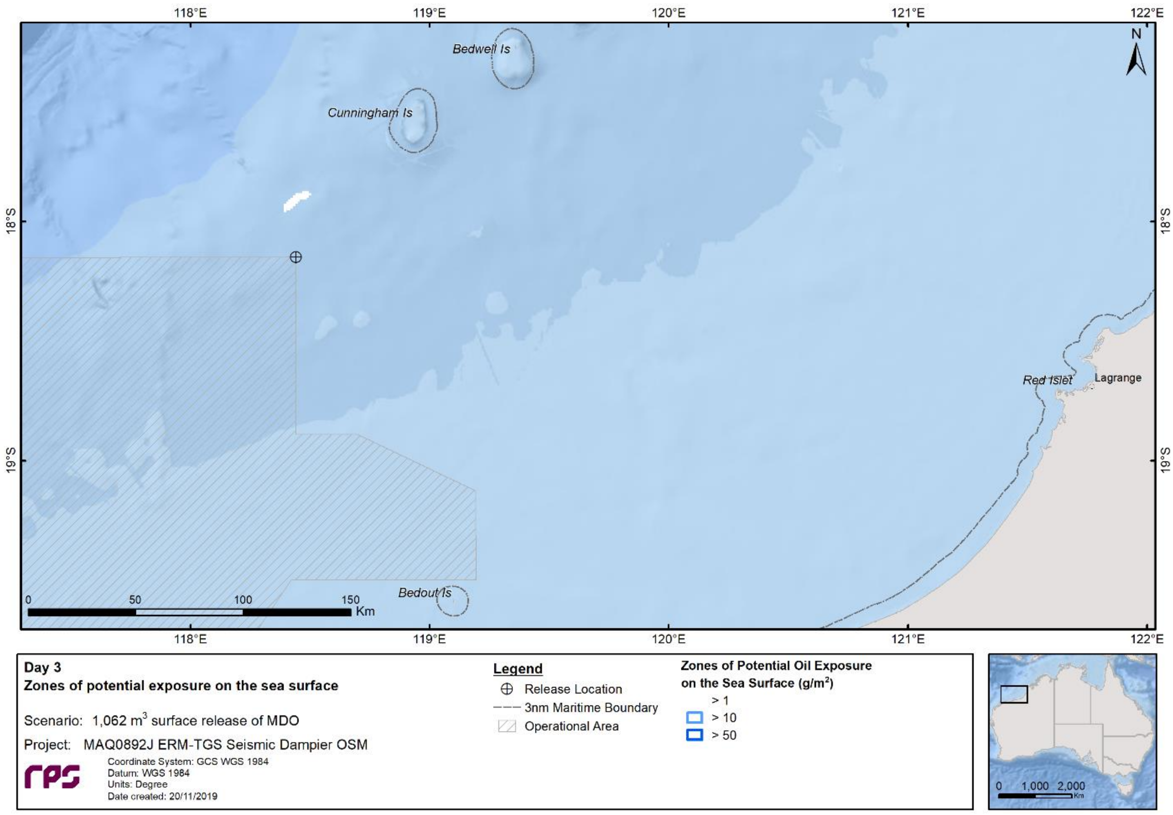

Figure 8.5 Maximum Potential Area of Exposure on the Sea Surface (>1 g/m^2) on Day 3 of the Deterministic Model Simulation

8.1.4.2 Shoreline Accumulation

Hydrocarbon contact and accumulation is only predicted to occur at Bedout Island from spills originating at Release Site 2 (9.3 km from Bedout Island. Note, Bedout Island is located 44 km from the Operational Area). This release site represents the location within the Operational Area that is closest to Bedout Island or any other shoreline. Table 8-9 presents a summary of the predicted shoreline contact at Bedout Island based on 100 spill trajectories at release site 2. The maximum length of shoreline contacted by hydrocarbons exceeding 100 g/m^2 from any single spill simulation (3 km) represents the entire length of shoreline at Bedout Island.

No shoreline contact was predicted to occur at any other location or from spills originating at release site 1 (closest to the shorelines of the Dampier Archipelago) or release site 3 (closest to the shorelines and emergent reefs of the Rowley Shoals).

Table 8-9 Summary of Shoreline Accumulation Statistics at Bedout Island

Shoreline statistics	Bedout Island – Release Site 2
Probability of contact to any shoreline (%)	7
Absolute minimum time for visible oil to shore (hours)	8
Maximum volume of hydrocarbons ashore (m^3)	72.3
Average volume of hydrocarbons ashore (m^3)	10.7
Maximum length of the shoreline at **10 g/m^2** (km)	3.0
Maximum length of the shoreline at **100 g/m^2** (km)	3.0
Maximum length of the shoreline at **1,000 g/m^2** (km)	2.0

8.1.4.3 Water-Accommodated (Dissolved and Entrained) Hydrocarbons

Spilled hydrocarbons may enter the upper water column through entrainment of droplets by wind and wave action, and from the dissolution of the soluble aromatic hydrocarbon fractions (i.e. polycyclic aromatic hydrocarbons - PAHs). Both the dissolved and entrained phases may result in impacts to marine organisms.

Dissolved hydrocarbons are known to be the primary source of toxicity exerted by hydrocarbons. Dissolved hydrocarbons are bioavailable and taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract (RPS 2020; Appendix G). These bioavailable hydrocarbons are broken down by microbial decay and biodegradation. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets (RPS 2020; Appendix G).

Entrained hydrocarbons refer to the droplets of oil within the water column. The toxicity of entrained hydrocarbons is determined by the content of soluble aromatics. Entrained hydrocarbons that are significantly weathered and have lost much of their soluble aromatic content (dissolved hydrocarbons) comprise insoluble hydrocarbons that are less toxic, but have the potential for physical effects to marine organisms through direct contact with tissues of organisms (such as adhering to fish gills or filter feeding organisms) and uptake of oil droplets by direct consumption (RPS 2020; Appendix G).

Therefore, dissolved hydrocarbons represent the hydrocarbon phase with the main potential for toxicity effects, while entrained hydrocarbons have the potential for physical effects. Given their inherent relationship, the modelling results for dissolved and entrained hydrocarbons are described together.

Dissolved and entrained hydrocarbons are predicted to be limited to the upper 20 m of the water column and principally within the upper 10 m. Therefore, exposure of offshore benthic habitats and communities (such as at Glomar Shoal) is not predicted to occur.

Figure 8.6 and Figure 8.7 show the zones of dissolved and entrained hydrocarbon exposures in the 0-10 m depth layer produced by overlaying the results from all 300 simulations originating from Release Sites 1, 2 and 3.

Dissolved hydrocarbons that exceed the moderate (50 ppb) exposure level (indicative of potential ecological impacts) may occur up to approximately 75 km from some release locations (Figure 8.6). Entrained hydrocarbons are predicted to exceed exposure levels at greater distances from the release sites (Figure 8.7). At these greater distances, the most toxic hydrocarbons will have dissolved and so the entrained oil has reduced potential for toxicity effects.

The exposure levels predicted at specific receptor locations are discussed in the evaluation of impacts and risks in Section 8.1 below, where applicable.

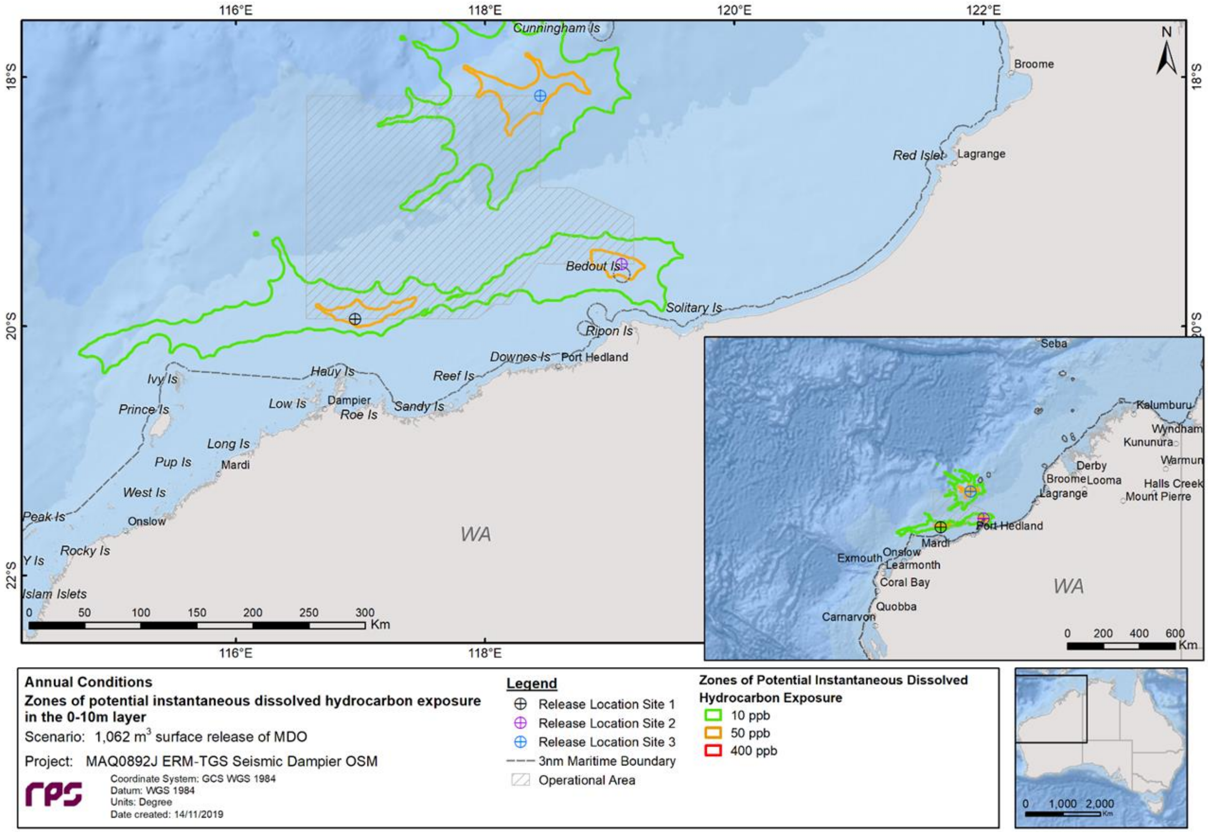

Figure 8.6 Maximum Potential Area of Dissolved Hydrocarbon Exposure in the 0 – 10 m Layer Produced from all 300 Simulations for Release Sites 1, 2 and 3, Tracked for 40 days

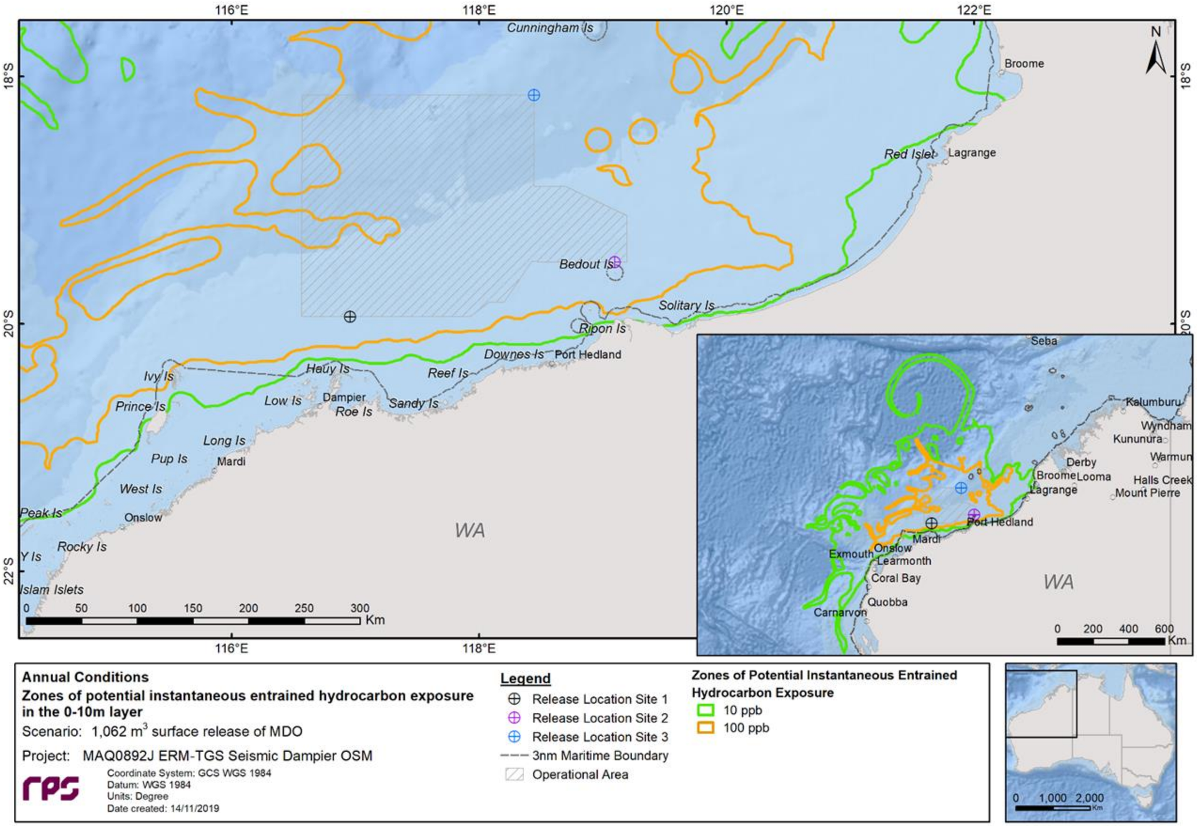

Figure 8.7 Maximum Potential Area of Entrained Hydrocarbon Exposure in the 0 – 10 m Layer Produced from all 300 Simulations for Release Sites 1, 2 and 3, Tracked for 40 Days

8.2 Hydrocarbon Spill: Vessel Tank Failure

8.2.1 Assessment Summary

Source of Impact / Risk

An accidental hydrocarbon release to the marine environment could result from a vessel fuel tank failure, following a vessel collision. The potential hazards associated with the release of large volumes of marine diesel on to the sea surface within the Operational Area are temporary and localised reduction in water quality and temporary toxicity effects to marine biota.

If a collision involving the seismic vessel occurred, the worst case credible scenario would be the loss of the largest single fuel tank volume, which is 1,062 m^3 of MDO, as described in Section 8.1.2.

Receptors

- Water quality;
- Benthic habitats, communities and shoreline habitats (Bedout Island);
- Marine fauna:
  - Cetaceans;
  - Marine reptiles;
  - Marine birds;
  - Fishes and elasmobranchs;
  - Planktonic communities (zooplankton, fish eggs and larvae);
- Marine protected areas;
- Commercial fisheries;
- Commercial shipping;
- Tourism and recreation.

Summary of Impacts and Risks

A vessel fuel tank failure spill of up to 1,062 m^3 of MDO may result in localised exposures of receptors to surface, dissolved and entrained hydrocarbons. Potential exposures to spilt surface oil >10 g/m^2, considered representative of potential lethal and sub-lethal impacts to marine fauna such as turtles, cetaceans and marine birds are expected to be limited to a localised area for a few days at most. Acute (short-term) exposures of marine fauna to dissolved and entrained concentrations are also expected to result in limited impacts and population level impacts are not expected.

In the highly unlikely event that a spill occurs in close proximity to Bedout Island, MDO that reaches the shoreline may impact regionally significant resident breeding populations of seabird and migratory shorebird species. Impacts to turtle nesting and hatchlings are not expected as the seismic vessel is not planned to operate near Bedout Island during the turtle nesting and internesting period.

Therefore, worst case impacts are expected to be limited to sub-lethal impacts or potential mortality to a small number of individuals, although shoreline impacts to birds at Bedout Island have the potential to be significant.

A spill may also result in temporary closures and disruption to on-the-water stakeholders, primarily commercial fisheries, commercial shipping, recreation and tourism operators.

Decision Context

A	The decision context for a worst-case hydrocarbon spill as a result of a vessel collision and fuel tank failure has been assessed as 'Type A', given the impact and risks associated with vessel based marine diesel spills are well understood. Given the non-persistent nature of marine diesel and predictive modelling undertaken for multiple

	release locations within the Operational Area, uncertainty is minimal and there is limited stakeholder interest in marine diesel spills from a survey vessel.		
Adopted Control Measures			**EPS #**
Seismic survey vessel will utilise MDO, which is stored in multiple fuel tanks on board. Fuel tanks can be isolated and contents transferred between them.			9.1
Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.			9.2
Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent and crew are trained in its implementation.			9.3
Vessels will adhere to the 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.			9.4
Notification to stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing.			9.5
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.			9.6
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).			9.7
Daily look-ahead reports will be provided to stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.			9.8
At least one support vessel (supply or chase vessel) will accompany the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with other marine users.			9.9
In the event of a spill to the marine environment, the OPEP presented in Section 10.4.2 will be implemented.			9.10
Vessels will not operate within 40 km of the State waters limit surrounding Bedout Island during the flatback turtle internesting season (October to March).			9.11
Vessels will not conduct side-by-side activities (e.g. refuelling, re-provisioning) within 40 km of the State waters limit surrounding Bedout Island at any time.			9.12
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Major	Unlikely	**Medium**
Residual Risk	Major	Remote	**Low**

8.2.2 Detailed Evaluation of Impacts / Risks

An accidental hydrocarbon release to the marine environment could result from a vessel fuel tank failure, following a vessel collision. As identified in Section 4.5, 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.

The likelihood of predicted worst-case impacts occurring to marine receptors from a vessel fuel tank release depends upon the likelihood of a vessel collision occurring, the likelihood of a fuel tank being ruptured and releasing its full contents as a result of the collision, plus the likelihood that a release occurs in a location and at a time where the worst-case exposures and impacts to receptors may occur.

AMSA have assessed the likelihood and risk of marine oil spill occurring in Australian waters (DNV 2011). The potential frequency of a spill from a vessel exceeding 100 tonnes in waters offshore from Port Hedland was found to range from a 1 in 10 to 100 year event within 50 Nm of the coast where shipping traffic is greatest. These waters are representative of parts of the Operational Area that overlap shipping fairways extending from the port of Port Hedland. The potential frequency of a similar spill occurring in waters further offshore from Port Hedland was found to range from a 1 in 100 to 1,000 year event (DNV 2011). Consistent with the TGS risk assessment methodology and terminology in Section 6, the likelihood of such an event is defined as possible to unlikely. Note, however, that the frequencies predicted in DNV (2011) relate to a spill from any vessel during a year; the likelihood of a spill occurring from a specific individual vessel is less, therefore the likelihood of spill occurring from the seismic vessel or a support vessel during the Capreolus-2 3D MSS is unlikely. The likelihood that a full tank volume is lost and a release occurs in a location and at a time where the worst-case exposures and impacts to receptors occur is also generally less. Therefore, the overall likelihood of the worst-case consequences described below for individual receptor categories is considered to be highly unlikely to remote.

8.2.2.1 Water Quality

Water quality will be reduced within the footprint of the marine diesel spill, with total hydrocarbons in the water column elevated above background levels and/or national/international water quality standards. Surface, dissolved and entrained hydrocarbons are predicted by the modelling to exceed the low exposure values associated with water quality triggers at maximum distances of 115 km, 75 km and several hundred kilometres respectively. However, these distances do not represent a continuous slick or area of contamination. For example, deterministic spill modelling of the largest potential surface exposures (RPS 2020; Appendix G) predicts that the maximum area of coverage by surface hydrocarbons exceeding 1 g/m^2 is 50 km^2. The areas of dissolved and entrained hydrocarbons will also comprise isolated and patch occurrences. Due to evaporation, dispersion and degradation of the marine diesel, all hydrocarbons above water quality trigger values are expected to have disappeared within a timeframe in the order of weeks following the spill (RPS 2020; Appendix G). Therefore, impacts to water quality would be temporary and highly localised in nature.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of temporary and localised impacts to water quality is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.2 Benthic and Shoreline Habitats and Communities (Bedout Island)

Surface, dissolved and entrained hydrocarbons in the upper water column (top 20 m) are not expected to result in exposure of benthic habitats and communities in deep offshore waters. However, spilled hydrocarbons may reach Bedout Island where the subtidal fringing coral reef may be exposed to dissolved and entrained hydrocarbons, and hydrocarbons may accumulate on the sandy shoreline.

Exposure of entrained and dissolved hydrocarbons to shallow subtidal corals has the potential to result in lethal or sublethal toxic effects, resulting in acute impacts or death at moderate to high exposure thresholds (Loya & Rinkevich 1980; Shigenaka 2001). Potential effects include increased mucus production, impaired respiration and photosynthesis by zooxanthellae, decreased growth rates, tissue decomposition, decline in metabolic rates, and expulsion of zooxanthellae (Peters et al. 1981; Knap et al. 1985; Negri and Heyward 2000). Adult coral colonies, injured by oil, may also be more susceptible to colonisation and overgrowth by algae or to epidemic diseases (Jackson et al. 1989).

However, such effects occur as a result of prolonged exposure and corals are not considered to be acutely sensitive to short-term elevations in oil concentrations (IPIECA 2015). The stochastic modelling predicts only a 1% probability of dissolved hydrocarbons exceeding the 50 ppb exposure value in State waters around Bedout Island, with the maximum dissolved hydrocarbon exposure level over 1 hour reaching 95 ppb. Therefore, impacts to the coral reef surrounding Bedout Island are unlikely to occur. Any response from corals to momentary increases in hydrocarbons may not be discernible from natural changes and variability in the reef.

In the evet of a spill near Bedout Island, modelling predicts a 7% probability of shoreline contact and accumulation. The sandy shoreline of Bedout Island is unlikely to experience significant impacts to habitat structure and community function. Sandy shorelines are considered to be of low environmental sensitivity and impacts are typically short term because hydrocarbons are usually removed rapidly by water movement, contamination does not persist for long in the relatively coarse sediments and any recovery of affected communities of animals living within the sediment is a function of natural ecological processes (IPIECA 2015; 2016). Therefore, shoreline impacts are expected to be short-term. However, it is recognised that Bedout Island supports protected species such as marine turtles and birds and impacts to these fauna are assessed further below.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of short-term impacts to shallow benthic habitats and shoreline sediment quality at Bedout Island is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.3 Cetaceans

No critical habitats or aggregation areas (feeding, breeding, nursing, resting) for cetaceans have been identified within the EMBA or adjacent waters. Seasonal BIAs have been defined for the migration pathways of two species:

- Humpback whale migration in the southern portion of the Operational Area and EMBA between June and October; and
- Pygmy blue whale migration along the continental shelf edge in the northern portion of the Operational Area and EMBA between April and August (northern migration) and between October and December (southern migration).

Therefore, cetaceans within the EMBA are generally expected to be transient and are unlikely to remain in the vicinity of spilled hydrocarbons for extended periods.

It is noted that TGS will not acquire within the southern part of the Operational Area during the humpback whale peak migration (July – October), or in the northern part of the Operational Area during the pygmy blue whale migrations (April – August and October – December). Therefore, in the already unlikely event that a spill occurs, there is limited potential for freshly spilled hydrocarbons to occur within the migration BIAs.

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 (Geraci et al. 1990; Geraci et al. 1983; Smith et al. 1983; Würsig 1990). 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.

As air-breathers, marine mammals, if they surface, are vulnerable to exposure to hydrocarbon spill impacts through skin contact, inhalation or ingestion of hydrocarbons. Direct contact with hydrocarbons may result in eye irritations and skin lesions (AMSA 2019a), however, oil does not easily adhere to cetaceans relatively smooth skin and it would not be expected to accumulate in or around the eyes, mouth, blow hole, or other potentially sensitive external areas (Helm et al. 2015). Insulation in cetaceans is provided by a layer of blubber rather than hair or fur, so it is unlikely oil would compromise the thermoregulatory ability of cetaceans (Helm et al. 2015). Dissolved hydrocarbons in the water column may also result in eye irritation, but are not likely to have any lasting effect on cetacean's eyes, even at high concentrations, because of the very brief exposure period.

The inhalation of evaporating volatiles compounds may lead to damage to lungs and airways (Helm et al. 2015; AMSA 2019a). For the short time that the majority of volatile components of the spilled marine diesel are present (approximately the first day of the spill), vapours from the spill are considered the most significant risk to cetacean health. Vapours, if inhaled, have the potential to damage the mucous membranes of the airways. Inhaled volatile hydrocarbons are transferred rapidly to the bloodstream and may accumulate in tissues, such as in the brain and liver, resulting in neurological disorders and liver damage (AMSA 2019a; Gubbay & Earll 2000; Etkins 1997).

Baleen whales such as pygmy blue whales and humpback whales that may filter-feed or gulp-feed near the surface are more likely to ingest hydrocarbons at the surface and within the upper water column than toothed-whales and dolphins that target specific prey items throughout the water column. Spilled hydrocarbons may also foul the baleen fibres of baleen whales, thereby decreasing the ability to intake prey (AMSA 2019a). If the prey of cetaceans (fish and plankton) is also contaminated through exposure and uptake of high hydrocarbon concentrations, which can result in the absorption of the toxic aromatic components of the hydrocarbons (AMSA 2019a).

The deterministic spill modelling of the largest potential surface exposures (RPS 2020; Appendix G) predicts that the maximum area of coverage by surface hydrocarbons exceeding the high exposure value (>50 g/m^2) covers approximately 5.9 km^2. This occurs only for a brief period 6 hours after the commencement of the release and rapidly disperses so that no hydrocarbons exceeding 50 g/m^2 remain after 18 hours. These high surface exposures are most likely to result in effects to cetaceans, particularly through inhalation of volatile compounds. The maximum area of coverage by surface hydrocarbons exceeding moderate exposures (10 g/m^2) was predicted to occur between 6 hours and 1.5 days following the spill start and covered approximately 16 km^2, dispersing after 2.75 days. Less severe effects are expected from these exposures. Therefore, the greatest potential for effects to cetaceans is limited to approximately the first day of the spill and no harmful exposures are expected anywhere after 2-3 days. Given the relatively localised and temporary areas exposed, only a limited number of cetaceans (e.g. individuals or small groups) may be exposed. The potential for lethal effects would be limited to significant inhalation or ingestion of hydrocarbons during the first few hours of the spill. Otherwise, effects are more likely to be sub-lethal, but may still result in tissue damage and disorders in some individuals. Low numbers of cetaceans may be effected and populations are not expected to be compromised.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of potential lethal or sub-lethal impacts to a small number of cetaceans exposed to hydrocarbons is **Moderate**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.4 Marine Reptiles

The EMBA overlaps with the internesting BIA and Habitat Critical for flatback turtles. Internesting BIAs and Habitat Critical for green, hawksbill and loggerhead turtles are located approximately 30 km south-west of the Operational Area. A turtle foraging BIA has been defined for waters approximately 1 km south of the Operational Area and it is possible that transient marine turtles may occur within the Operational Area. Turtle foraging and nesting may also occur at Bedout Island (approximately 44 km from the Operational Area), although the island is not designated as a BIA. Sea snakes may also occur within the EMBA, although no significant habitats have been designated as BIAs.

It is noted that TGS will not acquire within the southern part of the Operational Area during the nesting period for marine turtles along this stretch of coastline (October – March). Consequently, survey acquisition and associated vessel activities will be located approximately 40 km from Bedout Island during the nesting period (note, the Operational Area is located 44 km from Bedout Island). Therefore, in the already unlikely event that a spill occurs, there is limited potential for freshly spilled hydrocarbons to occur near nesting beaches or foraging habitats, including Bedout Island.

Adult sea turtles exhibit no avoidance behaviour when they encounter hydrocarbon slicks (Odell and MacMurray 1986; Milton et al. 2003). 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 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).

Similar to cetaceans, turtles are primarily affected by contact with floating hydrocarbons and inhalation of volatile hydrocarbons evaporating from on the sea surface. The greatest potential for lethal effects to turtles is limited to within a few kilometres of the release location for approximately the first day of the spill when surface exposures may exceed 50 g/m^2. Sub-lethal or lethal effects may also occur where surface hydrocarbon exposures exceed 10 g/m^2 which may occur up to 2-3 days after the spill. Turtles and sea snakes may also be exposed to dissolved and entrained hydrocarbons in the upper water column for short periods, which may cause eye irritation, but are unlikely to result in long term impacts given the relatively short exposure periods.

Hydrocarbons that accumulate on the shore of nesting beaches, such as at Bedout Island, may result in impacts to nesting adults, reduced hatching rates, or developmental abnormalities in hatchlings (French McCay 2016). Shoreline exposures of 100 g/m^2 or greater are considered to have the potential for lethal and sub-lethal effects (RPS 2020; Appendix G). Modelling for the release site closest to Bedout Island (9.3 km north of the island) predicts 7% probability of shoreline contact. The maximum length of shoreline that may be exposed to 100 g/m^2 is 3 km, which represents the entire shoreline of the island, though the average predicted length is 1.8 km. If such an event were to coincide with the turtle nesting period, some nesting adult turtles could experience lethal or sub-lethal effects, or the hatching success of eggs on the island or survival of the hatchlings could be compromised. However, given that TGS will not acquire within the southern part of the Operational Area during the nesting period (October – March), vessel activities will be located approximately 40 km from Bedout Island during the nesting period and so shoreline contact during the turtle nesting period is unlikely.

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.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of potential lethal or sub-lethal impacts to a small number of marine turtles exposed to hydrocarbons is **Moderate**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.5 Marine Birds

There are 23 seabird and migratory shorebird 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. As described in Section 4.5.9, the Operational Area overlaps with breeding BIAs for eight marine bird species and one resting BIA. Seabirds may also forage within the Operational Area.

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).

Sea surface exposures of 10 g/m^2 or greater have the potential to impact birds. The deterministic spill modelling of the largest area of potential surface exposures (RPS 2020; Appendix G) predicts that the maximum area of coverage by surface hydrocarbons exceeding 10 g/m^2 is approximately 16 km^2, which was predicted to occur between 6 hours and 1.5 days following the start of the release. Surface exposures of 10 g/m^2 or greater are unlikely to occur anyway after 2-3 days following a release. Secondary contamination through ingesting contaminated prey may also occur. Therefore, if seabirds are present on the sea surface or foraging near the release site in the first few days following the release, there is the potential for a range of sub-lethal and lethal impacts to occur.

Bedout Island 44 km to the south of the Operational Area is identified as one of several islands in the Pilbara region that provide important breeding and nesting habitat for birds, including brown booby, lesser crested tern and lesser frigatebird. Population estimates on Bedout Island include 1,000-10,000 breeding pairs of brown booby, 900-2,289 breeding pairs of lesser frigatebird, as well as smaller breeding populations of masked booby, white-bellied sea-eagle, silver gull, crested tern and lesser crested tern (Burbridge et al. 1987; BirdLife International 2020). The breeding population on the island represents one of the largest colonies of brown boobies in Western Australia (DEWHA 2008a). Breeding occurs during the autumn and winter months, commencing as early as February/March through to September/October for some species. Acquisition of the Capreolus-2 3D MSS in the southern part of the Operational Area may occur during this period, therefore, there is the potential for a vessel collision and spill to occur near Bedout Island during the breeding and nesting season.

In the unlikely event of a release in the Operational Area at a location closest to Bedout Island (Release Site 2, 9.3 km north of the island), modelling predicts a 15% probability of surface exposures of 10 g/m^2 or greater reaching State waters surrounding Bedout Island, and as soon as six hours after the release (RPS 2020; Appendix G). Shoreline contact and accumulation may begin to occur 8 hours following the release. The modelling also predicts 7% probability of shoreline contact. The maximum length of shoreline that may be exposed to 100 g/m^2 is 3 km, which represents the entire shoreline of the island, though the average predicted length is 1.8 km. While nesting birds will mainly be located on the upper foreshore, *Spinifex* grasses and vegetated areas of the island, which lie above the tide line, it is possible that a significant number of birds utilising the sandy foreshore may be exposed to hydrocarbons in the intertidal zone or while foraging in surrounding coastal waters. Exposure and fouling of feathers may also subsequently contaminate nests and eggs which could result in reduced hatching success or effect chick survival.

The potential for such shoreline exposures will remain for as long as hydrocarbons remain on the shore, but hydrocarbons may be remobilised and carried away on the next high tide and/or evaporation and weathering of the largely non-persistent hydrocarbons may occur so that harmful exposures are highly unlikely to remain after a few days. While the number of birds effected during the hours or days that the shoreline is exposed is unlikely to include every bird on the island, the number may still be significant, given the number of breeding pairs that may be present at the time. The number of birds that may be impacted may therefore comprise a measurable proportion of the breeding population on the island (or the WA breeding population of brown booby), although is unlikely to pose a threat to the viability of the overall population over the longer term.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of potential lethal or sub-lethal impacts to a small number of seabirds exposed to hydrocarbons is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

The consequence of potential measurable impacts to shorelines and the breeding populations of birds at Bedout Island, but with no threat to long term population viability, is conservatively assessed as **Major**, the likelihood of this consequence is **Remote** and the residual risk is considered to be **Low.**

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

8.2.2.6 Fishes and Elasmobranchs

Fishes and elasmobranches may primarily be effected by dissolved and entrained hydrocarbons in the upper water column. 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). In offshore waters near to the release point, demersal fishes are expected to be unaffected, as they will be at depths greater than near-surface hydrocarbons. Pelagic fish are potentially at risk of exposure to the more toxic aromatic components of marine diesel.

The effects of dissolved and entrained hydrocarbon exposures to fishes may occur through ingestion or gill contamination. 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 (Couillard et al. 2005; Theodorakis et al. 2012). However, toxic effects to fishes are expected to be limited as pelagic are highly mobile species and mortalities resulting from hydrocarbon spills in open waters are generally rare (Burns et al. 2011). Pelagic fish in offshore waters are highly mobile and comprise species such as tunas, mackerels and sharks. Due to their mobility, it is unlikely that pelagic fish would be exposed to toxic components for long periods of time, limiting the uptake of toxic aromatic compounds. Therefore, impacts to pelagic fishes from acute exposures to spilled hydrocarbons are expected to be limited. If pelagic fishes are affected, the effects are likely to be sub-lethal. The toxic components of the marine diesel would also rapidly weather and disperse so that concentrations would significantly diminish with distance from the spill site, limiting the potential area of impact.

Demersal fishes associated with reef habitat surrounding Bedout Island may also be exposed to dissolved and entrained hydrocarbons. However, the stochastic modelling predicts only a 1% probability of dissolved hydrocarbons exceeding the 50 ppb exposure value in State waters around Bedout Island, with the maximum dissolved hydrocarbon exposure level over 1 hour reaching 95 ppb. Therefore, impacts to the reef fishes at Bedout Island are unlikely.

The Operational Area overlaps with a foraging BIA for the whale shark. This migration and foraging route follows the continental shelf within the 200 m isobath and extends from Ningaloo to waters in the north Kimberley region. Individuals tagged at Ningaloo Reef have been shown to migrate north, north-east or north-west into Indonesian waters, using both inshore and offshore habitats (Reynolds et al. 2017; Sleeman et al. 2010; Wilson et al. 2006). The foraging BIA that overlaps the Operational Area represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November).

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 have been observed using two different feeding strategies, including passive sub-surface 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 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 whale shark BIA is not a known aggregation area and does not support whale sharks in high abundance in the way that Ningaloo Reef does. Instead, the Operational Area and surrounding waters of the EMBA will most likely be traversed by solitary 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. Although modelled entrained hydrocarbons are predicted to reach waters near Ningaloo Reef, the predicted concentrations are well below those that may result in impacts to whale sharks.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of temporary and localised impacts to fishes and elasmobranches exposed to hydrocarbons is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.7 Plankton, Fish Eggs and Larvae

Planktonic communities within the EMBA for a worst case marine diesel spill within the Operational Area will comprise zooplankton, including the 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 that different fish species may spawn at different times of year, the Capreolus-2 3D MSS has the potential to overlap with the spawning periods for some fish species.

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 the quick evaporation and dispersion of marine diesel, impacts to fish eggs and larvae are not expected to be significant.

Any planktonic communities impacts 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 in nature.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of temporary and localised impacts to planktonic communities exposed to hydrocarbons is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.8 Marine Protected Areas

The following assessment of potential impacts and risks to the values of AMPs and State Marine Parks from a worst case marine diesel spill within the Operational Area considers the potential impacts and risks to the relevant individual receptor categories assessed in the sub-sections above and below and the potential hydrocarbon exposures within each marine park.

Argo-Rowley Terrace AMP

The AMP supports a range of species including species listed as threatened, migratory, marine or cetacean under the EPBC Act. Biologically important areas within the AMP include resting and breeding habitat for seabirds, including white-tailed tropicbird which extends into the EMBA. As assessed in Section 8.2.2.5, any potential impacts to birds in these open waters are expected to be limited to individuals exposed to surface hydrocarbons in close proximity to the release within the first 2-3 days.

The migratory pathway for the pygmy blue whale is also a value of the AMP. As assessed in Section 8.2.2.3, the Capreolus-2 3D MSS will not be acquired within the northern part of the Operational Area during the pygmy blue whale migrations (April – August and October – December), therefore limiting the potential for pygmy blue whales to be exposed to hydrocarbons within the migration BIA. In the event of a spill low numbers of cetaceans may be effected and populations are not expected to be compromised.

Within the EMBA, the AMP includes the Mermaid Reef and Commonwealth waters surrounding Rowley Shoals KEF, which provides an area of enhanced productivity, aggregations of marine life and high species richness, including fish and sharks. Modelling predicts that the KEF may be exposed only to entrained hydrocarbon droplets, but not fresh surface hydrocarbons or dissolved aromatics. The entrained hydrocarbons will, therefore, contain limited toxic components by the time it reaches the KEF and marine life at the Rowley Shoals. As assessed in Section 8.2.2.6, acute exposures of mobile pelagic fish, sharks and other biota to elevated levels of entrained hydrocarbon droplets in the upper water column are expected to have limited impact.

Commercial fishing is also recognised as a socio-economic value of the AMP. In these offshore waters, the active commercial fishery is the North West Slope Trawl Fishery which targets scampi and demersal species in deep water. These species will not be exposed to hydrocarbons, which are limited to the upper water column. Further impacts to commercial fisheries are assessed below in Section 8.2.2.9.

Eighty Mile Beach AMP

The natural values of the AMP include BIAs for 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.

As assessed in Section 8.2.2.3, the Capreolus-2 3D MSS will not be acquired within the southern part of the Operational Area during the humpback whale peak migration (July – October), therefore limiting the potential for humpback whales to be exposed to hydrocarbons within the migration BIA. In the event of a spill low numbers of cetaceans may be effected and populations are not expected to be compromised.

As assessed in Section 8.2.2.4, the Capreolus-2 3D MSS will not be acquired within the southern part of the Operational Area during the nesting period for marine turtles (October – March). Therefore, limited impacts to turtle internesting and nesting habitats are predicted.

As assessed in Section 8.2.2.5, any potential impacts to birds in the open waters of the AMP are expected to be limited to individuals exposed to surface hydrocarbons in close proximity to the release within the first 2-3 days. Bird species supported within the AMP include species that breed and forage at Bedout Island (within State waters), where significant numbers of birds have the potential to be impacted in the remotely likely event that a major spill occurs in the vicinity of the island and causes significant contamination of shorelines. Control measure will be implemented to reduce the potential for such an event and prevent such impacts from occurring.

The spilled hydrocarbons, which are confined to the upper water column, are not expected to impact demersal fish populations. Nursing and pupping habitat for sawfish in coastal and estuarine waters of Eighty Mile Beach are not predicted to be exposed to harmful concentrations of hydrocarbons.

Recreation, tourism, commercial fishing and pearling are recognised socio-economic values of the AMP. The potential impacts to these values are assessed below in Section 8.2.2.9 to 8.2.2.11.

Montebello AMP

The natural values of the AMP include BIAs for breeding habitat for seabirds, internesting, foraging, mating, and nesting habitat for marine turtles, migrating humpback whales, and foraging habitat for whale sharks. The AMP also includes two prominent coral reefs called Trial Rocks. Tourism, recreation and commercial fishing are socio-economic values.

The Montebello AMP is located approximately 61 km south west of the Operational Area and the nearest possible release location. It is not predicted to be exposed to surface hydrocarbons or dissolved hydrocarbons above levels that may result in ecological impacts. The modelling predicts a 10% probability of entrained hydrocarbons above 100 ppb reaching the AMP. However, by the time the entrained hydrocarbons reach the AMP, they will have become significantly weathered and will contain limited toxic aromatic components. Although droplets could theoretically result in physical fouling of fish gills and filter feeding organisms, the short term and patchy occurrences of these micro droplets are not expected to result in any discernible ecological impacts or impacts to marine park values. Water quality triggers could be temporarily exceeded but no other impacts are predicted.

Other Marine Parks

Other marine parks that are predicted to be exposed to hydrocarbons within the EMBA include the Montebello Islands and Rowley Shoals State Marine Parks. However, in the already highly unlikely event of a spill, there is only a small probability (≤4%) of entrained hydrocarbons greater than 100 ppb reaching these marine parks. The short term and patchy occurrences of these micro droplets are not expected to result in any discernible ecological impacts or impacts to marine park values

It is also acknowledged that a number of other marine parks beyond the boundary of the defined EMBA may receive low entrained hydrocarbon exposures, including the Carnarvon Canyon, Dampier, Gascoyne, Roebuck and Ningaloo AMPs as well as the Eighty Mile Beach, Barrow Island and Ningaloo

State Marine Parks. The concentrations of entrained droplets that are predicted to occur here are below levels that may result in ecological impacts and therefore below the levels used to define the EMBA. Water quality triggers may be temporarily exceeded but no discernible impacts to marine park values are predicted.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of short term impacts to marine park values is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.9 Commercial Fisheries

A worst case marine diesel spill in the Operational Area is considered unlikely to cause significant direct impacts on the target fish species. As described in Section 8.2.2.6, demersal fishes will not be exposed to hydrocarbons in the upper water column (0-20 m depth) in the waters that are fished by the Pilbara Demersal Scalefish Fisheries. The effects of low and short term entrained and dissolved hydrocarbon exposures on invertebrates in coastal waters near where the Nickol Bay Prawn Fishery and Pearl Oyster Fishery operate are also expected to be negligible. Pelagic fishes, such as mackerels targeted by the Mackerel Managed Fishery, may be exposed to hydrocarbons in the upper water column near the release site, however, as described in Section 8.2.2.6, pelagic fish species are highly mobile and acute exposures are expected to have limited effects.

The main ways in which commercial fisheries may be impacted in the event of a marine diesel spill, include:

- Fishing closures, which may occur at locations where hydrocarbons are below levels that cause environmental harm, but where visible sheens on the sea surface result in perceived impacts and closure as a precautionary measure;
- Fouling of fishing gear and vessels with hydrocarbons in close proximity to the spill site; and
- Stakeholder and public perception that target fish and products may be affected by spilled hydrocarbons.

Such events could potentially lead to subsequent economic impacts on commercial fishing and pearling operators and seafood distributors. Visible hydrocarbons on the sea surface may persist for several days so any potential closures will be temporary (for example 1-2 weeks). The extent of visible hydrocarbons will also be limited relative to the fishing grounds available to each of the fisheries. However, some temporary economic impacts are possible.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of temporary displacement and economic impacts is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.10 Commercial Shipping

Shipping in the region includes relatively dense vessel traffic associated with the ports of Port Hedland and Dampier, including a defined network of marine fairways. In the event of a vessel collision and significant marine diesel spill, the AMSA Joint Rescue Coordination Centre may issue a warning to shipping traffic in the area to avoid the incident location. This may include the immediate area of the incident and an area where volatile aromatic vapours evaporating from the sea surface may present a safety hazard during the first day or so of the release. Some commercial shipping may be asked to deviate from their intended routes. However, with controls adopted as identified below, no significant implications to shipping traffic patterns are expected. Activities will be managed in accordance with well-established maritime practices.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of temporary displacement and economic impacts to commercial shipping is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.2.11 Recreation and Tourism

Recreational fishing occurs in coastal waters and to a lesser degree at offshore sites such as Glomar Shoals. Aquatic recreational activities such as boating, diving and fishing also occur in coastal waters, including around Bedout Island. In the unlikely event of a marine diesel spill, there is the potential for specific sites close to the spill or areas affected by visible hydrocarbons to be temporarily closed to recreational activities, which may inconvenience tourism and charter boat operators that may have to conduct their activities elsewhere.

Summary

Based on the assessment above and the implementation of the controls identified in Section 8.2.3, the consequence of temporary and localised impacts to recreation and tourism is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.2.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Vessels will adhere to the 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	Vessels will maintain appropriate lighting, shapes, radar navigation and communication in accordance with the requirements of the *Navigation Act 2012* and associated AMSA Marine Orders.
Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.	Yes	In accordance with the requirements of Annex I of MARPOL 73/78, vessels will have a SOPEP. The Vessel Master is responsible for activating and implementing the vessel SOPEP.
In the event of a spill to the marine environment, the OPEP presented in Section 10.4.2will be implemented.	Yes	In accordance with the requirements of the OPGGS (E) Regulations 2009, an OPEP accompanies this EP, which details the spill preparedness and response arrangements that will be implemented in the event of a spill. The OPEP includes arrangements for notifying AMSA and engaging the National Plan resources.
Good Industry Practice		
Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent and crew are trained in its implementation.	Yes	Vessels < 400T that do not have a SOPEP must have a spill response plan that deals with spill response, pollution monitoring and provisions for testing the plan (approved by TGS). The Vessel Master is responsible for activating and implementing the vessel SOPEP. Good industry practice, socio-economic benefit outweighs the additional cost.
Seismic survey vessel and support vessels will utilise MDO, which is stored in multiple fuel tanks on board.	Yes	The risk profile of a vessel fuel tank rupture is based on a release of MDO. Use of another fuel type, such as heavy fuel oil, would result in different impacts and risk due to the different oil characteristics. TGS will ensure the seismic vessel and support vessels use MDO.

Control Measure	Control Adopted	Justification
Fuel tanks can be isolated and contents transferred between them.		If a fuel such as HFO is on board the vessel prior to coming under contract to TGS, the HFO will either be removed or will be pumped to a central fuel tank that is not adjacent to the hull. Good industry practice, socio-economic benefit outweighs the additional cost.
Notification to stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing.	Yes	Notification will be provided to fisheries stakeholders 4 weeks prior to commencement of the survey. Implementation of the control will reduce the likelihood of interactions with marine users. Good industry practice, socio-economic benefit outweighs the additional cost.
Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Yes	AHS will be contacted 4 weeks prior to the commencement of the survey for the publication of related Notices to Mariners. This will ensure that marine users are aware of the survey. Implementation will reduce the likelihood of interactions with vessels. Good industry practice, socio-economic benefit outweighs the additional cost.
Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Yes	The AMSA JRCC will be contacted 24-48 hrs before operations commence for issuing of radio-navigation warnings. This will ensure that other vessels are aware of the survey. Implementation will reduce the likelihood of interactions. Good industry practice, socio-economic benefit outweighs the additional cost.
Daily look-ahead reports will be provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Yes	TGS will provide fisheries stakeholders with a daily look-ahead report, detailing the upcoming activities and planned seismic survey location within the next 72 hours. As part of this report, TGS will request information from commercial fishers on upcoming fishing activities for the next 24-72 hours. This will allow the seismic survey vessel to consider alternative lines, where practicable. Good industry practice, socio-economic benefit outweighs the additional cost.
At least one support vessel (supply or chase vessel) will accompany the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with marine users.	Yes	A support vessel will conduct advanced scouting when safe to do so (e.g. outside of inclement weather periods) to ensure that commercial fishers (and other marine users) in the area are provided with advance notice of seismic activities. Good industry practice, socio-economic benefit outweighs the additional cost.
Alternatives/Substitute Considered		
No practicable alternative	N/A	N/A
Additional Controls Considered		

Control Measure	Control Adopted	Justification
Vessels will not operate within 40 km of the State waters limit surrounding Bedout Island during the turtle internesting season (October to March).	Yes	The greatest potential risk to marine turtles in the event of a worst case spill is the potential for shoreline contamination at the nesting beach at Bedout Island. Seismic acquisition is planned to avoid the southern part of the Operational Area during the turtle internesting season, therefore, acquisition will occur approximately 50 km from Bedout Island at the closest point of approach during this season. Allowing for some additional vessel operating area around the planned acquisition lines, it is considered practicable to also avoid vessel activities within 40 km of the State waters limit surrounding Bedout Island during the turtle internesting season (October to March). Therefore, a spill will be prevented from happening in waters near Bedout Island during the nesting season and shoreline contact from hydrocarbons is highly unlikely to occur.
No vessel activities near Bedout Island during the main bird breeding season (February to October)	No	As outlined in Section 3.2 and Section 7.1, the survey schedule has been planned to reduce impacts to a number of receptors (turtles, humpback whales, commercial fisheries) from underwater noise impacts that may occur as a result of planned seismic acquisition activities. The southern portion of the Operational Area near Bedout Island can only be acquired in April or May. Therefore, it is not practicable to eliminate vessel activities in these waters during the bird breeding season.
Vessels will not conduct side-by-side activities (e.g. refuelling, re-provisioning) within 40 km of the State waters limit surrounding Bedout Island at any time.	Yes	Vessel side-by-side activities, which may restrict vessel manoeuvrability and reduce the vessel's ability to avoid other approaching vessels. Therefore, the potential for a vessel collision may increase if undertaking side-by-side activities. To reduce the risk, vessel procedures will confirm no side-by-side activities within 40 km of the State waters limit surrounding Bedout Island at any time. The only exception to this rule will be in a situation where the vessel or crew is immobilised and/or there is a risk to life that requires some side-by-side assistance from a support vessel, as determined by the Vessel Master.
Dedicated spill response vessel and resources on standby.	No	The option of having a dedicated spill response vessel on standby for the survey was discounted on the basis that the cost would be grossly disproportionate to any reduction in risk (which is already determined to be Low), particularly as the expected behaviour of an MDO spill would limit the effectiveness of on-water response options. Additional vessels could also increase the risk of interference and potential for collisions.
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risk of a hydrocarbon spill from a vessel fuel tank failure. 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.		

8.2.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	Given the very low likelihood of a vessel fuel tank rupture and subsequent worst-case impacts occurring, the residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing the risk of a hydrocarbon spill from a vessel fuel tank failure, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines The spill risk has been assessed based on the maximum case spill scenario identified in accordance with AMSA guidance on oil spill risk assessment (AMSA 2013a). Proposed controls are consistent with the National Plan and the NOPSEMA (2017) Information Paper on Oil pollution risk management.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles The risk of a worst-case spill event has the potential to result in lethal and sub-lethal effects to a small proportion of protected species that are prescribed as natural values of the north west AMP network. There is also the potential for localised and temporary disruption to socio-economic values of the AMP network. However, with the proposed preventative and mitigative control measures in place, no significant or long term impacts to species populations or marine parks values are expected. The Operational Area does not overlap with any AMPs, therefore, the activity will not be undertaken in a manner that is inconsistent with marine park zone rules. The objectives of the AMP Multiple Use Zone and Special Purpose Zones, consistent with IUCN management principles, is to provide for ecologically sustainable use and the conservation of ecosystems, habitats and native species. Given that a hydrocarbon spill and associated impacts are highly unlikely to occur, and any impacts caused by a spill will be localised and temporary, the activity and risks are not inconsistent with the objective for ecologically sustainable use.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to interactions with marine fauna during the survey. The risk is considered to be addressed and will be managed to acceptable levels.

Context	Factor	Demonstration
		OPEP arrangements are consistent with the National Plan, administered by AMSA. Details of the OPEP and potential hydrocarbon exposures and risks within State waters have also been provided to the WA Department of Transport.
Legislation, Conventions & Other	Legal Requirements	Preventative controls are consistent with COLREGS; SOLAS; the Navigation Act 2012 and associated AMSA Marine Orders. The SOPEP and OPEP controls are consistent with the requirements of AMSA Marine Orders made under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and also fulfil TGS' obligations under the OPGGS (E) Regulations and the National Plan for Maritime Environmental Emergencies which in turn provides for Australia's obligations under the International Convention on Oil Pollution Preparedness, Response and Co-operation 1990.

Industry Standards	Industry Best Practice	Control measures adopted are compliant with industry standards and best practice:
		■ IAGC Environmental Manual for Worldwide Geophysical Operations:
		    ▪ Implement SOPEPs in the event of a spill, adopt mitigation measures and incident reporting.
		■ APPEA Code of Environmental Practice
		    ▪ reduce impacts from spill events, with evidence of appropriate management procedures and emergency response plan in-place.

Ecological Sustainable Development (ESD)	ESD Application	The potential consequences of a spill of MDO include potential lethal and sub-lethal impacts to a relatively small number of marine fauna individuals; disruption to marine users; negligible impacts to fish, eggs and larvae that may receive low but chronic exposures of entrained hydrocarbons. It is highly unlikely that any population and stock level impacts would occur given the main window for exposure is within the first 24 hours of the spill and limited to within several kilometres of the release. With the proposed preventative and mitigative control measures in place, the likelihood of a vessel incident occurring, and resulting in a fuel tank rupture and the loss of a full tank volume, and resulting in the impacts described above is considered highly unlikely to remote. Therefore, the impacts and risks are not expected to result in lasting, serious or irreversible ecological damage and the activity is consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the risk of a hydrocarbon spill from a vessel fuel tank failure to an acceptable level.		

8.2.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 9 No release of hydrocarbons to the marine environment.	**9.1** **9.2** **9.3** **9.4** **9.5** **9.6** **9.7** **9.8** **9.9** **9.10** **9.11** **9.12**

8.3 Hydrocarbon Spill: Vessel Refuelling Failure

8.3.1 Assessment Summary

Source of Impact / Risk

An accidental MDO spill during vessel refuelling (up to 25 m^3) has the potential to result in the following adverse effects on the environment:

- Toxic effects on marine fauna that come into contact with surface hydrocarbons; and
- Toxic effects to juvenile fish, eggs and larvae from entrained hydrocarbon droplets.

Receptors

- Water quality; and
- Marine fauna (i.e. marine mammals, marine reptiles, seabirds, fishes/elasmobranchs, planktonic communities).

Summary of Impacts and Risks

A refuelling spill of up to 25 m^3 of MDO may result in localised exposure of receptors to localised surface and entrained hydrocarbons. Potential exposures to spilt surface oil >10 g/m^2, considered representative of potential lethal and sub-lethal impacts to marine fauna such as turtles, cetaceans and birds are expected to be limited to a localised area for a few hours or less than a day. Therefore, worst case impacts are expected to be limited to sub-lethal impacts or potential mortality to a small number of individuals Entrained exposures are also expected to be low, resulting in limited interactions with small numbers of fish, eggs and larvae in the upper water column that are largely incidental in nature.

Decision Content

A	The decision context for vessel refuelling failure has been assessed as 'Type A', given the risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

Adopted Control Measures	EPS #
Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.	9.2
Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent and crew are trained in its implementation.	9.3
In the event of a spill to the marine environment, the OPEP presented in Section 10.4.2 will be implemented.	9.10
Vessels will not conduct side-by-side activities (e.g. refuelling, re-provisioning) within 40 km of the State waters limit surrounding Bedout Island at any time.	9.12
Spill kits are available on board the seismic survey vessel and crew are trained in its implementation.	9.13
Dry-break couplings will be installed on refuelling hoses.	9.14
Refuelling operations will be undertaken within the Operational Area (unless as required in an emergency.	9.15
Refuelling operations will only take place during daylight hours and within strict weather limit guidelines.	9.16

Seismic survey vessel contractor procedures include requirements to be implemented during 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.			9.17
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Minor	Unlikely	**Low**
Residual Risk	Minor	Highly Unlikely	**Low**

8.3.2 Detailed Evaluation of Impacts / Risks

8.3.2.1 Water Quality

The accidental release of up to 25 m^3 of MDO to the marine environment may result in the temporary and localised reduction in water quality. The behaviour, weathering and fates of the spilt MDO are expected to be the similar to those described for a vessel fuel tank rupture (refer to Section 8.2) with the majority of the MDO forming a film on the surface and rapidly evaporating and dispersing following release, with a proportion becoming entrained in the upper water column by wind and wave action. Potential impacts are expected to be limited both temporally and spatially due to the expected small volumes spilt and rapid evaporation and dilution of the spill in the offshore marine environment.

8.3.2.2 Marine Fauna

Surface exposures are expected to rapidly fall below the 10 g/m^2 threshold considered representative of potential lethal and sub-lethal impacts to marine fauna (such as turtles, cetaceans and birds), with the greatest concentrations occurring for a brief period in the immediate vicinity of the spill in the Operational Area (e.g. a few hours or less than a day). Entrained exposures are also expected to be low, resulting in limited interactions with small numbers of fish, eggs and larvae in the upper water column that are largely incidental in nature. Potential impacts to marine fauna and fish assemblages are expected to be highlight localised and short-term.

8.3.2.3 Summary

Based on the assessment above and the implementation of the controls identified in Section 8.3.3, the consequence of a temporary reduction in water quality and short-term toxicity to marine fauna is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.3.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.	Yes	In accordance with the requirements of Annex I of MARPOL 73/78, vessels will have a SOPEP. By ensuring a SOPEP is in place for the vessel, the likelihood of a spill entering the marine environment is reduced.
In the event of a spill to the marine environment, the OPEP presented in Section 10.4.2 will be implemented.	Yes	In accordance with the requirements of the OPGGS (E) Regulations 2009, an OPEP accompanies this EP, which details the spill preparedness and response arrangements that will be implemented in the event of a spill.
Good Industry Practice		
Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent and crew are trained in its implementation.	Yes	By ensuring a Spill Management Plan is in place for the vessel, the likelihood of a spill entering the marine environment is reduced. Good industry practice, environmental benefit outweighs additional cost.
Spill kits are available on board the seismic survey vessel and crew are trained in its implementation.	Yes	By ensuring a spill kits are available on board, the likelihood of a spill entering the marine environment is reduced. Good industry practice, environmental benefit outweighs additional cost.
Dry-break couplings will be installed on refuelling hoses.	Yes	Dry-break couplings will be used to reduce the risk of a refuelling incident from occurring. Good industry practice, environmental benefit outweighs additional cost.
Alternatives/Substitute Considered		
No offshore refuelling. Refuelling in port only.	No	To reduce the potential for refuelling spills, consideration was given to refuelling only in port. Refuelling in port will be considered during the survey based on location of the vessel and any other requirements to go into port; however the requirement to return to port for all refuelling operations would increase survey duration, fuel use and associated vessel movements and emissions. The potential for near-shore interactions with other users of the area would also increase. As such, the option of requiring all refuelling to occur in port was not considered operationally viable and would not necessarily deliver a net reduction in environmental risk. Controls listed were deemed sufficient based on the nature and scale of the potential impacts and risk. No additional controls were identified to further reduce the likelihood or consequence.

Control Measure	Control Adopted	Justification
Additional Controls Considered		
Refuelling operations will be undertaken within the Operational Area (unless as required in an emergency.	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. Environmental benefit outweighs additional cost.
Refuelling operations will only take place during daylight hours and within strict weather limit guidelines.	Yes	Refuelling will only be undertaken during daylight hours and appropriate weather/sea conditions. Implementation of this control will reduce the risk of a refuelling incident from occurring. By limiting refuelling to daylight hours also reduces the likelihood of a spill entering the marine environment. Environmental benefit outweighs additional cost.
Seismic survey vessel contractor procedures include requirements to be implemented during 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.	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. Environmental benefit outweighs additional cost.
Survey vessels will not conduct side-by-side activities (e.g. refuelling, re-provisioning) within 40 km of the State waters limit surrounding Bedout Island at any time.	Yes	Vessel side-by-side activities, which may restrict vessel manoeuvrability and reduce the vessel's ability to avoid other approaching vessels. Therefore, the potential for a vessel collision may increase if undertaking side-by-side activities. To reduce the risk, vessel procedures will confirm no side-by-side activities within 40 km of the State waters limit surrounding Bedout Island at any time. The only exception to this rule will be in a situation where the vessel or crew is immobilised and/or there is a risk to life that requires some side-by-side assistance from a support vessel, as determined by the Vessel Master.
Dedicated spill response vessel and resources on standby.	No	The option of having a dedicated spill response vessel on standby for the survey was discounted on the basis that the cost would be grossly disproportionate to any reduction in risk (which is already determined to be Low), particularly as the expected behaviour of an MDO spill would limit the effectiveness of on-water response options. Additional vessels could also increase the risk of interference and potential for collisions.

Control Measure	Control Adopted	Justification
ALARP Statement		
The decision context has been assessed as Type A and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risk of refuelling failure. As no reasonable additional or alternative controls were identified that would further reduce the risk, without jeopardising the objectives of the survey, the risks are considered to be ALARP.		

8.3.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing refuelling operations, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines No advice or guidelines have been identified that specifically address potential impacts to protected species resulting from a hydrocarbon release from a refuelling failure.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No significant impacts are predicted to occur to the natural, cultural and socio-economic values of surrounding AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to interactions with marine fauna during the survey. The risk is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	All requirements under the *Navigation Act* and associated Marine Orders for prevention of pollution are identified as control measures. The SOPEP controls are consistent with the requirements of AMSA Marine Orders made under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and also fulfil TGS' obligations under the OPGGS (E) Regulations and the National Plan for Maritime Environmental Emergencies, which in turn provides for Australia's obligations under the International Convention on Oil Pollution Preparedness, Response and Co-operation 1990.
Industry Standards	Industry Best Practice	Control measures adopted are compliant with industry standards and best practice: ■ IAGC Environmental Manual for Worldwide Geophysical Operations: ▪ Implement SOPEPs in the event of a spill, adopt mitigation measures and incident reporting. ■ APPEA Code of Environmental Practice

Context	Factor	Demonstration
		▪ reduce impacts from spill events, with evidence of appropriate management procedures and emergency response plan in-place
Ecological Sustainable 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 accidental a hydrocarbon release to the marine environment from refuelling operations during the Capreolus-2 3D MSS. Therefore, the impact is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the risk of a hydrocarbon spill from refuelling operations to be of an acceptable level.		

8.3.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 9 No release of hydrocarbons to the marine environment.	**9.2** **9.3** **9.10** **9.12** **9.13** **9.14** **9.15** **9.16** **9.17**

8.4 Chemical Spill: Single Point Failure

8.4.1 Assessment Summary

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.			
Receptors			
■ Water quality; and ■ Marine fauna (i.e. marine mammals, marine reptiles, seabirds, fishes/elasmobranchs, planktonic communities).			
Summary of Impacts and Risks			
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 or chemicals 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, impacts to marine fauna and fish are expected to be highly localised and short term, and limited to the vicinity of point of discharge.			
Decision Content			
A	The decision context for an accidental release of up to 1m^3 of hydraulic fluids or chemicals has been assessed as 'Type A', given the risks are well understood and uncertainty is minimal, with little or no stakeholder interest.		
Adopted Control Measures			**EPS #**
Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.			10.1
Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent and crew are trained in its implementation.			10.2
Storage, handling and use of hazardous substances (including hydraulic fluids and chemicals) shall be in accordance with the product's Safety Data Sheet (SDS).			10.3
Spill kits and scupper plugs are available on board the seismic survey vessel and crew are trained in their implementation.			10.4
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Slight	Unlikely	**Low**
Residual Risk	Slight	Highly Unlikely	**Low**

8.4.2 Detailed Evaluation of Impacts / Risks

8.4.2.1 Water Quality

The accidental release of up to 1 m^3 of hydraulic fluids or chemicals to the marine environment may result in a highly localised and temporary reduction in water quality. Given the open water dispersive location of the Operational Area, the extent and duration of potential exposures, impacts to water quality are expected to be highly localised and short term, and limited to the vicinity of the point of discharge.

8.4.2.2 Marine Fauna

Hydraulic fluids or chemicals 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, impacts to marine fauna and fish are expected to be highly localised and short term, and limited to the vicinity of the point of discharge.

8.4.2.3 Summary

Based on the assessment above and the implementation of the controls identified in Section 8.4.3, the consequence of a temporary reduction in water quality and short-term toxicity to marine fauna is **Slight**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.4.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Vessels > 400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.	Yes	In accordance with the requirements of Annex I of MARPOL 73/78, vessels will have a SOPEP. It is a legislative requirement for vessels to comply with MARPOL.
Good Industry Practice		
Vessels <400 GRT hold a TGS approved and tested Spill Management Plan or equivalent, and crew are trained in its implementation.	Yes	Vessels <400 GRT that are not required to have an approved SOPEP (in accordance with MARPOL Annex I) will have a TGS approved and tested Spill Management Plan or equivalent. Good industry practice, environmental benefit outweighs the additional cost.
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 chemical and hydraulic spills on board the vessel. Good industry practice, environmental benefit outweighs the additional cost.
Spill kits and scupper plugs are available on board vessels and crew are trained in their implementation.	Yes	Spill kits and scupper plugs can prevent spills from entering the marine environment. Good industry practice, environmental benefit outweighs the additional cost.
Alternatives/Substitute 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.
Additional Controls Considered		
No additional control measures have been identified.	N/A	N/A
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risks of chemical spill: single point failure. As no reasonable additional or alternative controls were identified that would further reduce the risks, without jeopardising the objectives of the survey, the risks are considered to be ALARP.		

8.4.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing chemical spill: single point failure is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines No advice or guidelines have been identified that specifically address potential impacts to protected species resulting from an accidental chemical release.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No significant impacts are predicted to occur to the natural, cultural and socio-economic values of surrounding AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to accidental chemical releases during the survey. The risk is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	All requirements under the Navigation Act and associated Marine Orders for prevention of pollution are identified as control measures. The SOPEP controls are consistent with the requirements of AMSA Marine Orders made under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and also fulfil TGS' obligations under the OPGGS (E) Regulations and the National Plan for Maritime Environmental Emergencies, which in turn provides for Australia's obligations under the International Convention on Oil Pollution Preparedness, Response and Co-operation 1990.
Industry Standards	Industry Best Practice	Control measures adopted are compliant with industry standards and best practice: ■ IAGC Environmental Manual for Worldwide Geophysical Operations: ▪ Any hazardous materials used by the crew are handled and stored correctly, and that the safety information provided by the manufacturer is available to the crew.

Context	Factor	Demonstration
		▪ Complete records of hazardous material purchases, use, storage, disposal, and spills according to local or company requirements. ■ APPEA Code of Environmental Practice ▪ Waste management practices are carried out based on the prevention, minimisation, recycling, treatment and disposal of wastes in accordance with statutory requirements and procedures.
Ecological Sustainable 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 accidental chemical release to the marine environment from a single point failure during the Capreolus-2 3D MSS. Therefore, the impact is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the risks of chemical spill: single point failure to be of an acceptable level.		

8.4.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 10 No release of chemicals or hydraulic fluids to the marine environment.	**10.1** **10.2** **10.3** **10.4**

8.5 Physical Presence: Collision / Entanglement with Marine Fauna

8.5.1 Assessment Summary

Source of Impact / Risk

The physical presence of the seismic survey vessel (and towed in-water equipment) and support vessel(s) within the Operational Area provides a risk of potential entanglement/collision with marine fauna.

This section assesses the risk of entanglement or collision with marine fauna from the physical presence of vessels and in-water equipment (i.e. streamers and seismic source) in the Operational Area. Potential acoustic impacts on marine fauna are addressed in Sections 7.1 to 7.3.

Receptors

- EPBC listed marine fauna, including threatened and migratory marine mammals, marine turtles and whale sharks.

Details of Impacts and Risks

The risk of a vessel collision or entanglement with marine fauna is limited to the footprint of the vessels, which is temporary in nature at any one position, as the vessels transits within the Operational Area for the acquisition period. Vessel collisions have the potential to result in serious injury that may affect life functions (e.g. movement and reproduction) or cause mortality to marine fauna.

As the seismic survey vessel transits at low speeds (4-5 knots), with MFO observers on-board, the likelihood of a vessel-strike and associated injury to marine fauna is considered highly unlikely. Support vessels generally travel at higher speeds within the Operational Area and are considered to have a slightly higher potential for collision with marine fauna, relative to the survey vessel.

While the seismic source is in operation it is unlikely that marine fauna would become entangled in the towed in-water 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.

Decision Content

A	The decision context for physical presence: collision / entanglement 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.

Adopted Control Measures	EPS #
Vessels will comply, when safe to do so, with the relevant requirements of the 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; and ■ not exceeding a speed of 6 knots within the caution zone of a cetacean (300 m).	11.1
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 or dugong.	11.2
Vessels, when safe to do so, will also adopt measures consistent with the DPaW Whale Shark Management Programme (2013), including:	11.3

■ taking action to avoid approaching or drifting closer than 30 m of a whale shark; and ■ not exceeding 8 knots within 250 m of a whale shark.	
No operation of the seismic source in the pygmy blue whale migration BIA during the migration period (April – August and October – December).	11.4
No operation of the seismic source in the humpback whale migration BIA during the peak migration period (July to October).	11.5
No operation of the seismic source in the flatback turtle internesting BIA during the internesting period (October – March).	11.6
Two MFOs will be available on board the seismic survey vessel to manage shift duties during daylight hours.	11.7
Turtle guards installed on tail buoys or tail buoys will be of a design that does not represent an entrapment risk to turtles.	11.8
Marine fauna entangled within the in-water equipment will be returned to sea (where possible and safe to do so).	11.9
Vessel crews will complete an environmental induction covering the requirements for vessel interactions with marine fauna.	11.10
Any collision with a cetacean in Commonwealth waters will be reported to the National Strike Database within 72 hr of the collision.	11.11

Risk Ranking	Consequence	Likelihood	Risk
Inherent Risk	Moderate	Possible	**Medium**
Residual Risk	Moderate	Highly Unlikely	**Low**

8.5.2 Detailed Evaluation of Impacts / Risks

Vessel movements can result in collisions between the vessel (hull, propellers and in-water equipment) 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.

While the seismic source is in operation it is unlikely that marine fauna would become entangled in the array or collide with the seismic equipment, as the sound generated during operations would act as a deterrent. During line turns, when typically the seismic source is not in full operation, the source is activated at low power in accordance with industry standards as a precautionary measure to reduce the likelihood of entanglement or contact during line turns. It should also be noted, that during the survey, the seismic survey vessel will already be moving at low speed (4.5 knots), and approaching seismic and/or vessel noise will provide some level of warning to marine fauna at the surface.

To date, there have been no reported cases of marine fauna becoming entangled in seismic equipment in Australian waters.

8.5.2.1 Marine Mammals

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 marine mammals occur more frequently where high vessel traffic and important 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 vessel and fast ferries), moving faster than 10 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 marine mammals are known to occur in the NWMR and have wide distributions that are associated with feeding and migration patterns linked to reproductive cycles. Five threatened and migratory, and seven migratory marine mammal species were identified by a search of the EPBC Act Protected Matters Database, as potentially occurring in the Operational Area.

The Operational Area overlaps with the pygmy blue whale distribution and migration BIA (April – August and October – December). In addition, the Operational Area also overlaps with the humpback whale migration BIA (June – October). Individuals may pass through the Operational Area during these migration periods. Other cetacean species and dugongs may be present within the Operational Area (refer to Section 4.5.7).

Given no seismic acquisition will occur within the migration BIAs for the humpback whale and pygmy blue whale during peak migration periods, the low operating speed of the seismic survey vessel and the presence of MFOs on board the seismic survey vessels, the risk of entanglement or collision with marine mammals 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 (2.2 knots), 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. The Operational Area partially overlaps with the internesting BIA for the flatback turtle and a habitat critical for the flatback turtle. No foraging BIAs are located within the Operational Area (refer to Section 4.5.6).

The 60 km internesting buffer for flatback turtles in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017) is based primarily on the movements of tagged internesting flatback turtles along the NWS reported by Whittock et al. (2014), which found that flatback turtles may demonstrate internesting displacement distances up to 62 km from nesting beaches. However, these movements were confined to longshore movements in nearshore coastal waters or travel between island rookeries and the adjacent mainland (Whittock et al., 2014). There is no evidence to date to indicate flatback turtles swim out into deep offshore waters during the internesting period.

A more recent paper by the same authors (Whittock et al., 2016) has more precisely defined flatback turtle internesting habitat along the NWS. The Whittock et al. (2016) study developed a habitat suitability map to identify areas where internesting flatback turtles may be present along the NWS, based on data compiled for a suite of environmental variables and satellite tracks of 47 internesting flatback turtles from five different mainland and island rookeries tracked over 1289 days. Whittock et al. (2016) defined suitable internesting habitat as water 0–16 m deep and within 5–10 km of the coastline, while unsuitable internesting flatback habitat was defined as waters >25 m deep and >27 km from the coastline (refer to Figure 7.3).

The primary environmental variables that influenced flatback internesting movement were bathymetry, distance from coastline, and sea surface temperature. Suitable areas of internesting habitat were located close to many known flatback turtle rookeries across the region (Whittock et al., 2016). This modelling study clearly demonstrates that the internesting buffer BIA and 'habitat critical' overlapped by the Operational Area, or immediately adjacent to it, do not represent suitable habitat for flatback turtles during internesting periods. Hence it is highly unlikely that significant numbers of flatback turtles will be in these offshore, deep waters.

The evidence that suitable internesting habitat for flatback turtles is likely to be limited to relatively shallow waters within close proximity of the coastline is further supported by data from satellite telemetry of 11 flatback turtles after nesting on the Lacepede Islands (Thums et al., 2017). The study found that flatback turtles migrated along the coast in water depths of 63 ± 5 m, passing near Adele Island on the way to foraging grounds on the Sahul Shelf in the Timor Sea (Thums et al., 2017).

It is important to note that flatback turtle hatchlings do not have an offshore pelagic phase. Instead, hatchlings grow to maturity in shallow coastal waters close to their natal beaches (DoEE 2017). Flatback turtle hatchlings do not undertake oceanic migrations like the juveniles of other turtle species do, but spend their juvenile life phase within continental shelf waters (Limpus 2009).

The majority of the Operational Area is located in water depths greater than 60 m, typically outside of the preferred depth range for marine turtles. The occurrence of marine turtles within the Operational Area is expected to be low, in particular in the deeper waters of the Operational Area.

Given no seismic acquisition will occur within the internesting BIA and habitat critical during nesting periods for the flatback turtle (October – March), the low operating speed of the seismic survey vessel and the presence of MFOs on board the seismic survey vessel, the risk of entanglement or collision with marine turtles 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 the offshore waters of the NWS within the Operational Area during their migrations to and from Ningaloo Reef.

The Operational Area overlaps with the foraging BIA for whale sharks, which extends northwards from Ningaloo Reef along the 200 m isobath. The foraging BIA represents waters where solitary whale sharks may forage during the migration from Ningaloo, which occurs primarily in spring (September to November). It is expected that whale shark presence in the Operational Area would not comprise of significant numbers, given main aggregations are recorded in coastal waters (MPRA 2005; Sleeman et al. 2010) and their presence would be transitory and of a short duration.

Given the controls adopted, the low operating speed of the vessels and the presence of MFOs on board the seismic survey vessel, the risk of entanglement or collision is considered low.

8.5.2.4 Summary

Based on the assessment above and the implementation of the controls identified in Section 8.5.3 the consequence of entanglement or collision with marine fauna is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.5.3 *Identification of Control Measures and Demonstration of ALARP*

Control Measure	Control Adopted	Justification
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; and ■ not exceeding a speed of 6 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. 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.
Good Industry Practice		
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 or dugong.	Yes	In addition to implementing avoidance measures for cetaceans, TGS has considered extending the prescribed avoidance measures to turtles and dugongs. For safety reasons, the distance requirements are not applied for vessels with limited manoeuvrability. Good industry practice, environmental benefit outweighs additional cost.
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; and ■ not exceeding 8 knots within 250 m of a whale shark.	Yes	In addition to implementing the EPBC Regulations 2000 avoidance measures for cetaceans, TGS has extended avoidance measures to whale sharks. For safety reasons, the distance requirements are not applied for vessels with limited manoeuvrability. Good industry practice, environmental benefit outweighs additional cost.
Two MFOs will be available on board the seismic survey vessel to manage shift duties during daylight hours. The MFOs will have >12 months experience in Australian waters.	Yes	Compliance with EPBC Act Policy Statement 2.1 Part B.1 – Additional Management Measures: Marine Mammal Observers. Two MFOs will alternate shifts during daylight hours (during operation of the seismic source). Good industry practice, environmental benefit outweighs additional cost.

Control Measure	Control Adopted	Justification
Turtle guards installed on tail buoys or tail buoys will be 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.
Vessel crews will complete an environmental induction covering the requirements for vessel interactions with marine fauna.	Yes	Environmental inductions will be included as part of the crew induction package, including requirements for vessel interaction managed with marine fauna, consistent with the controls described in this EP. Good industry practice, environmental benefit outweighs additional cost.
Any collision with a cetacean in Commonwealth waters will be reported to the National Strike Database within 72 hr of the 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.
Alternatives/Substitute 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.
Additional Controls Considered		

Control Measure	Control Adopted	Justification
No seismic acquisition will occur within the pygmy blue whale migration BIA during the migration period (April – August and October – December).	Yes	TGS considers it appropriate to not acquire within the migration BIA during peak migration periods. Implementation of this control will minimise the potential for collision / entanglement with pygmy blue whales. The environmental benefit outweighs the additional cost.as
No seismic acquisition will occur within the humpback whale migration BIA during the peak migration period (July to October).	Yes	TGS considers it appropriate to not acquire within the migration BIA during peak migration periods. Implementation of this control will minimise the potential for collision / entanglement with pygmy blue whales. The environmental benefit outweighs the additional cost.
No seismic acquisition will occur within the flatback turtle internesting BIA during the internesting period (October – March).	Yes	TGS considers it appropriate to not acquire within the internesting BIA and habitat critical during peak nesting periods. Implementation of this control will minimise the potential for collision / entanglement with marine turtles. The environmental benefit outweighs the additional cost.
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.
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.
ALARP Statement		
The decision context has been assessed as Type A, and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risks of collision / entanglement with marine fauna. As no reasonable additional or alternative controls were identified that would further reduce the risks, without jeopardising the objectives of the survey, the risks are considered to be ALARP.		

8.5.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing physical presence: collision / entanglement with marine fauna is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, Recovery Plans and Other Guidelines The activity will be undertaken in a manner consistent with the applicable objectives and actions of the following species conservation or recovery plans, threat abatement plans, and conservation advice: ■ Conservation Management Plan for the Blue Whale: The Conservation Management Plan states that the risk of vessel strikes on blue whales is to be considered when assessing actions that increase vessel traffic. With the implementation of EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') and no seismic acquisition during migration periods within the migration BIA for pygmy blue whales, no disturbance or injury to blue whales is expected and the level of impact is considered to be acceptable. ■ Approved Conservation Advice for Megaptera novaeangliae (humpback whale): The Conservation Advice states that the risk of vessel strikes on humpback whales is to be considered when assessing actions that increase vessel traffic. With the implementation of EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') and no seismic acquisition during peak migration periods within the migration BIA for humpback whales, no disturbance or injury to humpback whales is expected and the level of impact is considered to be acceptable. ■ Conservation Advice for sei and fin whales: The Conservation Advice for both species do not specify required standards for managing vessel interactions, but they do recognise vessel collisions as a potential threat to the species. With the implementation of EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') and the lack of foraging, migration

Context	Factor	Demonstration
		and distribution BIAs within the Operational Area, no disturbance or injury to sei and fin whales is expected and the level of impact is considered to be acceptable. ■ Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017): ▪ 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 nesting seasons. This supports a defined level of acceptable impact for seismic noise impacts to marine turtles, whereby the seismic survey shall not take place within internesting BIAs or habitats critical to the survival of turtle species during nesting/internesting periods. Given that seismic acquisition will not occur within the internesting BIA or habitat critical for flatback turtles during the nesting period, no disturbance to marine turtles is expected and the level of impact and risk is considered to be acceptable. ▪ The Recovery Plan also recognises that activities resulting in impacts to foraging habitats may indirectly contribute to a decreased viability of multiple stocks by reducing food availability. The survey is not expected to result in the displacement of turtles from foraging BIAs, given that the Operational Area is located entirely outside of foraging BIAs. Therefore, the survey is not expected to indirectly impact the viability of any turtle stocks and the level of impact and risk to marine turtles is considered to be acceptable. ■ Whale shark – wildlife management program no. 57 (DPaW 2013): This management program is relevant to the management of whale sharks within the Ningaloo Marine Park (approximately 500 km from the Operational Area) and does not extend to seismic surveys. However, given the conservation status of whale sharks and that disturbance to whale sharks is a focus of the wildlife management program, TGS considers the level of impact and risk to whale sharks to be acceptable if practicable measures are put in place, to prevent injury and reduce the potential for disturbance to whale sharks. Control measures for the Capreolus-2 3D MSS include speed and proximity restrictions, therefore, no injury is expected, the potential for disturbance is limited and the level of impact and risk is considered to be acceptable.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No impacts are expected to the cultural, natural, and socio-economic values of the surrounding AMP. No population-level impacts or serious or irreversible ecological implications are predicted to the values of the AMPs. The biological diversity and natural values of these AMPs will not be impacted in the long term, and therefore, management measures are consistent with IUCN management prescriptions and the ecological use of the AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to interactions with marine fauna during the survey. The risk is considered to be addressed and will be managed to acceptable levels.

Context	Factor	Demonstration
Legislation, Conventions & Other	Legal Requirements	The requirements of the EPBC Regulations 2000 (Part 8 Division 8.1 'Interacting with cetaceans') will be implemented. In addition, the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for cetaceans, vessels will also take action to avoid approaching or drifting closer than 50 m to a turtle or dugong.
Industry Standards	Industry Best Practice	Control measures adopted are in accordance with industry standards and best practice: ■ IAGC Environmental Manual for Worldwide Geophysical Operations: ▪ turtle guards to be fitted to tail buoys to avoid trapping turtles in the equipment. ■ APPEA Code of Environmental Practice: ▪ reduce impacts on cetaceans and other marine life to ALARP and acceptable levels.
Ecological Sustainable Development (ESD)	ESD Application	The potential interactions between vessels and marine fauna are well understood and the proposed controls meet or exceed well established industry management measures that are designed to reduce the risk of collisions with marine fauna. Therefore, marine fauna injury or mortality is not expected and there is no risk of population level impacts or threats of serious or irreversible environmental damage. TGS considers the level of risk to marine turtles to be acceptable, given there is no risk of population level impacts and displacement from critical habitats are not likely to occur.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impacts of physical presence: collision / entanglement with marine fauna to be of an acceptable level.		

8.5.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 11 No injury or death of large marine fauna due to collision or entanglement with vessels or in-water seismic equipment.	**11.1** **11.2** **11.3** **11.4** **11.5** **11.6** **11.7** **11.8** **11.9** **11.10** **11.11**

8.6 Physical Presence: Loss of Equipment

8.6.1 Assessment Summary

Source of Impact / Risk

The risk of physical loss of equipment (e.g. seismic streamers and/or source) within the Operational Area could result in localised seabed disturbance and disruptions to commercial fisheries and other marine users.

Equipment associated with the Caprelous-2 3D MSS has the potential to be lost within the Operational Area, 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 6-10 m) and a series of hydrophone streamers (up to 12). These streamers will be towed at a depth of approximately 8-15 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 accidental loss of solid wastes (hazardous or non-hazardous) are assessed in Section 8.7.

Receptors

- Commercial fisheries and other marine users;
- Benthic habitats and communities.

Summary of Impacts and Risks

In the unlikely event that equipment is lost, commercial fisheries and 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).

Loss of equipment also 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 (8-15 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.

Decision Content

A	The decision context for physical presence: loss of equipment has been assessed as 'Type A', given the risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

Adopted Control Measures	EPS #
Solid streamers will be used for the survey and fitted with the following equipment: ■ Self-inflating streamer recovery devices (SRDs) ■ Surface marker buoys ■ Secondary retaining devices ■ Tail buoys	12.1
The seismic survey vessel will operate under approved procedures for streamer deployment/retrieval and these procedures are adhered to at all times.	12.2
Streamer equipment will be routinely maintained and inspected for wear and tear to ensure the equipment is fit-for-purpose.	12.3

At least one support vessel will accompany the seismic vessel at all times and will, if necessary and safe to do so, assist in the recovery of lost equipment.			12.4
AMSA JRCC, and other marine users in the Operational Area, will be notified in the event of equipment loss.			12.5
All lifting gear used for deployment and retrieval of equipment over the vessel shall be load rated for the working load.			12.6
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Slight	Unlikely	**Low**
Residual Risk	Slight	Highly Unlikely	**Low**

8.6.2 Detailed Evaluation of Impacts / Risks

8.6.2.1 Commercial Fisheries and Other Marine Users

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 may result in a minor navigational hazard. 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 (8-15 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 Operational Area is expected to primarily consist of soft, fine unconsolidated sediments, which are typical of the broader NWMR (Section 4.5.2). As such physical impacts to the seabed are expected to be short-term and highly localised. Due to the presence of soft sediments, 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).

The Ancient coastline at 125 m depth contour KEF overlaps with the Operational Area. Parts of the KEF, may provide significant habitat for benthic communities in an area predominantly made up of soft sediment (Section 4.5.2). In addition, the Glomar Shoals KEF located entirely within the Operational Area also provides significant benthic habitat and is known to be an important area for a number of commercial fish species. The KEF is regionally important for high biological diversity and localised productivity. Important benthic communities may be associated with the KEF.

Given the size of equipment used for the survey, only a relatively small area of the seabed would be disturbed and lasting impacts are not expected. Impacts to benthic habitats such as shelf and slope habitats and the KEFs are not expected.

8.6.2.3 Summary

Based on the assessment above and the implementation of the controls identified in Section 8.6.3 the consequence of highly localised seabed disturbance and temporary interference with marine users is **Minor,** the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.6.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
No relevant legislation has been identified.	N/A	N/A
Good Industry Practice		
Solid streamers will be used for the survey and fitted with the following equipment: ▪ Self-inflating streamer recovery devices (SRDs) ▪ Surface marker buoys ▪ Secondary retaining devices ▪ Tail buoys	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. Streamers are fitted with equipment to allow for the ease in deployment and retrieval of in-water equipment. Good industry practice, environmental benefit outweighs additional cost.
The seismic survey 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. Good industry practice, environmental benefit outweighs additional cost.
Streamer equipment will be 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. Good industry practice, environmental benefit outweighs additional cost.
At least one support vessel will accompany the seismic vessel at all times and will, if necessary and safe to do so, assist in the recovery of lost equipment.	Yes	A support vessel or work boat will be able to assist in the search and recovery of lost equipment. Good industry practice, environmental benefit outweighs additional cost.
AMSA JRCC, and other marine users in the Operational Area, will be notified in the event of equipment loss.	Yes	Notification to AMSA and other marine users to alert them of the navigational hazard (if applicable). Good industry practice.
All lifting gear used for deployment and retrieval of equipment over the vessel shall be load rated for the working load.	Yes	All lifting gear used for deployment and retrieval of equipment over the vessel shall be load rated for the working load. The environmental benefit outweighs the additional cost.

Control Measure	Control Adopted	Justification
Alternatives/Substitute Considered		
No practicable alternative or substitutes to the above controls have been identified.	N/A	N/A
Additional Controls Considered		
No additional controls have been identified.	N/A	N/A
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risks of physical presence: loss of equipment. As no reasonable additional or alternative controls were identified that would further reduce the risk, without jeopardising the objectives of the survey, the risks are considered to be ALARP.		

8.6.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing physical presence: loss of equipment, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	<u>EPBC Policy Statement 1.1. – Significant Guidelines</u> The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		<u>Conservation Advices, Recovery Plans and Other Guidelines</u> 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. TGS 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).
		<u>AMP Values, Management Prescriptions and IUCN Reserve Management Principles</u> Although the Operational Area is not located within any AMPs, management of loss of equipment is consistent with the management prescriptions of AMPs. No impacts are predicted to occur to the natural, cultural and socio-economic values of the AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to the loss of equipment to the marine environment during the survey. The risk is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	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 Best Practice	Control measures adopted are in accordance with industry standards and best practice: ■ <u>IAGC Environmental Manual for Worldwide Geophysical Operations:</u>

Context	Factor	Demonstration
		▪ contingency plans for retrieval of lost equipment must be documented and communicated to help mitigate environmental impacts from lost equipment; ▪ lost equipment must be retrieved as soon as possible after a sighting is reported, and a reasonable effort must be made to retrieve lost equipment; ▪ the appropriate regulatory agencies should be notified when equipment is lost; and ▪ fully recover equipment (e.g. anchored buoys) as soon as they are not needed or the survey is completed. ■ APPEA Code of Environmental Practice: ▪ environmental objective to reduce risk to benthic communities to ALARP and acceptable levels.
Ecological Sustainable Development (ESD)	ESD Application	There is no threat of serious or irreversible ecological damage from the loss of equipment to the marine environment during the Capreolus-2 3D MSS. Therefore, the risk is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impacts of physical presence: loss of equipment to be of an acceptable level.		

8.6.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 12 No loss of equipment to the marine environment.	**12.1** **12.2** **12.3** **12.4** **12.5** **12.6**

8.7 Discharge: Loss of Hazardous or Non-Hazardous Solid Waste

8.7.1 Assessment Summary

Source of Impact / Risk	
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 survey vessel and support vessel(s). 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 aboard the project vessels may have potential to be blown or knocked off the vessel, or otherwise be lost overboard to the marine environment. 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.	
Receptors	
■ Water quality; ■ Marine biota; and ■ Marine fauna.	
Summary of Impacts and Risks	
Impacts resulting from the routine management of solid hazardous and non-hazardous wastes are expected to be negligible, as there will be no planned discharge of solid wastes to the marine environment. Discharge of solid wastes has the potential to temporarily create a localised change in water quality and temporary ecological impacts. Solid wastes may also be blown off the vessel, which could have the potential to result in fauna mortality or injury through ingestion or entanglement. Windblown waste would be rare as wastes will be stored in closed containers. With the proposed management and discharge controls in place, discernible impacts to water quality and marine biota are not expected in the open water location of the survey. The consequence of reduction in water quality and impacts to marine biota is therefore slight given the nature and scale of the impact, though any changes would rarely be discernible.	
Decision Content	
A	The decision context for discharge: loss of hazardous or non-hazardous solid waste has been assessed as 'Type A', given the risks are well understood and uncertainty is minimal, with little or no stakeholder interest.
Adopted Control Measures	**EPS #**
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 GRT (or certified for >15 persons on board) will have a Waste Management Log Book	13.1
Solid hazardous and non-hazardous wastes generated during the survey are segregated on board the vessels and are either incinerated (using an IMO-approved incinerator, on seismic survey vessel only) or appropriately disposed of at a licensed onshore facility in accordance with the Vessel Waste Management Plan.	13.2

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).			13.3
Recycling or re-use of non-hazardous solid waste, where possible.			13.4
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Slight	Highly Unlikely	**Low**
Residual Risk	Slight	Highly Unlikely	**Low**

8.7.2 Detailed Evaluation of Impacts / Risks

The seismic survey vessel and support vessel(s) will generate a variety of solid waste including non-hazardous wastes (e.g. paper, plastics, waste metal and glass) and/or hazardous wastes (e.g. batteries and oil filters). Hence, there is the potential for solid wastes to be discharged to the marine environment.

Solid wastes will not be discharged to sea but rather will be stored on board the vessels prior to transfer to a support vessel for onshore recycling or disposal. Where practical solid waste will be minimised and non-hazardous waste will be either re-used or recycled, where practical. Solid waste generated will be segregated on board the vessel in specific bins in accordance with the vessel Waste Management Plan. Bins will be fitted with lids/cargo nets for any waste with the potential to be windblown.

If solid wastes on board vessels are not managed or disposed of appropriately, small quantities of solid waste (e.g. packaging and other domestic waste products) may be released with the potential to impact the environment. All domestic waste discharge will be managed in accordance with the requirements of MARPOL 73/78 and the AMSA Marine Orders made under the Protection of the Sea (Prevention of Pollution from Ships) Act 1983.

Loss of solid wastes to the marine environment have the potential to:

- Temporarily create a localised change in water/sediment quality resulting in localised, minor and temporary ecological impacts; and
- Cause injury, ingestion or entanglement by marine fauna.

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, dugongs, 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).

Windblown waste is likely to be a rare event as wastes will be stored in closed/covered containers. In the event of waste being 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 marine 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 epibenthos. Benthic habitats within the Operational Area are considered to primarily consist of soft, fine unconsolidated sediments inhabited by a low abundance and patchy distribution of sessile filter-feeding organisms (e.g. gorgonians, sponges, ascidians and bryozoans) and mobile invertebrates (e.g. echinoderms, prawns and detritus-feeding crabs). Such habitats are well represented throughout the region. The Ancient coastline at the 125 m depth contour KEF and the Glomar Shoals KEF overlap with the Operational Area. These KEFs provide areas of hard substrate that are important for sessile species benthic invertebrates and aggregations of demersal fish species (Brewer et al. 2007; Nichol et al. 2013) (refer to Section 4.5.2). Any impact associated with this risk would be highly localised and proportional to the size of the solid waste.

Consequently, the potential impacts to marine fauna as a result of windblown waste or waste knocked overboard are unlikely and would be limited to individual occurrences.

8.7.2.3 Summary

Based on the assessment above and the implementation of the controls identified in Section 8.7.3, the consequence of localised disturbance to marine fauna and benthic habitat is **Minor**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.7.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
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 GRT (or certified for >15 persons on board) will have a waste management log book	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 over 400 GRT or certified to carry more than 15 persons, will hold a Waste Management Log Book. It is a legislative requirement for vessels to comply with MARPOL and AMSA Marine Orders.
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.	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		
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.
Recycling or re-use of non-hazardous solid waste where possible.	Yes	Non-hazardous solid waste generated on board the vessel will either be recycled where practical or re-used. Good industry practice, environmental benefit outweighs additional cost.
Alternatives/Substitute Considered		

Control Measure	Control Adopted	Justification
No practicable alternative or substitutes to the above the controls have been identified	N/A	N/A
Additional Controls Considered		
No practicable alternative or substitutes to the above the controls have been identified.	N/A	N/A
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risks of discharge: loss of hazardous and non-hazardous solid waste. As no reasonable additional or alternative controls were identified that would further reduce the risks, without jeopardising the objectives of the survey, the impacts are considered to be ALARP.		

8.7.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing discharge: loss of hazardous and non-hazardous solid waste, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	EPBC Policy Statement 1.1. – Significant Guidelines The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, 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. TGS 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).
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles 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 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 the loss of hazardous or non-hazardous solid waste.
Legislation, Conventions & 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*.
Industry Standards	Industry Best Practice	Control measures adopted are compliant with industry standards and best practice: ■ IAGC Environmental Manual for Worldwide Geophysical Operations:

Context	Factor	Demonstration
		▪ No direct discharge of any products into the sea. ▪ Vessel have a waste or garbage management plan in line with relevant regulations and providing procedures for collecting, segregating, storing, processing and disposing of garbage. ▪ Ensure that any hazardous materials used by the crew are handled and stored correctly, and that the safety information provided by the manufacturer is available to the crew. ▪ Waste that cannot be disposed by incineration is segregated and stored for disposal ashore. ▪ Keep complete records of hazardous material purchases, use, storage, disposal, and spills according to local or company requirements. ■ APPEA Code of Environmental Practice: ▪ waste management practices are carried out based on the prevention, minimisation, recycling, treatment and disposal of wastes in accordance with statutory requirements and procedures.
Ecological Sustainable Development (ESD)	ESD Application	There is no threat of serious or irreversible ecological damage from the loss of solid waste to the marine environment during the Capreolus-2 3D MSS. Therefore, the risk is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the impacts of discharge: loss of hazardous and non-hazardous solid waste to be of an acceptable level.		

8.7.5 Environmental Performance Outcomes

<table>
<tr><th>Environmental Performance Outcomes</th><th>EPS #</th></tr>
<tr><td>EPO 13.1
No release of solid hazardous or non-hazardous waste to the marine environment.</td><td rowspan="2">13.1
13.2
13.3
13.4</td></tr>
<tr><td>EPO 13.2
Management of solid waste (hazardous or non-hazardous) to meet or exceed the requirements of MARPOL Annex V and AMSA Marine Order 95.</td></tr>
</table>

8.8 Introduction of Invasive Marine Species: Biofouling and Ballast Water Exchange

8.8.1 Assessment Summary

Source of Impact / Risk

The seismic survey vessel and support vessel(s) present in the Operational Area have the potential to introduce invasive marine species (IMS) via the following mechanisms:

- Discharge of ballast water containing IMS; and
- Translocation of IMS through biofouling of the vessel hull, internal seawater systems (e.g. sea chests, bilges) or immersible equipment (e.g. towed seismic source and streamers).

Receptors

- Marine ecological communities (alterations to ecosystems).

Summary of Impacts and Risks

IMS are widely recognised as a 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).

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, 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.

The Operational Area is unlikely to support the establishment of IMS, due to the unfavourable water depths (22 m to 1,684 m) and the limited availability of suitable habitat. 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 and Glomar Shoals KEF. Successful establishment of IMS in relation to these substrates could potentially result in long term-impacts to the regionally significant ecological communities present.

Decision Content

A	The decision context for of introduction of invasive marine species: biofouling and ballast water exchange has been assessed as 'Type A', given the risks are well understood and uncertainty is minimal, with little or no stakeholder interest.

Adopted Control Measures	EPS #
Vessels entering Australian territorial waters will obtain all the necessary Department of Agriculture, Water and the Environment biosecurity approvals, prior to mobilisation.	14.1
All vessels will maintain a current anti-fouling coating that complies with the requirements of Annex 1 of the International Convention on the Control of Harmful Anti-Fouling Systems on Ships and the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006*.	14.2
In accordance with the Australian Ballast Water Management Requirements, vessels will not exchange ballast water within 12 nm of the Australian coastal baseline or in water depths of less than 50 m.	14.3

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 (as defined in the *Biosecurity (Ballast Water and Sediment) Determination 2017*); ■ 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; or ■ discharge to an approved ballast water reception facility.			14.4
Vessels will have an approved Ballast Water Management Plan and valid Ballast Water Management Certificate, unless an exemption applies or is obtained from the Department of Agriculture, Water and the Environment.			14.5
Vessels will maintain complete and accurate records of ballast water exchange consistent with the Australian Ballast Water Management Requirements.			14.6
A biofouling risk assessment will be completed for each vessel entering Australian territorial seas prior to mobilising to the Operational Area.			14.7
All towed seismic equipment (source and streamers) will be removed from the water, inspected and cleaned (where required) prior to deployment in Australian territorial waters.			14.8
Risk Ranking	**Consequence**	**Likelihood**	**Risk**
Inherent Risk	Moderate	Unlikely	**Medium**
Residual Risk	Moderate	Highly Unlikely	**Low**

8.8.2 Detailed Evaluation of Impacts / Risks

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. IMS are widely recognised as a potentially significant threats to marine ecosystems worldwide.

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; and
- Translocation of IMS through biofouling of the vessel hull, internal seawater systems (e.g. sea chests, bilges) or immersible equipment (e.g. towed seismic source and streamers).

The most common transfer mechanisms for IMS are via uptake and discharge of ballast water or due to marine fouling on the hulls and internal niches (e.g. seawater intakes) on vessels. However, not all species that are introduced to an area outside of their natural range survive to become an IMS, with the majority of introduced species failing to establish (Williamson and Fitter 1996). The successful 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 vessels activities in shallow water locations; and,

- Environmental conditions during transit and at destination compared with the point of origin, such as water temperature, salinity and light availability; and
- 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, 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.

The Operational Area is unlikely to support the establishment of IMS, due to the unfavourable water depths (22 m to 1,684 m) and the limited availability of suitable habitat. 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 and Glomar Shoals KEF (refer to Section 4.5.2). Successful establishment of IMS in relation to these substrates could potentially result in long term-impacts to the regionally significant ecological communities present.

Vessels operating in offshore environments are less likely to accumulate or translocate marine pests than vessels that spend prolonged periods in shallow port or coastal waters (Commonwealth of Australia 2009; Wells et al. 2009). Highly disturbed, shallow water environments such as ports and marinas are more susceptible to colonisation than open-water environments, such as the Operational Area, where the rate of dilution and the degree of dispersal are high (Williamson and Fitter 1996; Paulay et al. 2002).

Prior to entering Australian waters, all vessels are required to obtain Department of Agriculture, Water and the Environment biosecurity clearance (via submission of a Pre-Arrival Report at least 12 hours prior to arrival, to confirm that the vessel is meeting requirements of the *Biosecurity Act 2015* for entry into Australian waters. Survey mobilisation will only occur after clearance is received and a valid anti-fouling certificate is confirmed. Valid hull anti-fouling certificates will meet the requirements of Annex 1 of the International Convention on the Control of Harmful Anti-Fouling Systems on Ships and the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006*.

Vessels arriving in Australian waters, will also be required to adhere to the Australian Ballast Water Management requirements (DAWR 2017), including deep water exchange of ballast water in the open ocean. Vessels not exchange ballast water within 12 nm of the Australian coastal baseline or in water depths of less than 50 m (noting the shallowest depth in the Operational Area is 22 m).

Submersible equipment used as part of survey activities may be retrieved out of the water from time to time, for maintenance purposes and during transit. The time this equipment spends outside of the water will facilitate the desiccation and death of any biofouling present. Seismic streamers are also routinely cleaned to prevent excessive biofouling that could lead to interference of the received signal, and consequently, the quality of the seismic data. Inspection, cleaning and maintenance of survey equipment during retrieval (e.g. due to transit, crew change, inclement weather) will be implemented as a management measure throughout the survey.

8.8.2.1 Summary

Based on the assessment above and the implementation of the controls identified in Section 8.8.3, the consequence of introducing IMS is **Moderate**, the likelihood of this consequence is **Highly Unlikely** and the residual risk is considered to be **Low**.

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

8.8.3 Identification of Control Measures and Demonstration of ALARP

Control Measure	Control Adopted	Justification
Legislative Requirements		
Vessels entering Australian territorial waters will obtain all the necessary Department of Agriculture, Water and the Environment biosecurity approvals, prior to mobilisation.	Yes	Vessels are required to submit a pre-arrival report prior to entering Australian territorial waters, and obtain Department of Agriculture, Water and the Environment (DAWE) biosecurity clearance. Clearance confirms that the vessel meets the requirements of the *Biosecurity Act 2015* 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 DAWE. It is a legislative requirement for vessels to comply the *Biosecurity Act 2015*.
All vessels will maintain a current anti-fouling coating that complies with the requirements of Annex 1 of the International Convention on the Control of Harmful Anti-Fouling Systems on Ships and the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006*.	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. It is a legislative requirement for vessels to comply with the *Protection of the Sea (Harmful Antifouling Systems) Act 2006.*
In accordance with the Australian Ballast Water Management Requirements, vessels will not exchange ballast water within 12 nm of the Australian coastal baseline or in water depths of less than 50 m.	Yes	Regulation D-2 of the Ballast Water Management Convention as implemented through the Australian Ballast Water Management Requirements, requires vessels to exchange ballast water at least 12 nm from the nearest land and in water at least 50 m deep. It is a legislative requirement for vessels to comply with the *Biosecurity Act 2015.*
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:	Yes	Regulation D-2 of the Ballast Water Management Convention as implemented through the Australian Ballast Water Management Requirements, requires vessels to have an IMO approved Ballast Water Management System or use one of the other approved methods of management.

Control Measure	Control Adopted	Justification
■ an approved ballast water management system; ■ ballast water exchange conducted in an acceptable area (as defined in the *Biosecurity (Ballast Water and Sediment) Determination 2017*); ■ 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; or ■ discharge to an approved ballast water reception facility.		It is a legislative requirement for vessels to comply with the *Biosecurity Act 2015.*
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 Department of Agriculture, Water and the Environment	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 IMO Ballast Water Management Convention. It is a legislative requirement for vessels to comply with the *Biosecurity Act 2015.*
Vessels will maintain complete and accurate records of ballast water exchange consistent with the Australian Ballast Water Management Requirements.	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. It is a legislative requirement for vessels to comply with the *Biosecurity Act 2015.*
Good Industry Practice		

Control Measure	Control Adopted	Justification
A biofouling risk assessment will be completed for each vessel entering Australian territorial seas prior to mobilising to the Operational Area.	Yes	TGS will use the Biofouling Risk Assessment Tool 'Vessel Check' developed by the WA DPIRD (or equivalent). The assessment will consider hulls, niche areas, seawater 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 Capreolus-2 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 TGS 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.
All towed seismic equipment (source and streamers) will be removed from the water, inspected and cleaned (where required) prior to deployment in Australian territorial waters.	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.
Alternatives/Substitute Considered		
No discharge of ballast water from vessels during the survey.	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.
Additional Controls Considered		
Towed seismic equipment will be regularly cleaned.	No	This control would add to the cost and timeframe of the survey, due to the requirements for retrieval of the survey equipment for inspection and cleaning on board the vessel. At this time, the vessel cannot acquire data, making this measure impractical. Additionally, this measure would only remove fouling accumulated in the

Control Measure	Control Adopted	Justification
		Operational Area that is unlikely to present a risk of IMS (noting that the equipment would have been confirmed free of IMS prior to use in the Operational Area).
ALARP Statement		
The decision context has been assessed as 'Type A' and the residual risk has been determined to be Low. TGS considers the adopted control measures appropriate to manage the risks of introduction of invasive marine species: biofouling and ballast water exchange. As no reasonable additional or alternative controls were identified that would further reduce the risks, without jeopardising the objectives of the survey, the risks are considered to be ALARP.		

8.8.4 Demonstration of Acceptable Levels

Context	Factor	Demonstration
Risk	Residual Risk Rating	The residual risk is assessed to be Low.
Internal	Company Policy and Management System	The risk management strategy for managing risks, is compliant with TGS's Environmental Policy commitments of: ■ Protecting the environment; and ■ Conducting operations in an environmental sustainable and responsible manner.
External	Values and Sensitivities of the Natural Environment	**EPBC Policy Statement 1.1. – Significant Guidelines** The residual risk has been determined to be Low, and will not have a significant impact upon protected matters in accordance with EPBC Policy Statement 1.1. – Significant guidelines.
		Conservation Advices, 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.
		AMP Values, Management Prescriptions and IUCN Reserve Management Principles No IMS impacts are predicted to occur to the natural values within the AMPs. Management of IMS species is in accordance with the requirements of MARPOL, which meets the management prescriptions for AMPs.
	Relevant Persons Expectations	N/A – Stakeholders have not raised any specific concerns relating to the introduction of IMS during the survey. The risk is considered to be addressed and will be managed to acceptable levels.
Legislation, Conventions & Other	Legal Requirements	The controls adopted will comply with the *Biosecurity Act 2016*, and the Australian Ballast Water Management Requirements.
Industry Standards	Industry Best Practice	Control measures adopted are compliance with industry standards and best practice: ■ IAGC Environmental Manual for Worldwide Geophysical Operations: ▪ ballast water management plans ensure that organisms cannot be transported significant distances by regularly changing the ballast water, cleaning tanks or other approved control plans. ■ APPEA Code of Environmental Practice:

Context	Factor	Demonstration
		▪ reduce the risk of marine pest introduction to ALARP and acceptable levels, with evidence of appropriate quarantine management measures. ■ National Biofouling Management Guidance for the Petroleum Production and Exploration Industry: ▪ Maintenance of a biofouling electronic records outlining marine fouling management actions. ▪ Completion of an IMS risk assessment prior to vessel entry into Australian waters which concludes a low risk of IMS presence. ▪ In-water equipment free of marine fouling prior to the commencement of the survey.
Ecological Sustainable Development (ESD)	ESD Application	Prevention of IMS within the Operational Area will ensure there is no threat of series or irreversible environmental damage or significant impact to biological diversity and ecology integrity as a result of the Capreolus-2 3D MSS. Therefore, the risk is considered to be consistent with the principles of ESD.
Acceptability Statement		
Based on the criteria above, TGS considers the adopted control measures appropriate to manage the risks of introduction of invasive marine species: biofouling and ballast water exchange to be of an acceptable level.		

8.8.5 Environmental Performance Outcomes

Environmental Performance Outcomes	EPS #
EPO 14 Prevent the introduction and establishment of IMS in the marine environment as a result of the survey.	**14.4** **14.2** **14.3** **14.4** **14.5** **14.6** **14.7** **14.8**

9. SUMMARY OF EPO, EPS AND MC

This section presents the EPO, EPS and MC for each of the identified environmental impacts and risks.

EPO #	EPS #	EPS	MC	Responsibility
Noise Emissions: Seismic Source				
1.1 1.2 1.3 1.4 1.5 1.6 1.7	1.1	Minimum source size selected (3,480 cui) to acquire survey data and meet the geophysical objectives of the survey.	Pre-survey environmental checklist confirms seismic source volume to be used is 3,480 cui or less. Mid-survey audit confirms the seismic source is 3,480 cui or less.	Vessel Operations Manager Survey Environmental Adviser Party Chief
	1.2	Acquisition does not exceed 10,000 km^2 per calendar year.	Seismic survey track records (VMS data) demonstrate acquisition did not exceed 10,000 km^2 per calendar year.	Vessel Operations Manager Survey Environmental Adviser Party Chief
	1.3	Part A of EPBC Policy Statement 2.1 is applied in full to mitigate potential impacts to whales, including: ■ 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 ■ Soft-start Procedures ■ Start-up Delay Procedures ■ Operational Shut-down and Low-power Procedures ■ Night-time and Low Visibility Procedures ■ Sighting Reports	MFO weekly report confirms compliance with Part A of EPBC Policy Statement 2.1.	MFO Survey Environmental Adviser
	1.4	EPBC Act Policy Statement 2.1 Part B.6 - Adaptive Management Measures will be applied to minimise potential impacts to whales, including: ■ If the survey is required to shutdown/power-down three or more times per day for three consecutive days as a result of sighting a whale, the shut-down zone will be	MFO weekly report confirms adaptive management measures were implemented (if required).	MFO Survey Environmental Adviser

EPO #	EPS #	EPS	MC	Responsibility
		extended to 2 km horizontal radius from the seismic source. ■ If less than three shutdowns occurs in the preceding 24 hours, normal precaution zones and shut down procedures may recommence, as per EPBC Act Policy Statement 2.1 Part A.		
	1.5	EPBC Act Policy Statement 2.1 Part B.6 - Adaptive Management Measures will be applied to minimise potential impacts to migrating humpback whales, including: ■ Ceasing seismic acquisition in the humpback whale migration BIA for 24 hours if the survey is required to shut-down/power-down three or more times per day for three consecutive days as a result of sighting a humpback whale in the migration BIA. ■ Seismic acquisition may recommence in the humpback whale migration BIA after 24 hours if there has been no further sightings of humpback whales. ■ No further seismic acquisition will occur within the humpback whale migration BIA (until after the peak migration period – July to October), if there is 3 consecutive days of no seismic acquisition due to the presence of migrating humpback whales.	MFO weekly report confirms adaptive management measures were implemented (if required).	MFO Survey Environmental Adviser
	1.6	Two MFOs will be available on board the seismic survey vessel to manage shift duties during daylight hours. At least one MFO will have >12 months experience on a seismic survey vessel as an MFO in Australian waters.	MFO weekly report confirms two MFOs were on board the seismic survey vessel to manage shift duties for daylight visual observations. Curriculum Vitae of the MFOs engaged for the survey confirms: ■ UK Joint Nature Conservation Committee (JNCC) accreditation (or equivalent); and	Survey Environmental Adviser Party Chief Vessel Operations Manager

EPO #	EPS #	EPS	MC	Responsibility
			■ at least one year (minimum four surveys) previous MFO experience.	
	1.7	A 100 m shut-down zone from the operating source is applied to dolphins.	MFO weekly reports confirm that the seismic source was shut-down if a dolphin was sighted within 100 m of the operating source.	MFO Survey Environmental Adviser Party Chief Vessel Master
	1.8	A 500 m shut-down zone from the operating source, as per the shut-down zone for whales in EPBC Act Policy Statement 2.1, is applied to dugongs.	MFO weekly reports confirm that the seismic source was shut-down if a dugong was sighted within the 500 m shut-down zone.	MFO Survey Environmental Adviser Party Chief Vessel Master
	1.9	A 250 m shut-down zone from the operating source, is applied to whale sharks and marine turtles.	MFO weekly reports confirm that the seismic source was shut-down if a whale shark or marine turtle was sighted within the 250 m shut down zone.	MFO Survey Environmental Adviser Party Chief Vessel Master
	1.10	Pre-start visual observations to include observations for dolphins, marine turtles, whale sharks and dugongs.	MFO weekly reports confirm that pre-start visual observations included observation for dolphins, marine turtles, whale sharks and dugongs.	MFO Survey Environmental Adviser Party Chief
	1.11	Vessel crews have completed an environmental induction covering the requirements for vessel interactions with marine fauna.	Environmental induction includes information on Part A of EPBC Policy Statement 2.1 and other requirements for vessel interactions with marine fauna. Induction register confirms vessel crews attended an environmental induction.	Vessel Operations Manager Survey Environmental Adviser Party Chief

EPO #	EPS #	EPS	MC	Responsibility
	1.12	No operation of the seismic source in water depths less than 50 m.	Survey logs confirm that the seismic source was not operated in depths less than 50 m.	Vessel Master Survey Environmental Adviser
	1.13	No operation of the seismic source in the designated Glomar Shoals KEF.	Survey logs confirm that the seismic source was not operated in the Glomar Shoals KEF.	Vessel Master Survey Environmental Adviser
	1.14	The seismic survey vessel will not return to acquire adjacent lines within 5.86 km of the KEF within a 24 hour period to enable for recovery of TTS in fishes associated with Glomar Shoal.	Survey log confirms that the seismic survey vessel did not return to acquire adjacent lines within 5.86 km of the KEF within a 24 hour period.	Vessel Master Survey Environmental Adviser
	1.15	No operation of the seismic source within 24 km of the pygmy blue whale migration BIA during the migration period (April – August and October – December).	Pre-survey environmental checklist confirms no seismic acquisition is planned within 24 km of the pygmy blue whale migration BIA during the migration period. Survey logs confirm that the seismic source was not operated in the pygmy blue whale migration BIA during the migration period.	Vessel Master Survey Environmental Adviser Vessel Operations Manager
	1.16	No operation of the seismic source in the humpback whale migration BIA during the peak migration period (July – October).	Pre-survey environmental checklist confirms no seismic acquisition is planned in the humpback whale migration BIA during the migration period. Survey logs confirm that the seismic source was not operated in the humpback whale migration BIA during the migration period.	Vessel Master Survey Environmental Adviser Vessel Operations Manager
	1.17	No operation of the seismic source in the flatback turtle internesting BIA during the internesting period (October – March).	Pre-survey environmental checklist confirms no seismic acquisition is planned during in the flatback turtle internesting BIA during the internesting period. Survey logs confirm that the seismic source was not operated in the flatback turtle internesting BIA during the internesting period.	Vessel Master Vessel Operations Manager Survey Environmental Adviser

EPO #	EPS #	EPS	MC	Responsibility
	1.18	Notification to scuba divers that are undertaken diving activities within 45 km of the seismic source.	Consultation log demonstrates that TGS has engaged with stakeholders identified as having potential scuba diving activities within 45 km of the proposed survey, prior to the survey commencing.	Vessel Operations Manager Survey Environmental Adviser
	1.19	A joint risk assessment is conducted where scuba diving and seismic activity occurs within 30 km of each other.	Records confirm a joint risk assessment was conducted where scuba diving and seismic activity occurs within 30 km of each other.	Vessel Operations Manager
	1.20	Notification to fisheries stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification is provided to fisheries stakeholders within 2 weeks of survey completion.	Consultation log confirms that fisheries stakeholders were notified four weeks prior to survey commencement and within two weeks of cessation of activities.	Vessel Operations Manager
	1.21	Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Consultation log confirms that the Australian Hydrographic Office was notified four weeks prior to survey commencement.	Vessel Operations Manager
	1.22	Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Consultation log confirms that AMSA JRCC received a daily notification during survey operations.	Vessel Operations Manager
	1.23	Daily look-ahead reports will be provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Consultation log confirms that stakeholders who registered for the service received daily look-ahead notifications.	Vessel Operations Manager
Cumulative: Seismic Sound & Interference with Commercial Fisheries				
2	2.1	TGS will engage with proponents identified as having potential concurrent seismic activities within 40 km of the Capreolus-2 3D MSS.	Consultation log confirms proponents were contacted (if potential concurrent seismic activities were identified).	Vessel Operations Manager

EPO #	EPS #	EPS	MC	Responsibility
	2.2	A minimum separation distance of 40 km shall be maintained between the Capreolus-2 3D MSS seismic sources and other operating seismic sources.	SIMOPS Plan documents the requirement to maintain at least 40 km separation distance between operating seismic survey vessels (if applicable).	Vessel Operations Manager
	2.3	TGS will not acquire the NWS Renaissance North 3D MSS and NWS Renaissance South 3D MSS concurrently with the Capreolus-2 3D MSS.	Pre-survey environmental checklist confirms no seismic acquisition under the NWS Renaissance North and South 3D MSS is planned during acquisition of the Capreolus-2 3D MSS.	Vessel Operations Manager
	2.4	A simultaneous operations (SIMOPs) Plan is developed and implemented, if a separate petroleum activity is undertaken concurrently with the Capreolus-2 3D MSS and within the Operational Area.	SIMOPs Plan documents vessel separation distances, exclusion zones and communication measures.	Vessel Operations Manager
Noise Emissions: Vessels, Helicopters & Mechanical Equipment				
3	3.1	Vessel activities are undertaken in accordance 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; and ■ not exceeding a speed of 6 knots within the caution zone of a cetacean (300 m).	Environmental induction includes information on vessel/fauna separation distances, speed requirements and reporting. Induction register confirms vessel crews attended an environmental induction. MFO weekly reports confirm that interactions between the seismic survey vessel and/or equipment and whales were managed in accordance with Part 8 of the EPBC Regulations.	MFO Vessel Master
	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; and ■ helicopters not to approach a cetacean from head on.	Induction register confirms helicopter pilot(s) were given an HSE induction prior to flying as part of the survey. Incident register confirms helicopter movements did not breach EPBC Regulations 2000 – Part 8 Division 8.1.	Vessel Operations Manager Survey Environmental Adviser

EPO #	EPS #	EPS	MC	Responsibility
	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, also: ■ take action to avoid approaching or drifting closer than 50 m to a turtle or dugong; and ■ not exceeding a speed of 6 knots within 300 m of a turtle or dugong.	Environmental induction includes information on vessel/fauna separation distances, speed requirements and reporting. Induction register confirms vessel crews attended an environmental induction. MFO weekly reports confirm that interactions between the seismic survey vessel and/or equipment and turtles/dugongs were managed in accordance with Part 8 of the EPBC Regulations.	Vessel Master MFO
	3.4	Vessels (taking into account the limited manoeuvrability of the seismic survey vessel) also adopt measures consistent with the DPaW Whale Shark Management Program (2013), including: ■ taking action to avoid approaching or drifting closer than 30 m of a whale shark; and ■ not exceeding 8 knots within 250 m of a whale shark.	Environmental induction includes information on vessel/fauna separation distances, speed requirements and reporting. Induction register confirms vessel crews attended an environmental induction. MFO weekly reports confirm that interactions between the seismic survey vessel and/or equipment and turtles were managed in accordance with Part 8 of the EPBC Regulations.	Vessel Master MFO
	3.5	Vessel engines and mechanical equipment maintained according to manufacturer's specifications.	Engineers log and engine service records confirm vessel engines and mechanical equipment are maintained according to manufacturer's specifications.	Chief Engineer Vessel Master
	3.6	Crew, survey personnel and MFOs are briefed in the marine fauna observation, management controls and reporting requirements relevant to this EP.	Environmental induction includes information on Part A of EPBC Policy Statement 2.1 and other requirements for vessel interactions with marine fauna. Induction register confirms vessel crews attended an environmental induction.	Vessel Operations Manager Survey Environmental Adviser
Physical Presence: Interference with Commercial Fisheries				

EPO #	EPS #	EPS	MC	Responsibility
4	4.1	Notification to fisheries stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification is provided to fisheries stakeholders within 2 weeks of survey completion.	Consultation log confirms that fisheries stakeholders were notified four weeks prior to survey commencement and within two weeks of cessation of activities.	Vessel Operations Manager
	4.2	Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Consultation log confirms that the Australian Hydrographic Office was notified four weeks prior to survey commencement.	Vessel Operations Manager
	4.3	Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Consultation log confirms that AMSA JRCC received a daily notification during survey operations.	Vessel Operations Manager
	4.4	Daily look-ahead reports are provided to fisheries stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Consultation log confirms that stakeholders who registered for the service received daily look-ahead notifications.	Vessel Operations Manager
	4.5	Access to seismic survey vessel tracking information via Google Earth for fisheries stakeholders who have registered for the service.	Consultation log confirms that stakeholders who registered for the service received seismic survey vessel tracking information via Google Earth.	Vessel Operations Manager
	4.6	The seismic survey vessel changes sail lines to accommodate commercial fisher's requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel and providing TGS is afforded a reasonable opportunity to complete the survey in a timely and efficient manner.	Consultation log confirms that the commercial fisher provided the seismic survey vessel with advanced communication (i.e. 24 hours). Survey log demonstrates that the seismic survey vessel changed sail lines to accommodate commercial fishers request (if it was feasible to do so and there was open/advanced communication between the seismic survey vessel and commercial fishing vessel). Daily look-ahead report requests information from commercial fishers on upcoming fishing activities for the next 24-72 hours.	Vessel Operations Manager Survey Environmental Adviser Vessel Master

EPO #	EPS #	EPS	MC	Responsibility
	4.7	All evidence-based compensation claims made by commercial fishing licence holders or vessel crews for equipment damage/loss will be assessed for merit in accordance with the TGS Fisheries Compensation Process (Appendix H).	Records demonstrate claims made by commercial fishing licence holders were assessed in accordance with the TGS Fisheries Compensation Process (Appendix H).	Vessel Operations Manager
	4.8	Seismic survey vessel adheres to the 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.	Vessel crew training and competency records demonstrate that all relevant marine crew are competent to STCW95 / Elements of Shipboard Safety Standards.	Vessel Operations Manager Survey Environmental Adviser
	4.9	At least one support vessel (supply or chase vessel) accompanies the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with other marine users.	Survey logs confirm at least one support vessel accompanied the seismic survey vessel when in operation and when safe to do so.	Vessel Operations Manager
	4.10	No recreational fishing activities occurs from any activity vessels during survey operations.	Pre-survey environmental checklist confirms no recreational fishing gear on board the vessel. Pre-survey vessel audit confirms no recreational fishing gear is onboard the vessels.	Survey Environmental Adviser
	4.11	Acquisition is limited to a maximum of 10,000 km^2 per calendar year.	Seismic survey track records (VMS data) demonstrate acquisition did not exceed 10,000 km^2 per calendar year.	Vessel Operations Manager

EPO #	EPS #	EPS	MC	Responsibility
	4.12	Streamers are marked with tail buoys (fitted with virtual or installed AIS).	Pre-survey environmental checklist confirms streamers are marked with tail buoys (and fitted with virtual or installed AIS).	Survey Environmental Adviser Vessel Operations Manager
Physical Presence: Interference with Other Marine Users				
5	5.1	Notification to stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing. Notification is provided to stakeholders within 2 weeks of survey completion.	Consultation log confirms that fisheries stakeholders were notified four weeks prior to survey commencement and within two weeks of cessation of activities.	Vessel Operations Manager
	5.2	Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Consultation log confirms that the Australian Hydrographic Office was notified four weeks prior to survey commencement.	Vessel Operations Manager
	5.3	Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Consultation log confirms that AMSA JRCC received a daily notification during survey operations.	Vessel Operations Manager
	5.4	Daily look-ahead reports are provided to stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Consultation log confirms that stakeholders who registered for the service received daily look-ahead notifications.	Vessel Operations Manager
	5.5	Vessels adhere to the 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:	Vessel crew training and competency records demonstrate that all relevant marine crew are competent to STCW95 / Elements of Shipboard Safety Standards.	Vessel Master

EPO #	EPS #	EPS	MC	Responsibility
		■ Appropriate lighting, navigation and communication to inform other users. ■ Use of radar and 24/7 watch.		
	5.6	At least one support vessel (supply or chase vessel) accompanies the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with other marine users.	Survey logs confirm a support vessel is present within 10 nautical miles of the seismic survey vessel when the seismic vessel is in operation.	Vessel Operations Manager
	5.7	Adherence to the prohibition of vessel entry into designated petroleum safety zones surrounding petroleum wells, structures or equipment.	Written approval from titleholders allowing vessel access to petroleum safety zones.	Vessel Operations Manager Vessel Master
	5.8	A simultaneous operations (SIMOPs) Plan is developed and implemented, if a separate petroleum activity is undertaken concurrently with the Capreolus-2 3D MSS and within the Operational Area.	SIMOPs Plan documents vessel separation distances, exclusion zones and communication measures.	Vessel Operations Manager
	5.9	Streamers are marked with tail buoys (fitted with virtual or installed AIS).	Pre-survey environmental checklist confirms streamers are marked with tail buoys (and fitted with virtual or installed AIS).	Survey Environmental Adviser Vessel Operations Manager
Routine Discharges: Liquid Waste Management				
6	6.1	Sewage is managed in accordance with MARPOL Annex IV and AMSA Marine Order 96, using an IMO-approved sewage treatment plant, a sewage comminuting and disinfecting system or a sewage holding tank as applicable depending on vessel gross tonnage or people capacity (as evidenced by a current International Sewage Pollution Prevention (ISPP) Certificate).	Records show that vessels used for the survey that are engaged in international voyages of 400 gross tonnes or certified to carry more than 15 persons, have an appropriate sewage treatment plant, sewage comminuting and disinfecting system or sewage holding tank on board (with related IMO certificate). Pre-survey environmental checklist confirms an IMO-approved sewage treatment plant, sewage comminuting and disinfecting system or sewage holding tank on board (as required per above) is	Survey Environmental Adviser Chief Engineer Vessel Master

EPO #	EPS #	EPS	MC	Responsibility
			operational, where applicable depending on vessel class. Evidence of a current ISPP certificate.	
	6.2	In accordance with MARPOL Annex IV and AMSA Marine Order 96: ■ Sewage is only discharged via an IMO-approved sewage treatment plant; or ■ Comminuted/disinfected sewage via an IMO-approved system is only discharged when ≥ 3 nm from land and when the vessel is moving at ≥ 4 knots; or ■ Sewage that has not been comminuted/ disinfected via an IMO-approved system is only discharged when ≥ 12 nm from land and when the vessel is moving at ≥ 4 knots.	The engineers log shows that all sewage discharges during the survey have been treated by an appropriate on-board sewage treatment system such as a sewage treatment plant or sewage comminuting and disinfecting system prior to discharge, where applicable depending on vessel class.	Chief Engineer Vessel Master
	6.3	In accordance with MARPOL Annex V and AMSA Marine Order 95: ■ Putrescible waste is discharged while the vessel is moving and ⩾12 nm from the nearest land; or ■ Putrescible waste passes through a comminuter or grinder with the capacity to screen waste to less than 25 mm in diameter prior to discharge and discharged while the vessel is moving and ⩾3 nm from the nearest land	Vessel logs confirms discharges are compliant with MARPOL Annex V and AMSA Marine Order 95.	Chief Engineer Vessel Master
	6.4	Vessels >400 GRT 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.	Pre-survey environmental checklist confirms that vessel holds a current IOPP Certificate and an oil usage management log book, and oil discharge monitoring and control system and oil filtering equipment are on board and functioning. Oil-water separator service records are present.	Chief Engineer Vessel Master
	6.5	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. If oil discharge	Oil usage management electronic records confirm all discharges of bilge water during the survey occurred while the vessel was moving and via oil	Chief Engineer Vessel Master

EPO #	EPS #	EPS	MC	Responsibility
		monitoring and control system and oil filtering equipment are unavailable, bilge water mixtures is retained on board for on shore disposal.	discharge monitoring and control system and oil filtering equipment (or otherwise retained on board).	
	6.6	Oil discharge monitoring and control systems on board the vessels is maintained and calibrated to ensure monitoring readings are accurate.	Pre-survey environmental checklist confirms that the oil-in-water separator has undergone regular maintenance. Oil usage management electronic records confirm discharges meet the oil concentration of <15 ppm prior to discharge.	Survey Environmental Adviser Chief Engineer Vessel Master
Atmospheric Emissions: Vessels and Mechanical Equipment				
7	7.1	In accordance with MARPOL 73/78 Annex VI (Prevention of Air Pollution) and Marine Order 97, vessels have a valid IAPP Certificate (International air pollution prevention certificate) confirming: ■ Incinerators are certified to meet prescribed emissions standards; and ■ Diesel engines >130 kW are certified to meet prescribed emission standards.	Pre-survey environmental checklist confirms that a current IAPP certificate is present on board the vessel (if applicable).	Survey Environmental Adviser
	7.2	The sulphur content of fuel oil used on board vessels for propulsion or operation does not exceed 0.50% m/m.	Oil usage records confirm MDO grade fuel is used and fuel data sheet confirms low sulphur content.	Survey Environmental Adviser Chief Engineer
	7.3	Vessel engines and incinerators are maintained according to manufacturer’s specification.	Records confirm that the incinerator’s MARPOL 73/78 certification is current and sighted, and maintained as per manufacturers servicing guide (if applicable).	Survey Environmental Adviser Chief Engineer
Artificial Light Emissions: Vessels				

EPO #	EPS #	EPS	MC	Responsibility
8	8.1	Vessel crews are instructed at the pre-survey environmental induction to minimise unnecessary external lighting, where practicable during the survey.	Environmental induction includes the requirement to minimise any unnecessary external lighting during the survey. Induction register confirms vessel crews attended an environmental induction. Mid-survey audit confirms that light reduction measures have been adopted, where appropriate.	Vessel Master Vessel Party Manager
Hydrocarbon Spill: Vessel Tank Failure & Vessel Refuelling Failure				
9	9.1	Seismic survey vessel utilised MDO, which is stored in multiple fuel tanks on board. Fuel tanks can be isolated and contents transferred between them.	Bunkering records confirm MDO-grade fuel is used on the vessel for the survey. Pre-survey environmental checklist confirms tanks can be isolated and contents transferred.	Vessel Master Vessel Operations Manager Survey Environmental Adviser
	9.2	Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.	Pre-survey environmental checklist confirm that each vessel over 400 GRT holds an approved SOPEP and the SOPEP has been tested in the last 12 months. Induction register confirms that relevant crew have been trained on implementation of the SOPEP prior to the survey commencing.	Vessel Master Vessel Operations Manager Survey Environmental Adviser
	9.3	Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent and crew are trained in its implementation.	Pre-survey environmental checklist confirm that each vessel <400 GRT hold an approved TGS Spill Management Plan or equivalent. Induction register confirms that relevant crew have been trained on implementation of the TGS Spill Management Plan (or equivalent) prior to the survey commencing.	Vessel Master Vessel Operations Manager Survey Environmental Adviser

EPO #	EPS #	EPS	MC	Responsibility
	9.4	Vessels adhere to the 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.	Vessel crew training and competency records demonstrate that all relevant marine crew are competent to STCW95 / Elements of Shipboard Safety Standards. Survey logs and/or vessel marine traffic log show communications with, and actions taken when other third party vessels are in the vicinity of the Operational Area.	Vessel Master Vessel Operations Manager Survey Environmental Adviser
	9.5	Notification to stakeholders 4 weeks prior to the commencement of the survey, indicating location and expected timing.	Consultation log confirms that stakeholders were notified 4 weeks prior to survey commencement.	Vessel Operations Manager
	9.6	Notification to Australian Hydrographic Office, 4 weeks prior to the commencement of the survey for the promulgation of Notice to Mariners.	Consultation log confirms that Australian Hydrographic Office was notified 4 weeks prior to survey commencement.	Vessel Operations Manager
	9.7	Daily notification to Joint Rescue Coordination Centre (JRCC), for the promulgation of navigational warnings (i.e. AUSCOAST warnings).	Consultation log confirms that AMSA JRCC have received a daily notification during survey operations.	Vessel Operations Manager
	9.8	Daily look-ahead reports provided to stakeholders (who register for the service), detailing upcoming activities and planned seismic survey vessel location within the next 72 hours.	Consultation log confirms that stakeholders who registered for the service received daily look-ahead notifications.	Vessel Operations Manager
	9.9	At least one support vessel (supply or chase vessel) accompanies the seismic survey vessel when in operation and when safe to do so (e.g. outside of inclement weather periods), to manage interactions with other marine users.	Survey logs confirm at least one support vessel accompanied the seismic survey vessel when in operation and when safe to do so.	Vessel Operations Manager

EPO #	EPS #	EPS	MC	Responsibility
	9.10	In the event of a spill to the marine environment, the OPEP presented in Section 10.4.2 is implemented.	Environmental induction includes an overview of the spill response arrangements outlined in Section 10.4.2. Induction register confirms that relevant crew have been trained on implementation of spill response arrangements prior to the survey commencing.	Vessel Operations Manager Survey Environmental Adviser Vessel Master
	9.11	Vessels will not operate within 40 km of the State waters limit surrounding Bedout Island during the flatback turtle internesting season (October to March).	Survey logs confirm vessels did not operate within 40 km of the State waters limit surrounding Bedout Island during the flatback turtle internesting season (October to March).	Vessel Operations Manager
	9.12	Vessels will not conduct side-by-side activities (e.g. refuelling, re-provisioning) within 40 km of the State waters limit surrounding Bedout Island at any time.	Survey logs confirm vessels did not conduct side-by-side activities within 40 km of the State waters limit surrounding Bedout Island.	Vessel Operations Manager Vessel Master
	9.13	Spill kits are available on board the seismic survey vessel and crew are trained in their implementation.	Pre-survey environmental checklist confirms spill kits are available on board all vessels. Induction register confirms that relevant crew have been trained on the use of spill kits.	Vessel Operations Manager
	9.14	Dry-break couplings are installed on refuelling hoses.	Bunkering contractor selection was made in accordance with the contractor selection procedure to ensure the contractor will use dry-break couplings.	Vessel Operations Manager
	9.15	Refuelling operations are undertaken within the Operational Area (unless as required in an emergency.	Bunkering records confirm refuelling took place within the Operational Area.	Vessel Operations Manager Vessel Master Survey Environmental Advisor

EPO #	EPS #	EPS	MC	Responsibility
	9.16	Refuelling operations only take place during daylight hours and within strict weather limit guidelines.	Bunkering records confirm refuelling took place during daylight hours and within weather limit guidelines.	Vessel Operations Manager Vessel Master Survey Environmental Advisor
	9.17	Seismic survey vessel contractor procedures include requirements to be implemented during 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.	No record of contractor failing to follow procedures during refuelling operations.	Vessel Operations Manager Vessel Master
Chemical Spill: Single Point Failure				
10	10.1	Vessels >400 GRT (MARPOL 73/78 Annex I) hold an approved and tested SOPEP and crew are trained in its implementation.	Pre-survey environmental checklist confirms that each vessel >400 GRT holds an approved SOPEP and the SOPEP has been tested in the last 12 months. Induction Register confirms that relevant crew have been trained on implementation of the SOPEP prior to the survey commencing.	Vessel Operations Manager Vessel Master Survey Environment Advisor
	10.2	Vessels <400 GRT hold an approved TGS Spill Management Plan or equivalent.	Pre-survey environmental checklist confirms that each vessel > 400 GRT holds an approved SOPEP and the SOPEP has been tested in the last 12 months. Induction register confirms that relevant crew have been trained on implementation of the SOPEP prior to the survey commencing.	Vessel Operations Manager Vessel Master Survey Environment Advisor

EPO #	EPS #	EPS	MC	Responsibility
	10.3	Storage, handling and use of hazardous substances (including hydraulic fluids and chemicals) shall be in accordance with the product's Safety Data Sheet (SDS).	No recorded incidents relating to mishandling of hazardous substances. SDS for all hazardous substances are available onboard vessels.	Vessel Operations Manager Vessel Master Survey Environment Advisor
	10.4	Spill kits are available on board the seismic survey vessel and crew are trained in their implementation.	Pre-survey environmental checklist confirms spill kits are available on board. Induction register confirms that relevant crew have been trained on the use of spill kits.	Vessel Operations Manager Vessel Master Survey Environment Advisor
Physical Presence: Collision / Entanglement with Marine Fauna				
11	11.1	Vessels comply, when safe to do so, with the relevant requirements of the 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; and ■ not exceeding a speed of 6 knots within the caution zone of a cetacean (300 m)	Induction register confirms that relevant crew have been trained on vessel/fauna separation distance and speed requirements and requirement to report sightings. MFO weekly reports confirm that interactions between the seismic survey vessel and/or equipment and cetaceans were managed in accordance with Part 8 of the EPBC Regulations.	Vessel Master MFO
	11.2	In addition to the requirements of the EPBC Regulations 2000 - Part 8 Division 8.1 for cetaceans, vessels, when safe to do so, take action to avoid approaching or drifting closer than 50 m to a turtle or dugong.	Induction register confirms that relevant crew have been trained on vessel/fauna separation distance and speed requirements and requirement to report sightings. MFO weekly reports confirm that interactions between the seismic survey vessel and/or equipment and turtles/dugongs were managed in accordance with Part 8 of the EPBC Regulations.	Vessel Master MFO
	11.3	Vessels, when safe to do so, adopt measures consistent with the DPaW Whale Shark Management Programme (2013), including:	Induction register confirms that relevant crew have been trained on vessel/fauna separation	Vessel Master MFO

EPO #	EPS #	EPS	MC	Responsibility
		■ taking action to avoid approaching or drifting closer than 30 m of a whale shark; and ■ not exceeding 8 knots within 250 m of a whale shark	distance and speed requirements and requirement to report sightings. MFO weekly reports confirm that interactions between the seismic survey vessel and/or equipment and whale sharks were managed in accordance with the DPaW Whale Shark Management Programme (2013),	
	11.4	No operation of the seismic source in the pygmy blue whale migration BIA during the migration period (April – August and October – December).	Pre-survey environmental checklist confirms no seismic acquisition is planned in the pygmy blue whale migration BIA during the migration period. Survey logs confirm that the seismic source was not operated in the pygmy blue whale migration BIA during the migration period.	Vessel Operations Manager Vessel Master Survey Environment Advisor
	11.5	No operation of the seismic source in the humpback whale migration BIA during the peak migration period (July to October).	Pre-survey environmental checklist confirms no seismic acquisition is planned in the humpback whale migration BIA during the migration period. Survey logs confirm that the seismic source was not operated in the humpback whale migration BIA during the migration period.	Vessel Operations Manager Vessel Master Survey Environment Advisor
	11.6	No operation of the seismic source in the flatback turtle internesting BIA during the internesting period (October – March).	Pre-survey environmental checklist confirms no seismic acquisition is planned during in the flatback turtle internesting BIA during the internesting period. Survey logs confirm that the seismic source was not operated in the flatback turtle internesting BIA during the internesting period.	Vessel Operations Manager Vessel Master Survey Environment Advisor
	11.7	Two MFOs are available on board the seismic vessel to manage shift duties during daylight hours during the survey.	MFO weekly report confirms two MFOs were on board the seismic vessel for daylight visual observations during the survey.	Vessel Operations Manager MFO

EPO #	EPS #	EPS	MC	Responsibility
	11.8	Turtle guards installed on tail buoys or tail buoys are of a design that does not represent an entrapment risk to turtles.	Pre-survey environmental checklist confirms turtle guards are available on board the seismic survey vessel or tail buoys designed to prevent turtles becoming trapped. Mid-survey audit confirms turtle guards are fitted to tail buoys unless tail buoys designed to prevent turtles becoming trapped.	Vessel Operations Manager Survey Environment Advisor
	11.9	Marine fauna entangled within the in-water equipment is returned to sea (where possible and safe to do so).	Induction register confirms that survey induction was attended by all relevant crew. MFO weekly report documents any instances of fauna entanglement and confirms that fauna were quickly returned to the ocean.	Survey Environment Advisor MFO
	11.10	Vessel crews complete an environmental induction covering the requirements for vessel interactions with marine fauna.	Environmental induction includes information on Part A of EPBC Policy Statement 2.1, additional controls and adaptive management measures. Induction register confirms that the crew, survey personnel and MFO's are briefed in whale observation, separation distance estimation, adaptive management measures, and reporting.	Vessel Operations Manager Survey Environment Advisor
	11.11	Any collision with a cetacean in Commonwealth waters is reported to the National Strike Database within 72 hr of the collision.	MFO weekly records confirm ship strikes with cetaceans have been reported to the National Ship Strike Database. Reports to include vessel strike locations, frequencies and timings.	Survey Environment Advisor MFO
Physical Presence: Loss of Equipment				
12	12.1	Solid streamers are used for the survey and fitted with the following equipment: ■ Self-inflating streamer recovery devices (SRDs) ■ Surface marker buoys ■ Secondary retaining devices ■ Tail buoys	Pre-survey environmental checklist confirms streamers are fitted with redundant retainers, tail buoys and relative GPS.	Vessel Operations Manager Survey Environmental Adviser

EPO #	EPS #	EPS	MC	Responsibility
	12.2	The seismic survey vessel operates under approved procedures for streamer deployment/retrieval and these procedures are adhered to at all times.	Survey equipment list and pre-survey environmental checklist confirms solid streamers are used.	Vessel Operations Manager Survey Environmental Adviser
	12.3	Streamer equipment is routinely maintained and inspected for wear and tear to ensure the equipment is fit-for-purpose.	Mid-survey audit confirms equipment is maintained and fit-for-purpose.	Vessel Operations Manager Survey Environmental Adviser
	12.4	At least one support vessel accompanies the seismic vessel at all times and, if necessary and safe to do so, assists in the recovery of lost equipment.	Survey logs confirm a support vessel is present within 10 nautical miles of the seismic vessel when the seismic vessel is in operation.	Vessel Operations Manager Survey Environmental Adviser
	12.5	AMSA JRCC, and other marine users in the Operational Area, are notified in the event of equipment loss.	Consultation log confirms AMSA JRCC and other marine users in the Operational Area have been notified of any events of equipment loss (if applicable).	Vessel Operations Manager
	12.6	All lifting gear used for deployment and retrieval of equipment over the vessel is load rated for the working load.	Load ratings or load test certificates to be confirmed prior to survey commencement.	Chief Engineer Survey Environmental Adviser
Discharge: Loss of Hazardous or Non-Hazardous Solid Waste				
13.1 13.2	13.1	In accordance with MARPOL Annex V and Marine Order 95: ■ Vessels > 100 GRT (or certified for >15 persons on board) have a Waste Management Plan ■ Vessels >400 GRT (or certified for >15 persons on board) have a waste management log book.	Pre-survey environmental checklist confirms vessels > 100 T (or certified for >15 persons on board) have a Waste Management Plan, and vessels >400 T (or certified for >15 persons on board) have waste management log book.	Survey Environmental Adviser

EPO #	EPS #	EPS	MC	Responsibility
	13.2	Solid hazardous and non-hazardous wastes generated during the survey are segregated onboard the vessels and are either incinerated (using an IMO-approved incinerator, on seismic vessel only) or appropriately disposed of at a licensed onshore facility in accordance with the Vessel Waste Management Plan.	Environmental induction includes information on waste management and housekeeping requirements. Induction register confirms the survey induction was attended by all crew. Records confirm incinerator on board seismic vessel is IMO-approved (certificate current and sighted). Details of solid wastes incinerated or transferred to shore are maintained in the vessel's waste management log book, including records of the receiving company for transferred wastes.	Vessel Operations Manager
	13.3	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).	Environmental induction includes information on waste management and housekeeping requirements. Induction register confirms the survey induction was attended by all crew. Mid-survey audit confirms bins are available and labelled appropriately, and bins for potentially wind-blown wastes are suitably covered.	Vessel Operations Manager
	13.4	Recycling or re-use of non-hazardous solid waste, where possible.	Environmental induction includes information on waste management and housekeeping requirements, including recycling or re-use where practicable. Induction register confirms survey crew have received this induction.	Vessel Operations Manager
Introduction of Invasive Marine Species: Biofouling & Ballast Water				
14	14.1	Vessels entering Australian territorial waters obtain all the Department of Agriculture, Water and the Environment biosecurity approvals, prior to mobilisation.	Pre-survey environmental checklist confirms all seismic and support vessels have Department of	Vessel Operations Manager

EPO #	EPS #	EPS	MC	Responsibility
			Agriculture, Water and the Environment biosecurity clearance. Mid-survey audit confirms that any conditions imposed by the Department of Agriculture, Water and the Environment clearance are being complied with.	Survey Environmental Adviser Party Chief
	14.2	All vessels maintain a current anti-fouling coating that complies with the requirements of Annex 1 of the International Convention on the Control of Harmful Anti-Fouling Systems on Ships and the requirements of the *Protection of the Sea (Harmful Antifouling Systems) Act 2006*.	Pre-survey environmental checklist confirms vessels have current anti-fouling certification that complies with the stated convention and Act.	Vessel Operations Manager Survey Environmental Adviser Party Chief
	14.3	In accordance with the Australian Ballast Water Management Requirements, vessels do not exchange ballast water within 12 nm of the Australian coastal baseline or in water depths of less than 50 m.	In the event that a ballast water exchange is required, ballast water management log confirms the position of the vessel is >12 nm from nearest land and in water depths > 50 m when exchanging water taken up in a foreign port or coastal waters. Environmental induction includes a summary of IMS and ballast water management. Induction register confirms the survey induction was attended by all crew.	Vessel Operations Manager Survey Environmental Adviser Party Chief Vessel Master
	14.4	Compliant with the Australian Ballast Water Management Requirements, vessels 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 (as defined in the *Biosecurity (Ballast Water and Sediment) Determination 2017*);	Pre-survey environmental checklist confirms: ■ Biofouling Record Book is current and management actions are up to date; ■ IMS risk assessment has been completed prior to the vessel's entry into Australia and the risk has been determined as low; and ■ Equipment maintenance records confirm that in-water equipment is free of marine fouling prior to survey commencement.	Vessel Operations Manager Party Chief

EPO #	EPS #	EPS	MC	Responsibility
		■ 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; or ■ discharge to an approved ballast water reception facility.		
	14.5	Vessels have an approved Ballast Water Management Plan and valid Ballast Water Management Certificate, unless an exemption applies or is obtained from the Department of Agriculture, Water and the Environment.	IMO type approval certificate or BWM-T class vessel specification sheet for the ballast water treatment system.	Vessel Master Vessel Operations Manager
	14.6	Vessels maintain complete and accurate records of ballast water exchange consistent with the Australian Ballast Water Management Requirements.	Mid-survey audit confirms that all survey and support vessels have a Ballast Water Management Plan and ballast water record system/book, consistent with the Australian Ballast Water Management Requirements.	Vessel Master Vessel Operations Manager
	14.7	A biofouling risk assessment is completed for each vessel entering Australian territorial seas prior to mobilising to the Operational Area.	Pre-survey environmental confirms all survey and support vessels have a Ballast Water Management Plan and ballast water record system/book, consistent with the Australian Ballast Water Management Requirements.	Vessel Operations Manager Survey Environmental Adviser Party Chief
	14.8	All towed seismic equipment (source and streamers) removed from the water, inspected and cleaned (where required) prior to deployment in Australian territorial waters.	Survey log confirms streamers have been inspected and cleaned (if required) prior to deployment in the Operational Area (containing photographs where feasible).	Vessel Operations Manager Survey Environmental Adviser Party Chief

10. IMPLEMENTATION STRATEGY

In accordance with Regulation 14 of the OPGGS (E) Regulations, this section describes:

- The Environmental Management System (EMS);
- Compliance assurance arrangements, including arrangements for monitoring, review and reporting of environmental performances;
- Preparedness for responding to oil pollution emergencies through an OPEP and appropriate arrangements for environmental monitoring; and
- Arrangements for ongoing stakeholder consultation and notifications.

10.1 Environmental Management System

The Capreolus-2 3D MSS will be conducted under the framework of the TGS Environmental Policy (Appendix A) and Health and Safety Policy (Appendix B). The seismic programme will be supported by a bridging document between TGS and the contractor for the operation of the survey and support vessel(s).

To ensure TGS's environmental management standards and performance outcomes are achieved, the contractor will be required to comply with all relevant requirements of TGS' HSE systems, policies and standards.

TGS and its contractors will apply a tiered approach to optimising the environmental performance of the project and ensuring that TGS's environmental management standards and performance outcomes are achieved. The approach involves identification of local and regional environmental sensitivities, prioritisation of risks, determination of appropriate practices and procedures to reduce those risks, and clear designation of roles and responsibilities for implementation.

A series of work instructions, procedures and plans will be used for surveys undertaken within the Operational Area to ensure that appropriate management measures are applied as required to minimise the risk of environmental disturbance from operations. The work instructions, procedures and plans are documented within corporate systems/manuals developed by TGS as well as documents written specifically for marine seismic surveys undertaken within the Operational Area. The vessel contractor shall have a suite of procedures that may apply to all vessels in their fleet; however the associated work instructions are generally vessel specific.

10.2 Roles and Responsibilities

Key roles and responsibilities for TGS and contractor personnel in relation to the implementation and review of this EP are described below.

It is the responsibility of all TGS employees and contractors to ensure that the requirements of the corporate and Environment Policy (Appendix A) are applied in their areas of responsibility and that the personnel are suitably trained and competent in their respective roles.

10.2.1 Shore Personnel

Role	Responsibility Relevant to this EP
TGS Vessel Operations Manager (TGS VOM)	■ Ensure the activity is undertaken as per the performance objectives of the EP. ■ Provide sufficient resources to implement management measures to achieve the performance objectives of the EP.

Role	Responsibility Relevant to this EP
	▪ Manage change requests for the activity and notifying the TGS Survey Environmental Adviser (SEA) of any scope changes in a timely manner. ▪ Liaise with regulatory authorities such as NOPSEMA, NOPTA and AMSA as required. ▪ Review the EP as necessary and manage change requests ▪ Ensure the programme's contractual obligations in relation to environmental management are met by the survey vessel operator. ▪ Ensure that an annual audit of TGS's environmental management framework is carried out ▪ Ensure that audits of contractor HSE management systems are carried out annually or with every new contractor, whichever is more frequent ▪ Ensure environmental incident reporting meets regulatory requirements (as outlined in the EP) and TGS's internal HSE Incident Reporting Procedure. ▪ Monitor and close out corrective actions raised from environmental inspections/audits or incidents. ▪ Commit necessary resources to facilitate an emergency response strategy in the event of an incident ▪ Manage TGS's emergency response strategy in the event of an incident, including monitoring of response actions conducted by third parties such as vessel operators and designated combat agencies e.g. AMSA. ▪ Review results of compliance audit during the program and make recommendations where required. ▪ Ensure that all reportable and recordable incidents are reported to NOPSEMA. ▪ During survey(s), ensure Monthly Reporting requirements to NOPTA and Ingress Grantors are undertaken. ▪ Ensure that a full briefing to all project personnel is provided, including details of the environmental sensitivities of the survey area and environmental management procedures and performance outcomes detailed in this EP. ▪ Ensure that a Post-survey Environmental Review Report (PERR) is prepared and submitted to NOPSEMA. ▪ Liaise directly with Seismic Contractor's onshore management team re all matters pertaining to the EP, survey and support vessels' activity. ▪ Responsible for compliance to HSE Plan, ISM (International Safety Management) code, local, flag state, port state and class requirements for assigned vessels.
Seismic Contractor Vessel Operations Manager (VOC)	▪ Ensure the activity is undertaken as per the performance objectives of the EP. ▪ Ensure that the following documents are aboard and implemented: ▪ HSE Plan;

Role	Responsibility Relevant to this EP
	▪ Project Plan; ▪ Emergency Response Procedures; ▪ HSE Management Procedures; ▪ Hazard Management Procedures; ▪ Environmental Management Procedures; and ▪ this EP. ■ Ensure Seismic and Maritime personnel on survey and support/chase vessels are aware of their role and/or responsibility with regards to the EP and compliance with the EP commitments. ■ Responsible for compliance to HSE plan, ISM code, local, flag state, port state and class requirements for assigned vessels. ■ Responsible to ensure investigations are initiated on maritime events including breakdowns. ■ Responsible to follow up on maritime incidents and that corrective actions are identified and implemented. ■ Responsible to capture lessons learned and ensure Experience Transfers are issued. ■ Ensures latest copies of all survey-related documentation is available and on board all vessels involved in the survey, including support/support vessel. ■ Ensure all offshore personnel are made available for Project Inductions and are signed-off accordingly.
Onshore Environmental Advisor (EA)	■ Prepare and revise the survey EP as necessary. ■ Prepare environmental induction and vessel inspection information. ■ Provide a briefing to project personnel and survey vessel crew members of the environmental sensitivities of the survey area, environmental management procedures and performance objectives detailed in the EP as part of the environmental induction process. ■ Assist with review, investigation and reporting of environmental incidents. ■ Ensure environmental inspections/audits are undertaken as per the requirements of the EP. ■ Ensure stakeholder consultation is undertaken as per the requirements of the EP. ■ Assist in preparation of external regulatory reports required for the survey, in line with environmental approval requirements and TGS incident reporting procedures. ■ Assist in the preparation of the Annual Report (if required).

10.2.2 Vessel Personnel

Role	Responsibility Relevant to this EP
Marine Survey Vessel	■ Ensure the safe execution of all operations of the survey vessel. ■ Comply with all relevant State, Federal and International laws relating to vessel ■ Overall responsibility for HSE management aboard the survey vessel. ■ Ensure that appropriate control and mitigation measures are implemented to minimise potential environmental effects resulting from vessel operations (e.g. waste management/disposal; fuel/oil spill response). ■ Immediately notify the Client Site Representative and SEA 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. ■ Ensure compliance with this EP, and any relevant statutory regulations (e.g. vessel discharges to sea) ■ Ensure that vessel procedures and systems comply with the EPO, EPS and MC described in this EP. ■ Report hydrocarbon or other chemical spillage to AMSA, the Client Representative and SEA. ■ Establish and maintain radio contact with other vessels in the operational area and adjacent waters. ■ Provide SEA with any requested environmental compliance-related documents, tables, procedures and work instructions.
Chief Engineer Survey Vessel	■ Overall responsibility for operation and maintenance of engines, generators and other machinery aboard the survey vessel. ■ Verify that the vessel's computerised planned maintenance system (PMS) is used and updated and includes critical components and how to address them. ■ Select the correct survey modes for each machinery component. With special regard to fuel economy and life time costs for the different components. ■ Verify that engine room log, oil record book and other logs are kept according to laws, regulations and vessel contractor's instructions. ■ Have the daily supervision of the running of all machinery, including engines, compressors, and propulsion and power supplies. ■ Be responsible for the maintenance in the engine department. ■ Be responsible for waste management systems dealing with sewage, grey water, putrescible wastes and bilge water.
Party Chief	■ Ensure safe execution of all operations carried out by the seismic crew aboard the survey vessel.

Role	Responsibility Relevant to this EP
	■ Ensure that the following documents are aboard and implemented: ▪ HSE Plan; ▪ Project Plan; ▪ Emergency Response Procedures; ▪ HSE Management Procedures; ▪ Hazard Management Procedures; ▪ Environmental Management Procedures; and ▪ this EP. ■ Ensures the seismic operations are consistent with: ▪ TGS Environmental Policy; ▪ Bridging document between TGS and seismic contractor for the operation of the survey vessel if required; ▪ TGS and seismic contractor plans, procedures and work instructions; ▪ this EP; and ▪ relevant environmental legislative requirements or regulatory conditions. ■ Provide a daily log of activities and environmental incidents to the Client Site Representative. ■ Ensure that appropriate control and mitigation measures are implemented to minimise potential environmental impacts resulting from seismic acquisition (e.g. 'soft start' procedures, whale watch and stop work procedures, cetacean, whale shark and turtle sighting records). ■ Ensure compliance with all aspects of HSE reporting and for investigations of all incidents and near misses. ■ Immediately notify the Client Site Representative and SEA of any incidents/activities arising from seismic operations that are likely to have a negative impact on the performance objectives detailed in this EP.
Client Site Representative (CSR)	■ Ensure that the following documents are understood and adhered to: ▪ HSE Plan; ▪ Project Plan; ▪ Emergency Response Procedures including survey vessel SOPEP; ▪ HSE Management Procedures; ▪ Hazard Management Procedures; ▪ Environmental Management Procedures; and ▪ this EP.

Role	Responsibility Relevant to this EP
	■ Facilitate clear communications between the Perth office, the TGS Director, Vessel Operations Manager and the survey vessel personnel. ■ Ensure that, during all proposed surveys within the operational area all sub-contractors perform operations in a manner consistent with the environmental management procedures and performance outcomes detailed in this EP. ■ Ensure that the survey vessel Master and Party Chief are adhering to the requirements of this EP. ■ Ensure that he/she is fully aware of ongoing operations, particularly for environmentally critical activities. ■ Immediately alert the TGS Vessel Operations Manager of any changes in operations that could have a negative impact on environmental performance. ■ Immediately report any reportable incidents to the TGS Vessel Operations Manager. ■ Maintain records of daily logs, environmental incidents, waste inventory and cetacean, whale shark and turtle sightings provided by the Party Chief, SEA and MFOs. ■ Assist in the preparation of the Annual Report (if required). ■ Before each affected line commences, Client Representative confirm first and last shot point (including soft start location) are in the correct location and outside of exclusion zones and correct source capacity is selected for water depth.
Survey Environmental Adviser (SEA)	■ Adhere to the survey EP as necessary; ensure all seismic activities are undertaken in accordance with the Environment Plan and that all staff on the seismic vessel and support vessel are properly inducted and aware of the conditions of the Environment Plan. ■ Record and collate all measurable performance outcomes of the EP within the Environmental Compliance Register (ECR). ■ Prepare and maintain the ECR. ■ Prepare environmental induction and vessel inspection information. ■ Provide a briefing to project personnel and survey vessel crew members of the environmental sensitivities of the operational area, environmental management strategies, EPO, and EPS detailed in the EP as part of the environmental induction process. ■ Assist the MFO team with visual observations and required EBPC Policy Statement 2.1 reporting for cetacean interactions. ■ Assist MFOs and monitor for the presence of marine fauna. ■ Assist with review, investigation and reporting of environmental incidents. ■ Provide suitable support (i.e. training and materials) to assist the main seismic vessel and support vessel crews with the correct identification and reporting of cetacean and other marine fauna

Role	Responsibility Relevant to this EP
	■ Check and verify the accuracy of HSE totals provided in the daily and weekly reports, based upon independent observation of the events noted in the reports ■ Ensure environmental inspections/audits are undertaken as per the requirements of the EP. ■ Assist in preparation of external regulatory reports required for the survey, in line with environmental approval requirements and the TGS HSE incident reporting procedures. ■ Assist in the preparation of the Annual Report (if required). ■ Bring to the immediate attention of CSR and TGS onshore staff (TGS Vessel Operations Manager) any actions that are not compliant with the EP. Any recordable incidents will be logged within the ECR. ■ SEA will confirm the acoustic source is not located within exclusion zones or outside of the operational area prior to commencement of the acoustic source array.
Marine Fauna Observers (MFO)	■ Maintain watch for cetaceans, whale sharks and turtles and during the course of the survey advise the Client Representative and Party Chief, of the presence of these marine fauna. ■ Implement Part A Standard Management Procedures and additional Part B Additional Management Procedures as identified in this EP. ■ Monitor and record any interactions with cetaceans and other marine fauna. ■ Assist in the preparation of the MFO Final Report.
Seismic Operators, Technicians and Vessel Crew	■ Apply operating procedures in letter and in spirit. ■ Follow good housekeeping procedures and work practices. ■ Encourage improvement in environmental performance wherever possible. ■ Immediately report environmental incidents or spillage of >1 L of hydrocarbons or other chemicals to the survey vessel Master and survey Party Chief. ■ Before each affected line commences, Chief Navigator confirms first and last shot point (including soft start location) are in the correct location and outside of exclusion zones and correct source capacity is selected for water depth. ■ Seismic Navigators will confirm seismic acquisition lines entered into the integrated navigation system are not located within exclusion zones or outside of the operational area: ▪ start of line and end of line location are located only within acquisition area.

10.2.3 Training and Competency

All personnel on the vessel(s) are required to be competent to undertake their assigned positions. Specific responsibilities will be detailed in job descriptions and appropriate training provided to individuals with environmental responsibilities such as waste management measures; routine discharges; and deployment and recovery of streamer procedures. Training may be in the form of inductions, ‘on the job’ or external courses.

The survey vessel Master will possess appropriate skills, knowledge and qualifications to command the vessel.

TGS will ensure the vessel operator provides 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) or Elements of Shipboard Safety as relevant. A training, induction and competency matrix or similar will confirm that relevant crew have been trained as necessary for their position.

As per the EPBC Policy Statement 2.1 requirements, MFOs will have been “trained and experienced in whale identification and behaviour, distance estimation, and be capable of making accurate identifications and observations of whales in Australian waters. “At least one MFO or the SEA will have experience in implementing Policy 2.1 in Australian waters.

10.2.3.1 Environmental Inductions

All personnel required to work on the survey and support vessels will be given an HSE induction prior to the commencement of the Capreolus-2 3D MSS. The environmental component of the induction will cover:

- The EP
- Environmental sensitivities, heritage and conservation values of the individual survey location.
- Marine fauna likely to be in the area.
- Procedures for interaction with marine fauna.
- EPBC Policy 2.1 requirements.
- Procedures for reporting of any environmental incidents or hazards.
- Emergency response and spill management procedures.
- Waste and chemical management requirements.
- Roles and environmental responsibilities of key personnel aboard the survey vessel.
- Critical/relevant environmental management measures, EPO, EPS applicable to the location of an individual survey.

All personnel who undertake the induction will be required to sign an attendance sheet, which is retained by the TGS Vessel Operations Manager. All vessel based personnel will be required to conform to all applicable guidelines and requirements for management of HSE issues. All crew on board the vessel/s will be made aware of and will be required to become familiar with the requirements of both the contractor specific environmental management systems as well as the EP during the activity induction process.

10.3 Compliance Assurance

10.3.1 Monitoring

Monitoring will be undertaken for the survey, and records kept as detailed in Table 10-1.

Table 10-1 Monitoring Summary

Discharge/Incident	Parameters	Record	Responsibility
Atmospheric Emissions			
Engine emissions	Quantity of marine diesel used by the seismic vessel	Engineers log	Vessel Master
Discharges to Sea			
Oily water discharges	The volume of oily water discharge from the seismic vessel.	Oil usage management electronic records	Vessel Master
Food waste	The volume of food-scraps discharged from the seismic vessel	Waste management electronic records	Vessel Master
Sewage/grey water discharge	The volume of sewage and grey water discharged from the seismic vessel	Engineers log	Vessel Master
Disposal of Wastes			
Hazardous wastes	Volume of hazardous wastes transferred onshore.	Waste management electronic records/oil usage management electronic records	Vessel Master
Non-hazardous wastes	Volume of non-hazardous wastes transferred onshore	Waste management electronic records	Vessel Master
Marine Fauna Interaction			
Cetacean, whale shark, dugong and turtle sightings	Details required on the Whale and Dolphin Sighting reports (DAWE)	Sighting records	MFOs
Collisions with cetaceans in Commonwealth waters will be reported to the National Ship Strike Database.	Location, timing, species, vessel speed, what happened	National Ship Strike Database https://data.marine mammals.gov.au/report/ shipstrike/new	MFOs
Marine User Interaction			
Vessel Interaction/ Complaints	Communications with other vessels	Ships log	Vessel Master

10.3.2 Review of Environmental Performance

TGS will undertake an internal review of the environmental performance of the survey on completion. The review will consider:

- An evaluation of conformance with the compliance register (based on the environmental performance outcomes, standards and measurement criteria outlined in Section 9);
- Improvements to the implementation strategy included within the EP;
- Compliance with TGS' Policies, Manuals and Procedures;
- The management of non-conformances identified during the survey, including reportable and recordable incidents; and
- Concerns identified by stakeholders during and after the completion of each survey phase, followed by appropriate liaison as required.

The outcomes of the review will be circulated to relevant persons in TGS and to other stakeholders as appropriate. The outcomes of the review will be incorporated into environmental management measures applied to future activities to further improve TGS' environmental performance, and will be included in the Environmental Performance Report submitted to NOPSEMA.

10.3.3 Management of Change

In order to ensure that impacts and risks are continually reduced to ALARP and acceptable levels and the requirements of legislation will continue to be met, TGS will undertake periodic verification of environmental inputs used to inform the evaluation of impacts and risks in the EP, including identifying updates to legislative requirements and environmental information.

Review and verification of the information in the EP will be undertaken:

- Prior to mobilisation (of each survey phase); or
- Annually from the date of acceptance of the EP (whichever occurs first).

This will include relevant legislation, guidance, species conservation management plans, protected area management plans, new and significant environmental information and research and new stakeholder information.

A record of each verification will document identified changes or new information and an evaluation will be conducted to confirm:

- Applicable changes to controls, environmental performance outcomes, standards and measurement criteria;
- Currency of certificates for insurance policies (and that the policies would apply in the event of a hydrocarbon spill; and
- If the information/change results in a new or increased residual risk ranking, as determined in the EP.

In addition, opportunities for improvement identified during reviews of environmental performance will be evaluated for any potential changes to control measures, environmental performance outcomes, standards and measurement criteria.

The requirements to develop a revision to the EP (in accordance with Regulation 17 of the OPGGS (E) Regulations) will be triggered should the following be identified:

- Significant modification or new stage of activity;
- New or increased environmental impact or risk;
- Change in titleholder; or
- Changes to management of impacts and risks.

The above triggers (for a revision of the EP) will also trigger further consultation with relevant stakeholders to inform them of any changes to the proposed activity or associated risk profile.

10.3.4 EP Review and Resubmission

During review of environmental performance (Section 10.3.2), or during verification of information or following a change, any new information, changes or updates will 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 including the following:

- **17(1) New activity**, defined as a change to the extent that the regulatory levy category applied to the Capreolus-2 3D MSS would change.

- **17(5) Significant modification** of the activity or to how the activity is being managed and conducted. A modification to the activity is considered to be significant if any of the following significance criteria are met:
  i. The number of vessels used during the survey increases from that described in Section 3; or
  ii. The seismic source volume is increased beyond that defined in Section 3; or
  iii. The vessel fuel type changes from that described in Section 3; or
  iv. An Environmental Performance Outcome, or an Environmental Performance Standard is altered to the degree that it;
    - Materially alters the intent of a performance outcome or performance standard; or
    - If the overall activity or a potential impact or risk of the activity can no longer be managed to ALARP or acceptable levels.
- **17(5) New stage** of the activity, defined as either:
  i. A change to the spatial limits of the activity (an increase in the Acquisition Area or Operational Area boundary); or
  ii. A change to the temporal limits of the activity (an extension to the timeframe of this EP).
- **17(6) New or increased environmental impact or risk**. Only significant new or significant increased impacts or risks require resubmission of the EP to NOPSEMA.

A new impact or risk is considered by TGS to be significant if any of the following significance criteria are met:

i. The residual impact or risk, after determining controls and environmental performance standards, is categorised as 'Medium' or 'High'; or
ii. The impact or risk is not determined to be Acceptable;
iii. The impact or risk is not determined to be ALARP.

An increase in an impact or risk is considered by TGS to be significant if any of the following significance criteria are met:

i. The residual impact or risk ranking, after reviewing and identifying controls and environmental performance standards, increases by a category (e.g. from Low risk to Medium risk); or
ii. The impact or risk is no longer Acceptable;
iii. The impact or risk is no longer ALARP.

- **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).

10.3.5 Record Management

Record retention requirements relevant to the Capreolus-2 3D MSS are summarised in Table 10-2.

Table 10-2 Record Retention Requirements

Records
■ Environmental Induction Register; ■ Daily operational log; ■ Vessel communication log; ■ Maintenance records; ■ Measurement and recording of criteria that form the environmental performance outcomes; ■ Marine fauna sighting records and Activity Log, including records of action taken for managing interactions with marine fauna; ■ Waste management electronic records; ■ Oil usage management electronic records; ■ Marine User Consultation Logs (pre-mobilisation and during seismic survey); ■ Incident Register (including Marine User Complaints), incident investigation reports and corrective actions register; ■ Notice to Mariners and AUSCOAST warnings; ■ CVs of MFOs; ■ Emergency/Oil Spill Response Exercise Records; ■ Oil Pollution Reports (POLREPs), Situation Reports (SITREPs) and other incident documentation that would result from vessel oil spills; ■ Records of notifications to the DAWE (as required); ■ International Sewage Pollution Prevention (ISPP) certificate; ■ International Oil Pollution Prevention (IOPP) certificate; ■ International Air Pollution Prevention (IAPP) certificate; ■ Oil-water separator service records; ■ Engine service records; ■ Records of calibration and maintenance of monitoring devices; ■ Ballast water records and copies of required reports to the DAWE related to ballast water management; ■ Anti-fouling certificate; ■ Safety data sheets (SDS) for hazardous chemicals; and ■ End of Survey Closeout Report.

10.3.5.1 Storage of Records

Storage of Records Versions of the EP will be stored by TGS in such a way as to make retrieval of the EP reasonably practicable. Each version will be kept for at least five years after the date the version ceases to be in-force.

10.3.5.2 Making Records Available

In accordance with the provisions of Regulation 28(2), TGS will make available copies of records described in Section 10.3.5 to the following persons (or their agent), on request in writing by the person:

- NOPSEMA;
- A delegate of the responsible Commonwealth Minister; and
- A greenhouse gas project inspector or a petroleum project inspector.

The copies of the records will be made available:

- In the case of an emergency relating to an activity – as soon as possible at any time of the day or night during the emergency; and
- In any other case – during normal business hours in the place where the records are kept.

The copies of the records will be made available at the place where the records are kept, or if agreed between TGS and the person making the request (or the person's agent), at any other place (including by means of electronic transmission to the person or agent at that place). If the records are stored on a computer, the records will be made available in print-out form or, if TGS and the Regulator so agree, in electronic form.

10.3.6 Reporting Requirements

10.3.6.1 Environmental Performance Reporting

TGS will maintain a record of the environmental performance of the Capreolus-2 3D MSS in relation to the environmental performance outcomes, standards and measurement criteria detailed in Sections 7 and 8. This record will be documented in the form of an Environmental Compliance Register (ECR).

A detailed report on the environmental performance ('Environmental Performance Report'), including the ECR, will be submitted to NOPSEMA for assessment within two months of survey completion, or at least annually from the date of EP acceptance (whichever occurs first). The report and associated ECR will be retained by TGS for a period of five years and will be made available as stated in Section 10.3.5.2.

10.3.6.2 Reportable Incidents

TGS will notify NOPSEMA of an incident relating to the survey that has caused, or has the potential to cause, moderate to significant environmental damage (reportable incident). Based on the risk assessment undertaken, the following residual consequences rated as 'Massive' or higher (refer to Section 6) during the risk assessment for this EP, are considered consistent with the moderate to significant environmental damage defined in the Regulations:

- Collision or entanglement with large marine fauna resulting in injury/death of a listed species;
- Confirmed introduction of IMS resulting in alterations to local ecosystems; and
- A hydrocarbon or chemical spill categorised as a Tier 2 hydrocarbon (MDO) spill resulting in toxic effects and oiling of marine biota, and interruption to commercial and coastal fishing and shipping activities (for the purposes of this EP a Tier 2 hydrocarbon (MDO) spill is equivalent to a Level 2 incident under the National Plan for Maritime Environmental Emergencies (AMSA 2019)). A Tier 2 hydrocarbon spill, which is more complex in size, duration, resource management and risk, than a Level 1 incident (AMSA 2019), may require deployment of additional resources beyond the initial response, and which may require trans-jurisdictional involvement. This would be facilitated by AMSA.

As such, realisation of these consequences would be considered to constitute a reportable incident.

In the event of a reportable incident occurring during the survey that has an actual or potential reputational risk for TGS, NOPSEMA will also be notified. Reputational risks will be assessed as they apply to TGS' risk assessment and performance standards.

NOPSEMA will be notified of reportable incidents by TGS as soon as practicable, and not later than two hours after the first occurrence of the incident, and a written report submitted using NOPSEMA's FM0831 template (Report of an Accident, Dangerous Occurrence or Environmental Incident) within three days. Notification of reportable incidents will contain the following:

- Material facts and circumstances concerning the reportable incident that the operator knows or is able, by reasonable search or enquiry, to find out;
- Action taken to avoid or mitigate adverse environment impacts of the reportable incident;
- The corrective action that has been taken, or is proposed to be taken, to stop, control or remedy the reportable incident; and
- The corrective action that has been taken, or is proposed to be taken, to prevent a similar reportable incident.

When notifying NOPSEMA of a reportable incident, TGS will also notify NOPTA and the Department of the responsible State Minister in writing within seven days. TGS will submit a written report of a reportable incident in accordance with a notice given by the Regulator, if required to do so. Additional notifications and reporting relevant to oil spills are described in Section 10.4.6.

Although a Level 2 incident / Tier 2 hydrocarbon spill requires involvement from a third party Control and Combat agency, overall responsibility for reporting 'reportable incidents' under the OPGGS (E) Regulations remains with the titleholder (i.e. TGS).

It is therefore not expected that the required reporting of the incident to NOPSEMA by TGS would be delayed beyond the requirement of two hours after:

- The first occurrence of the reportable incident; or
- If the reportable incident was not detected by the titleholder at the time of the first occurrence—the time the titleholder becomes aware of the reportable incident.

10.3.6.3 Recordable Incidents

TGS will maintain a record via an ECR of breaches of an environmental performance outcome or environmental performance standard that is not a reportable incident (i.e. a recordable incident). Recordable incidents occurring during the survey that have actual or potential reputational risk to TGS will also be recorded in the ECR. The reputational risk of recordable incidents will be assessed as they apply to TGS' risk assessment and performance standards. This written record will be provided as soon as practicable to NOPSEMA for each calendar month in which the Capreolus-2 3D MSS is undertaken, and will be provided no later than 15 days following the end of a calendar month.

This report will contain:

- A record of any recordable incidents that occurred during the calendar month;
- Material facts and circumstances concerning the recordable incident(s) that the titleholder knows or is able, by reasonable search or enquiry, to find out;
- Action taken to avoid or mitigate adverse environment impacts of the recordable incident(s);
- The corrective action that has been taken, or is proposed to be taken, to stop, control or remedy the recordable incident(s); and
- The action that has been taken, or is proposed to be taken, to prevent a similar incident occurring in the future.

The Environmental Performance Report (Section 10.3.6.1) will include a summary of recordable incidents. Lessons learnt from the environmental compliance audit (Section 10.3.6.6) will be included in the Environmental Performance Report.

10.3.6.4 TGS Incident Reporting

Incidents involving people, environment and property (including reportable and recordable incidents) during the survey will be recorded, reported and investigated.

All corrective actions arising from incidents, audits and inspections are recorded and monitored for closure. Corrective and preventative actions taken to eliminate the cause of potential incidents will be commensurate with the magnitude of the environmental risks.

In line with TGS' commitment to continual improvement, environmental incidents and near misses will be shared amongst vessels (seismic and support vessels), and corrective actions will be applied to other vessels where relevant. In addition, TGS will carry forward the identified corrective/preventative actions from incidents for consideration in future seismic survey campaigns to ensure "lessons learnt" are captured and assist with continuous improvement in environmental management or to provide frequency data (i.e. likelihood determination) associated with seismic survey operations.

10.3.6.5 Cetacean Sighting Reports

In accordance with EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales, the interaction between the seismic survey vessel and cetaceans (and whale sharks) in the area will be documented using the Cetacean Sightings Application (v 3.0). A report detailing interactions will be provided to DAWE by TGS within two months of completion of each survey phase.

10.3.6.6 Compliance Audits

TGS will maintain an ECR that will serve as an audit tool during the Capreolus-2 3D MSS. The register will be sufficiently detailed to enable auditors to determine whether the environmental performance outcomes and standards for the survey have been met. The register includes:

- The environmental performance outcomes and environmental performance standards relevant to the survey as set out in this EP;
- Measurement criteria to enable an auditor to determine if the survey has complied with the relevant performance standards; and
- The person/party responsible for implementing the performance standard to meet the environmental performance outcome.

Prior to mobilisation TGS will complete:

- A pre-survey environmental checklist addressing pre-survey planning, preparedness for compliance with regulatory requirements, including this EP, operational considerations and on board preparedness. The activity will be documented and corrective actions rectified prior to mobilisation;
- An audit of the on-board spill response capability against the vessel SOPEP to verify spill preparedness;
- An inspection of the vessel(s) will be carried out before or during each survey phase to ensure vessel(s) are compliant with the EP.[34]

TGS will conduct a compliance audit against this EP during the survey (prior to survey completion). This will target confirmation that:

- Compliance with regulatory requirements detailed in this EP is being achieved;
- Environmental performance outcomes and standards are being monitored, measured and evaluated as required;
- Emissions and discharges are being monitored, measured and documented as required; and
- Management strategies and procedures to achieve the environmental performance outcomes are in place and being implemented effectively.

Any required remedial actions will be followed up. A copy of the environmental compliance audit will be forwarded to NOPSEMA upon request.

Lessons learnt from the environmental compliance audit will be included in the Environmental Performance Report submitted to NOPSEMA (refer to Section 10.3.6.1)

10.3.6.7 Management of Non-conformance

Non-conformances and opportunities for improvement will be identified and corrective actions will be tracked to completion in the ECR.

TGS will carry forward non-conformances identified during the Capreolus-2 3D MSS for consideration in future seismic surveys to assist with continuous improvement in environmental management controls and performance outcomes.

[34] Vessel inspections are not required, if vessels are moving immediately from one individual survey to another individual survey covered under a TGS' accepted EP in Commonwealth waters.

10.4 Emergency Management and Response

10.4.1 Emergency Response Procedure

A survey specific Emergency Response Procedure (ERP) will be included in the Project HSE Plan. The Project HSE Plan contains instructions for vessel emergency, medical emergency, search and rescue, reportable incidents, incident notification and contact information.

In the event of an emergency of any type the survey vessel(s) Master will assume overall onsite command and act as the Emergency Response Coordinator (ERC). All persons aboard the vessel/s will be required to act under the ERC's directions. The survey vessel(s) will maintain communications with the TGS Operations Manager and/or other emergency services in the event of an emergency. Emergency response support can be provided by TGS, if requested by the ERC.

The survey and support vessels will have equipment onboard for responding to emergencies, including but not limited to medical equipment, firefighting equipment and oil spill equipment.

10.4.1.1 Tropical Cyclones and Severe Weather

Tropical cyclones and other severe weather events have the potential to cause damage to survey equipment, risk to the health and safety of survey personnel and unplanned discharges of hazardous materials into the marine environment.

If the survey is undertaken during the cyclone season, TGS will ensure that vessel contractors have a procedure that covers dangerous weather situations including protocols for cyclones.

If sustained severe weather looks to be forming within the region, the vessels may leave the survey area for safer waters. Depending on the situation, the survey vessel may also retrieve the seismic equipment and in a worst-case scenario proceed to the nearest port.

10.4.2 Oil Pollution Emergency Plan

In order to encompass the nature and scale of the survey and respond to the identified credible spill scenarios (Section 8.1.2), the overall Oil Pollution Emergency Plan (OPEP) for the survey encompasses multiple levels of planning and response capability.

The overall seismic survey OPEP is therefore represented by various levels of emergency plan, which comprise of:

- Vessel(s) SOPEP – for spills contained on the vessel or spills overboard which can be managed by the vessel;
- The National Plan for Maritime Environmental Emergencies (National Plan) (AMSA 2014) - AMSA is the jurisdictional authority and control agency for spills from vessels which affect Commonwealth waters; and
- The Western Australian State Hazard Plan for Maritime Environmental Emergencies (State Hazard Plan) (DoT 2019) – for spills from vessels, which affect WA State waters.

10.4.3 Vessel SOPEPs

Vessels > 400 T are required to have a SOPEP onboard, prepared in accordance with the IMO guidelines for the development of shipboard oil pollution emergency plans (resolution MEPC.54(32) as amended by resolution MEPC.86(44)) and include emergency 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 Environment Regulations.

Vessels < 400T that do not have a SOPEP must have a spill response plan that deals with spill response, pollution monitoring and provisions for testing the plan. These vessels shall be included in the survey OPEP drills.

Priority actions in the event of a hydrocarbon spill are to make the area safe, stop the leak and ensure that further spillage is avoided. All deck spills will be cleaned-up immediately, using appropriate equipment from the on board spill response kits (e.g. absorbent materials) to minimise any likelihood of discharge of hydrocarbons or chemicals to the sea.

The Vessel Master is responsible for activating and implementing the vessel SOPEP.

10.4.4 Spill Response Options

Spill response mitigation measures will be implemented as appropriate to reduce the likelihood of impacts to key marine environmental receptors (refer to Section 8.2). The objectives of spill response includes the protection of human health, environmental values, and the protection of assets. The selection of spill response techniques in any situation will include an assessment of the net environmental benefit of the technique, taking account of priorities for protection and restoration and the sensitivity of the receptors at risk.

Based upon the outcome of the predictive spill modelling and the properties of MDO, the following spill response options are considered applicable for potential MDO spills:

- Source control, which will include locating the source of the leakage and may also include isolating the tanks, transferring oil to slack or empty tanks, ceasing bunkering operations or using scupper plugs;
- Monitor and evaluate the trajectory and extent of the spill; and
- Assisted natural dispersion using propeller wash, if advised by the Control Agency, AMSA, and deemed safe.

The above spill response options are not expected to introduce additional hazards to the marine environment or to result in significant additional potential impacts. The response options of source control, monitor and evaluate and assisted natural dispersion will use existing survey and/or support vessels, and the potential impacts associated with the use of vessels is evaluated in Section 7.4 and 7.5..

10.4.4.1 Preferred Response Strategy

The vessel master will initiate the vessel SOPEP (and first strike actions as outlined within it), in consultation with the relevant statutory Combat Agency (initial AMSA, given the location of the Operational Area in Commonwealth waters).

Due to the nature and scale of the activity, credible spill scenarios and characteristics of diesel, the initial response to any spill will be to monitor and evaluate. The preferred strategy for diesel spills will be to allow small spills to disperse and evaporate naturally, and monitor the position and trajectory of any surface slicks. Physical break up (using prop wash from the support vessel) by repeated transits through the slick may be considered for larger slicks (following consultation with the Combat Agency – AMSA or WA DoT).

Priority actions in the event of a fuel or oil spill are to make the area safe and to stop the leak and ensure that further spillage is not possible. All deck spills aboard vessel(s) will be cleaned-up immediately, using appropriate equipment from the on board spill response kits (e.g., absorbent materials etc.) to minimise any likelihood of discharge of spilt hydrocarbons or chemicals to the sea.

The survey vessel will carry spill containment and recovery kits with sufficient absorbent booms and materials to contain small to medium scale deck spills. The survey vessel Master will be responsible for ensuring that these kits are appropriately stocked at all times. Minor spills will be managed through housekeeping practices and the use of absorbent materials. Deck spills will not be discharged into the ocean

10.4.5 Statutory Oil Spill Contingency Plans

10.4.5.1 Australian Commonwealth Waters

The National Plan for Maritime Environmental Emergencies

The National Plan is an integrated government and industry framework that seeks to enable effective response to marine pollution incidents and maritime casualties. The framework, in accordance with the polluter pays principles of the OPRC 1990, provides for industry as the control agency for all spills which originate from offshore petroleum activities. NOPSEMA collaborates closely with the Australian Maritime Safety Authority (AMSA), as the manager of The National Plan, to ensure that arrangements under The National Plan, the OPGGS Act and associated regulations are aligned and understood.

In Commonwealth waters, initial actions will be undertaken by the vessel with subsequent actions determined in consultation with the regulatory authorities under the National Plan. AMSA is the responsible Combat Agency for hydrocarbon spills from vessels in waters under Commonwealth jurisdiction and will respond in accordance with its Marine Pollution Response Plan as approved by the AMSA Executive. Upon notification of an incident, AMSA will assume control of the incident.

Offshore Petroleum Incident Coordination Framework

The Australian Government established the Offshore Petroleum Incident Coordination (OPIC) framework for coordinating a whole of government response to a significant petroleum incident in Commonwealth waters. The framework interfaces with other emergency incident response/coordination arrangements, including The National Plan, titleholder oil pollution emergency plans and state/Northern Territory marine pollution contingency plans as appropriate.

10.4.5.2 Western Australian Waters

If surface slicks appear likely to enter WA State waters, then subsequent actions will be determined in consultation with the WA DoT under the State Hazard Plan for Maritime Environment Emergencies (State Hazard Plan). The WA DoT is the designated Combat Agency for oil spills from vessels in WA State jurisdiction.

10.4.6 Spill Notifications

In the event of a hydrocarbon release to the marine environment during the survey, appropriate notification arrangements are provided in Table 10-3. Any incidences onboard the seismic or support vessels are to be reported immediately to TGS.

In addition, TGS will advise potentially affected stakeholders identified through the stakeholder consultation (refer to Section 5), including stakeholders within the commercial fishing industry.

Table 10-3 Spill Notification Arrangements

Agency	Contact Details	Notification Trigger	Reporting Requirement and Timing	Reporting Forms	Reference
AMSA	1800 641 792 (Emergency) (02) 6230 6811 (Office)	■ All slicks trailing from a vessel ■ All spills in Australian Commonwealth Waters (notwithstanding the size or amount of oil or sheen) ■ All spills where National Plan equipment is used in a response	■ Immediate notification by the Vessel Master ■ Written Marine Pollution Report (POLREP) form submitted by the Vessel Master to AMSA; timing not specified	Incident Reporting Requirements: http://www.amsa.gov.au/forms-and-publications/AMSA1522.pdf AMSA POLREP: https://www.amsa.gov.au/environment/maritime-environmental-emergencies/national-plan/Contingency/Oil/documents/Appendix7.pdf	National Marine Oil Spill Contingency Plan
NOPSEMA	08 6461 7090	A Tier 2 or 3 hydrocarbon spill (i.e. a spill requiring third party support from AMSA).	■ Notification within 2 hours. ■ Written report submitted within 3 days	http://www.nopsema.gov.au/assets/Guidance-notes/N-03000-GN0926-Notification-and-Reporting-of-Environmental-Incidents-Rev-4-February-2014.pdf	OPGSS (E) Regulations
WA Department of Transport (DoT)	(08) 9480 9924 1300 905 866 marine.pollution@transport.wa.gov.au	■ Spill to State waters (including ports and inland waters) from a vessel or unknown source. ■ Spill that has the potential to drift into State waters.	■ Immediate notification by Vessel Master to the Oil Spill Response Coordination (OSRC) Unit. ■ Written POLREP submitted by Vessel	DoT POLREP: http://www.transport.wa.gov.au/mediafiles/marine/mac-f-pollutionreport.pdf SITREP: http://www.transport.wa.gov.au/mediafiles/marine/mac-f-situationreport.pdf	State Emergency Management Plan for Marine Oil Pollution (WestPlan – MOP)

Agency	Contact Details	Notification Trigger	Reporting Requirement and Timing	Reporting Forms	Reference
			Master, as soon as practicable. ■ Written Situation Report (SITREP) within 24 hours of being directed by DoT.		
Commonwealth Department of Agriculture, Water and the Environment (DAWE)	-	■ Spill has potential to cause significant impacts to a matter of national environmental significance (NES) during the survey	■ Written notification submitted within 7 days.	N/A	Environment Protection and Biodiversity Conservation Act 1999
NOPTA and WA Department of Mines, Industry Regulation and Safety (DMIRS)	-	■ Spill to Commonwealth waters during an activity that is reportable to NOPSEMA.	■ Copy of the same report as provided to NOPSEMA within 7 days of the initial report being submitted to NOPSEMA.	Same report submitted to NOPSEMA.	Guidance Note (N-03000-GN0926) Notification and Reporting of Environmental Incidents.
Director of National Parks (DoNP)	Marine Compliance Duty Officer – 0419 293 465	■ Oil/gas pollution incidents within a marine park or likely to enter/impact on a marine park.	■ Notification to be made to the 24hr Marine Compliance Duty Officer by Vessel Master, as soon as practicable. The notification should include: - titleholder details	N/A	

Agency	Contact Details	Notification Trigger	Reporting Requirement and Timing	Reporting Forms	Reference
			- time and location of the incident (including name of marine park likely to be effected) - proposed response arrangements as per the Oil Pollution Emergency Plan (e.g. dispersant, containment, etc.); and - contact details for the response coordinator.		

10.4.7 Testing and Review of Response Arrangements

A test of the oil spill emergency response arrangements (i.e. OPEP) will be conducted:

- during the mobilisation phase of the survey (prior to the commencement of seismic operations);
- if and when a new vessel is engaged for the activity: and
- not later than 12 months after the most recent test/review.

These arrangement for testing are commensurate with the nature and scale of the worst case oil spill scenario.

Vessel-based SOPEP/spill management plans will also be tested during the mobilisation phase as part of the OPEP. As required under Regulation 14(8C)(b), response arrangements shall be tested if they are significantly amended.

All tests will be reported as per MARPOL Annex I (Regulation 15) requirements and reviewed after each drill as part of the ongoing monitoring and improvement of emergency control measures. Identified improvements or recommendations shall be addressed as outlined in Section 10.3.

The objective of testing is to:

- ensure that the vessel SOPEP is current and applicable (including contact details) for dealing with a spill specific to the nature and location associated with an individual survey conducted within the operational area; and
- ensure type 1 ‘operational monitoring’ such as spill surveillance and tracking, specific to the nature and location associated with an individual survey conducted within the operational area, is appropriate, understood and practiced.

In compliance with Regulation 14(4) and 14(5) a designated Oil Pollution Prevention Team (OPPT) will be trained to ensure they are familiar with their tasks and the equipment in the event of an oil spill.

Implementation and testing of the survey vessel(s) SOPEP, plus adherence to the additional spill response and reporting measures detailed in Section 8.2, will enable TGS to demonstrate that environmental risks from hydrocarbon spills events during the proposed survey have been reduced to ALARP.

A planned maintenance system (PMS) will be implemented on the seismic survey vessel and support vessels, to ensure that all equipment used during operations are in full working order, and does not represent a hydrocarbon spill risk. Stocks of absorbent materials aboard the survey vessel will be checked for their adequacy and replenished as necessary prior to the commencement of activities.

The OPEP will be regularly reviewed to ensure it is appropriate to the nature and scale of the activities within its scope and to ensure maintenance of the response capability and the operator’s preparedness. In compliance with Regulation 14(8AA) the OPEP will be continuously reviewed and kept up-to-date to ensure new information or improved technology can be incorporated as specifies in the SOPEP.

10.4.8 Hydrocarbon Monitoring

AMSA (2003) recommends that monitoring programs reflect the scale and potential effects of the spill, and address key environmental issues relevant to the spill. This approach is considered best practice for oil spill monitoring in Australia and will be applied by TGS if spill monitoring is required. Monitoring appropriate to the nature and scale of the spill will be determined based on the hydrocarbon characteristics, the size and nature of the release (e.g. slow continuing release or instantaneous short-duration release), dispersion and dilution rates and the location of the spill that will determine the nature of the receiving environment.

10.4.8.1 Type I Operational Monitoring

In the event of a spill of MDO to the waters surrounding the seismic vessel or support vessels, AMSA, as the Control Agency will be responsible for initiating an appropriate level of Type I "Operational Monitoring" using National Plan resources to monitor the spill and any response effort, if required. Operational monitoring may include spill surveillance and tracking to validate oil spill trajectory modelling. TGS may, at the direction of the Control Agency, support Type I "Operational Monitoring" with on-the-water surveillance to:

- Determine the extent and character of a spill;
- Track the movement and trajectory of surface MDO slicks;
- Identify areas/ resources potentially affected by surface slicks; and
- Determine sea conditions and potential constraints to spill response activities.

This monitoring will enable the Vessel Master to provide the necessary information to the relevant Combat Agency (AMSA or DoT) via a POLREP form to determine and plan appropriate response actions under NATPLAN (if this plan is activated). In addition, provisions for real-time oil spill monitoring may be undertaken by a third part provider (e.g. RPS) if required. Specific monitoring / data requirements are:

- estimation of sea state;
- estimation of wind direction and speed;
- locating and characterising any surface diesel slicks;
- GPS tracking;
- manual or computer predictions (e.g., using ADIOS2 or real-time oil spill monitoring undertaken by third party provider) of movement of surface slicks; and
- GIS mapping.

Location and characterisation of slicks will be restricted to daylight hours only, when surface slicks will be visible from the seismic vessel or support vessels. However, evaluations of sea state and weather conditions from the vessel will continue until this function is taken over by the Combat Agency. The information gathered from this initial monitoring will be passed on to the relevant Combat Agency, via the POLREP form, but also via ongoing SITREP reports following the initial spill notification to AMSA RCC.

TGS will implement, assist with, or contribute to (including funding if required) any other Operational Monitoring (e.g. computer trajectory modelling) as directed by the Combat Agency.

10.4.8.2 Type II Scientific Monitoring

As described in Section 8.1, MDO is expected to undergo rapid evaporative weathering, with approximately 40% - 75% of the spill volume (comprising the most volatile and toxic fractions) expected to evaporate in the first 24 – 48 hours, and low exposures of entrained hydrocarbons subject to biodegradation and decay. Generally, negligible amounts of sea surface hydrocarbons persisted beyond 5 – 10 days.

In the event of a vessel incident resulting in a major fuel release, TGS will work with the Combat Agency and the relevant stakeholders (refer to Section 5), to develop and implement appropriate Type II Scientific Monitoring. The aim of the Scientific Monitoring is to understand the environmental impacts of the spill and response activities on the marine environment, with a focus on relevant environmental and social values and sensitive receptors.

Section 8.2, provides descriptions of the potentially affected environment and potential impacts of such a hydrocarbon spill on environmental and social receptors, including:

- Benthic communities;
- Marine mammals;
- Marine reptiles;
- Fish and sharks;
- Marine birds (seabirds and shorebird)s; and
- Other marine users (e.g. commercial fishing, commercial shipping and tourism/recreational activities).

The Scientific Monitoring program will be developed to ensure that it is sufficient to inform any remediation activities, and be consistent with monitoring guidelines and methodologies such as CSIRO (2016).

The Scientific Monitoring may comprise some or all of the monitoring studies described in Table 10-4. As described previously, in the event of a spill, TGS will engage with the relevant Combat Agency to coordinate and review Operational Monitoring data. Operational Monitoring may provide valuable surveillance and modelling data to confirm the predicted extent and degree of hydrocarbon exposure and impacts. These data will then be used to determine if Scientific Monitoring of relevant key sensitive receptors may be of value in the longer term to evaluate environmental impacts and recovery of affected receptors. The requirement for, and design of, Scientific Monitoring studies will be based on desktop/technical studies and/or field investigations, in order to ensure they are feasible and will obtain relevant information based on available monitoring data, the nature of the receiving environment and results of the consultation process.

For each Scientific Monitoring study triggered in Table 10-4, a detailed monitoring plan will be developed as per the template in Table 10-5. It is noted that where termination criteria for a study includes comparison to appropriate thresholds of concern, those thresholds will be confirmed and specified in the monitoring plan.

If deemed necessary, following consultation with the Combat Agency and relevant stakeholders (e.g. AMSA, DoT, DAWE and/or DBCA), TGS will activate a contract with the company-approved environmental service provider Environmental Resources Management Australia Pty Ltd (ERM) to design and implement the appropriate Scientific Monitoring studies. ERM has previously developed Scientific Monitoring plans and undertaken a wide range of relevant marine environmental monitoring studies in northern Australia and internationally. ERM has the relevant skills, expertise and resources in place to provide scientific monitoring support.

TGS will keep ERM informed of the progress of the Capreolus-2 3D MSS and of any changes related to the risk assessments as documented in this EP. In addition to the required notifications described in Section 10.4.6 should a hydrocarbon spill occur, TGS will notify ERM within 24 hours of the spill occurring. Following that notification, ERM will make the necessary preparations for the potentially required monitoring studies.

Table 10-4 Indicative Scientific Monitoring Studies

Scientific Monitoring Study	Objectives	Initiation Triggers	Termination Criteria
SM01: Hydrocarbon Exposures /Interactions and Marine Waters Study	■ Review and assess Operational Monitoring data and/or on-scene observations (e.g. aerial /vessel-based surveillance, shoreline assessment) to determine the extent, severity and persistence of hydrocarbon contamination; ■ Evaluate impacts to receptors (fauna, habitats) exposed to hydrocarbons based on observations, including surveillance and oiled wildlife records, if available; ■ Provide context on impact cause and effect relationships; and ■ Assess concentrations of hydrocarbons in marine waters.	■ A hydrocarbon spill results from the seismic survey; and ■ Agreement with relevant stakeholders that meaningful results can be provided by the study.	■ Operational Monitoring has ceased; ■ Operational Monitoring and other on-scene observational data has been reviewed and assessed; ■ Hydrocarbons are reported to be below thresholds of concern appropriate for the hydrocarbon / product; or ■ Elevated hydrocarbon concentrations are not detectable or statistically significant above background / reference concentrations (taking into account natural variability).
SM02: Shoreline Habitat Impact Study	■ Assess the range of shoreline habitats that were put at risk or exposed and collect information for the purposes of determining short-term and long-term impacts from hydrocarbon spill or the response activities.	■ Post-spill oil spill trajectory modelling predicts hydrocarbon contact or Operational Monitoring confirms that hydrocarbons have contacted shorelines; ■ SM01 identifies potential for longer-term impacts for the corresponding receptors that may be measurable above baseline conditions (taking into account natural variability); and	■ The extent, severity and persistence of impacts to the corresponding receptors has been assessed; or ■ The status and condition of the corresponding receptors cannot be statistically differentiated from background / reference conditions (taking into account natural variability).

Scientific Monitoring Study	Objectives	Initiation Triggers	Termination Criteria
		■ Agreement with relevant stakeholders that meaningful results can be provided by the study.	
SM03: Subtidal Habitat Impact Study	■ Assess the range of benthic primary producer habitats that were put at risk or exposed and collect information for the purposes of determining short-term and long-term impacts from hydrocarbon spill or the response activities.	■ Post-spill oil spill trajectory modelling predicts hydrocarbon contact or Operational Monitoring confirms that hydrocarbons have occurred at subtidal habitats; ■ SM01 identifies potential for longer-term impacts for the corresponding receptors that may be measurable above baseline conditions (taking into account natural variability); and ■ Agreement with relevant stakeholders that meaningful results can be provided by the study.	■ The extent, severity and persistence of impacts to the corresponding receptors has been assessed; or ■ The status and condition of the corresponding receptors cannot be statistically differentiated from background / reference conditions (taking into account natural variability).
SM04: Seabird and Shorebird Impact Study	■ Analyse records of oiled avifauna to evaluate potential impacts to seabird and shorebird populations; and ■ Evaluate the extent, severity and persistence of impacts of hydrocarbon exposure at targeted important bird areas (e.g. breeding colonies) if impacted by hydrocarbons.	■ Records of oiled avifauna made during Operational Monitoring or Operational Monitoring confirms that hydrocarbons have contacted important areas for seabirds or shorebirds (e.g. bird breeding colonies); ■ SM01 identifies potential for longer-term impacts for the corresponding receptors that may be measurable above baseline conditions (taking into account natural variability); and	■ The extent, severity and persistence of impacts to the corresponding receptors has been assessed; or ■ The status and condition of the corresponding receptors cannot be statistically differentiated from background / reference conditions (taking into account natural variability).

Scientific Monitoring Study	Objectives	Initiation Triggers	Termination Criteria
		■ Agreement with relevant stakeholders that meaningful results can be provided by the study.	
SM05: Marine Wildlife Impact Study	■ Analyse records of oiled wildlife to evaluate potential impacts to mobile marine megafauna (e.g. marine mammals, turtles, sharks and rays); and ■ Evaluate the extent, severity and persistence of impacts of hydrocarbon exposure at targeted important megafauna areas (e.g. turtle nesting beaches) if impacted by hydrocarbons.	■ Records of oiled megafauna made during Operational Monitoring or Operational Monitoring confirms that hydrocarbons have contacted important areas for marine megafauna (e.g. turtle nesting sites); ■ SM01 identifies potential for longer-term impacts for the corresponding receptors that may be measurable above baseline conditions (taking into account natural variability); and ■ Agreement with relevant stakeholders that meaningful results can be provided by the study.	■ The extent, severity and persistence of impacts to the corresponding receptors has been assessed; or ■ The status and condition of the corresponding receptors cannot be statistically differentiated from background / reference conditions (taking into account natural variability).
SM06: Fish Effects Study	■ Characterise the status and composition of fish assemblages (e.g. of representative functional trophic groups) exposed to hydrocarbons; and ■ Evaluate the extent, severity and persistence of impacts to fish assemblages, and their subsequent recovery	■ Post-spill oil spill trajectory modelling predicts hydrocarbon contact or Operational Monitoring confirms that hydrocarbons have occurred at important areas for fish; ■ SM01 identifies potential for longer-term impacts for the corresponding receptors that may be measurable above baseline conditions (taking into account natural variability); and	■ The extent, severity and persistence of impacts to the corresponding receptors has been assessed; or ■ The status and condition of the corresponding receptors cannot be statistically differentiated from background / reference conditions (taking into account natural variability).

Scientific Monitoring Study	Objectives	Initiation Triggers	Termination Criteria
		■ Agreement with relevant stakeholders that meaningful results can be provided by the study.	

Table 10-5 Scientific Monitoring Plan Template

Section	Content Description
Monitoring objectives and rationale	Study-specific objectives and critical success factors
Methodology	Approach, techniques and standards to be implemented
Termination criteria	Criteria for terminating the study
HSE Planning	HSE Risk Assessment and Management Plan (e.g. Job Hazard Analysis)
Survey / sampling plan (if applicable)	e.g. proposed sampling locations, numbers, frequencies, reference / control sites, statistical power analysis
Analysis plan	Analytical techniques to be implemented
Data and information requirements	Planning data and baseline / reference data
Field equipment and logistics (if applicable)	Required survey equipment, vessels, mobilisation and transport requirements
Personnel resources	Number of personnel required, qualifications and skill level
Subcontractor requirements	Required accreditations (e.g. NATA accredited laboratories) if applicable
Sample storage and transport requirements (if applicable)	Sample holding times, storage requirements and chain of custody procedures
Permits	Permit requirements/exemptions
Quality Control	QA/QC requirements for data and reporting
Reporting	Report format and communication of results to relevant stakeholders

10.5 Cost Recovery

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 is to be met by the titleholder before NOPSEMA can accept the EP.

TGS has insurance policies in place that would cover the costs of spill response, Type I Operational Monitoring and Type II Scientific Monitoring required in the event of a large hydrocarbon spill resulting from its activities. These policies cover activities in Australian Commonwealth and State waters.

TGS has determined the appropriate level of financial assurance required. A declaration and confirmation of financial assurance will be submitted to NOPSEMA prior to acceptance of this EP or prior to being granted SPA / AA titles.

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APPENDIX A TGS ENVIRONMENTAL POLICY

ENVIRONMENTAL POLICY

TGS is committed to protecting the environment in which we live and work, while also conducting our operations in an environmentally sustainable and responsible manner. TGS strives to lead the industry in minimizing the impact of our operations on the environment. TGS is dedicated to the continuous improvement of our environmental programs and standards across all our operations.

We will strive to achieve these commitments by:

- Planning operations to minimize and/or reduce environmental impacts to acceptable levels;
- Monitoring our performance against approved environmental management plans;
- Carrying out regular environmental audits, inspections and site visits of TGS and contractor operations;
- Maintaining compliance with applicable laws, regulations and guidance from trade associations;
- Monitoring the environmental performance of our contractors throughout the life cycle of each project;
- Ensuring that our contractors restore, in a reasonable and practical manner, all project sites to their original condition;
- Educating our employees and contractors in TGS' environmental stewardship and sustainability strategies;
- Communicating TGS' environmental expectations to all employees and contractors;
- Seeking continuous improvement and environmentally sustainable solutions;
- Annually reviewing this policy and related plans to ensure ongoing suitability and effectiveness;
- Providing appropriate financial and physical resources to enable compliance;
- Publishing our environmental performance in our yearly Corporate Social Responsibility report.

Our environmental efforts will be based on the implementation of the following key global strategies:

- Conducting environmental risk assessments of our operations and assessing our impact on the environment;
- Minimization and reduction of waste generated by design and purchase;
- Adoption of reduce, re-use and recycle programs where efficiencies can be found;
- Where hazardous chemicals, materials or products are used, adopt substitution techniques aimed at reducing or eliminating the handling, use and storage of such items;
- Minimization of carbon emissions by survey design and minimization of technical and non-technical downtime;
- Guarding against accidental and operational pollution;
- Development of emergency response plans for environmental incidents;
- Committing to implementing UN Global Compact Sustainable Development Goals.

Kristian Johansen
Chief Executive Officer – TGS
July 24th, 2019

APPENDIX B TGS HEALTH AND SAFETY POLICY

HEALTH & SAFETY POLICY

Our single greatest asset is our employee base. Therefore, TGS is committed to providing a safe, healthy and sustainable workplace for our employees, contractors, vendors and clients, while protecting the environment in which we live and work. TGS is also committed to the promotion and maintenance of the physical, psychological and social well-being of all workers. Furthermore, TGS is dedicated to the continuous improvement of health, safety and security standards for our employees, and insists that all contractors and vendors follow the same policy.

TGS has defined safe operating procedures in the HSE Management System that are designed to meet, or exceed, all appropriate legal requirements and, in the absence of any defined standards, to meet or exceed generally-accepted industry wide best operating practices. By employing our Statement of Values and the basic principles of Leadership, Risk Management, and Continuous Improvement, a high level of safety awareness shall always be maintained. All employees are encouraged to participate in the management of safety by striving to achieve and follow health, safety, and environmentally-driven objectives and standards, which are reviewed and appraised on a regular basis.

TGS holds all employees and contractors accountable for, and committed to, their own health and safety, as well as for those with whom they work. TGS supports, empowers, and encourages employees to intervene and STOP any operation or activity that they feel is unsafe or hazardous. These actions will be supported by all levels of management. To promote continuous improvement in workplace safety, all personnel are encouraged to propose improvement opportunities by means of direct communication with the Manager of Health, Safety & Environment.

Employees, contractors and visitors are responsible for obeying all safety policies, complying with applicable laws, following company standards, safe work procedures and practices, wearing personal protective equipment where required, participating in all aspects of the safety program, and informing Managers or Supervisors of unsafe work conditions or actions.

All levels of Management are responsible for the communication and implementation of TGS' Health and Safety Policies and Programs. Management shall ensure that employees have access to the appropriate information, instructions, training, financial and physical resources to enable compliance with all health and safety requirements. These health and safety requirements shall be reviewed on a regular basis to ensure ongoing suitability and effectiveness.

Kristian Johansen
Chief Executive Officer – TGS
July 24th, 2019

APPENDIX C EPBC ACT PROTECTED MATTERS SEARCH TOOL REPORTS

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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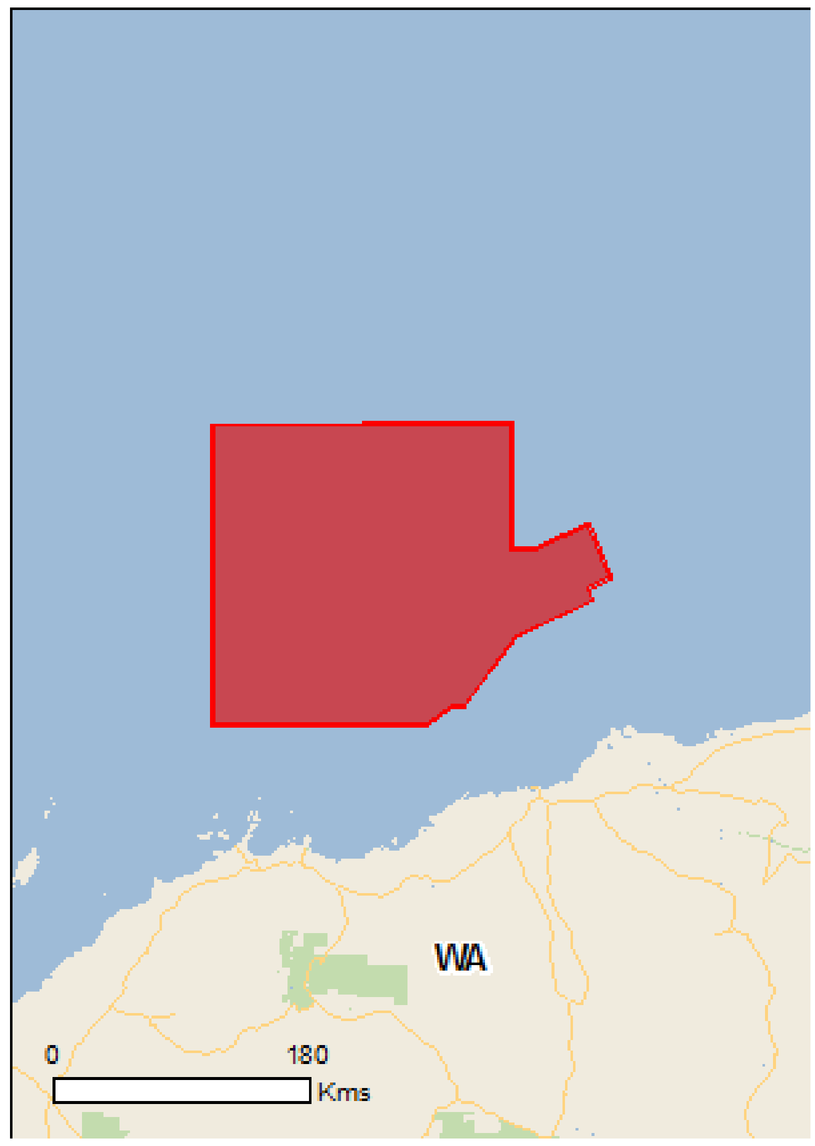

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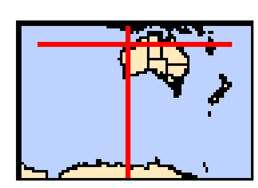

Summary

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:	20
Listed Migratory Species:	37

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	72
Whales and Other Cetaceans:	26
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	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
Sternula nereis nereis		
Australian Fairy Tern [82950]	Vulnerable	Foraging, feeding or related behaviour likely to 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

Name	Status	Type of Presence
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Congregation or aggregation known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	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

Name	Threatened	Type of Presence
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
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	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
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 aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		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
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Foraging, feeding or related behaviour likely to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
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

Name	Threatened	Type of Presence
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
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 grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus spinosissimus Hedgehog Seahorse [66239]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat 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 known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus 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

Name	Threatened	Type of Presence
		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	Species or species habitat known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
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
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

Name	Status	Type of Presence
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 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

Name	Status	Type of Presence
		area
Stenella longirostris Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area
Steno bredanensis Rough-toothed Dolphin [30]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area
Ziphius cavirostris Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area

Extra Information

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Glomar Shoals	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

-18.154 116.568,-19.936 116.568,-19.936 117.925,-19.823 118.071,-19.823 118.158,-19.405 118.481,-19.199 118.959,-19.127 118.932,-19.06 119.075,-18.751 118.94,-18.894 118.603,-18.894 118.445,-18.146 118.445,-18.154 116.568

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Australian Government
Department of the Environment and Energy

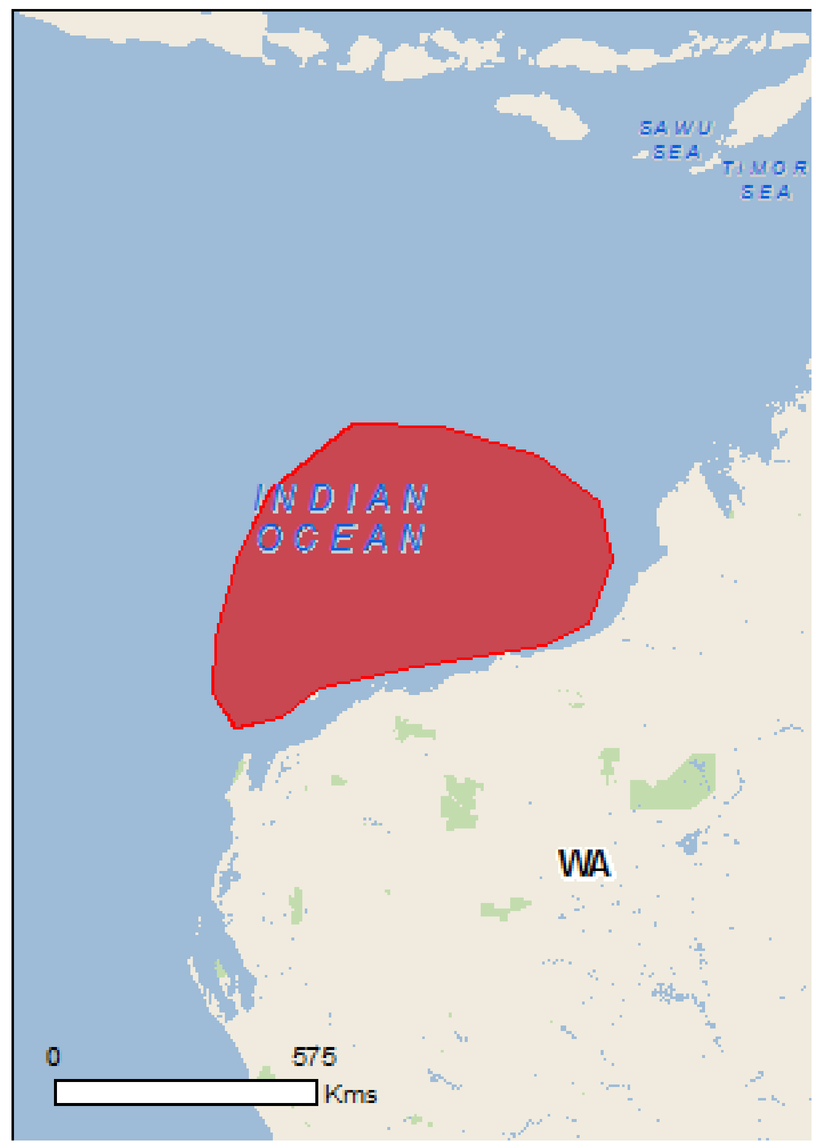
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

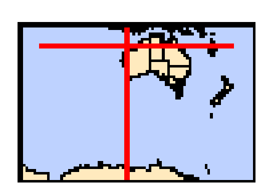
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 04/12/19 11:41:48



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

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:	2
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	31
Listed Migratory Species:	58

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:	104
Whales and Other Cetaceans:	31
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	7

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	6
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	1
Key Ecological Features (Marine)	5

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
Extended Continental Shelf

Marine Regions [Resource Information]

If you are planning to undertake action in an area in or close to the Commonwealth Marine Area, and a marine bioregional plan has been prepared for the Commonwealth Marine Area in that area, the marine bioregional plan may inform your decision as to whether to refer your proposed action under the EPBC Act.

Name
North-west

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Limosa lapponica baueri		
Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri		
Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Papasula abbotti		
Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Pterodroma mollis		
Soft-plumaged Petrel [1036]	Vulnerable	Species or species habitat may occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Endangered	Species or species

Name	Status	Type of Presence
		habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to 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
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Isoodon auratus barrowensis Golden Bandicoot (Barrow Island) [66666]	Vulnerable	Translocated population known to occur within area
Lagorchestes conspicillatus conspicillatus Spectacled Hare-wallaby (Barrow Island) [66661]	Vulnerable	Translocated population known to occur within area
Lagorchestes hirsutus Central Australian subspecies Mala, Rufous Hare-Wallaby (Central Australia) [88019]	Endangered	Translocated population known to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	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	Foraging, feeding or related behaviour known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat may occur within area
Pristis clavata		
Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Breeding known to occur within area
Pristis pristis		
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron		
Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding known to occur within area
Rhincodon typus		
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Listed Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus		
Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardenna carneipes		
Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Species or species habitat may occur within area
Ardenna pacifica		
Wedge-tailed Shearwater [84292]		Breeding known to occur within area
Calonectris leucomelas		
Streaked Shearwater [1077]		Species or species habitat likely to occur within area
Fregata ariel		
Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor		
Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Hydroprogne caspia		
Caspian Tern [808]		Breeding known to occur within area
Macronectes giganteus		
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Onychoprion anaethetus		
Bridled Tern [82845]		Breeding known to occur within area
Phaethon lepturus		
White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon rubricauda		
Red-tailed Tropicbird [994]		Breeding known to occur within area
Sterna dougallii		
Roseate Tern [817]		Breeding known to occur within area
Sternula albifrons		
Little Tern [82849]		Breeding known to occur within area
Sula dactylatra		
Masked Booby [1021]		Breeding known to occur within area

Name	Threatened	Type of Presence
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
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	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
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	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 known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour 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	Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour 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 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
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 known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat likely to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat likely to occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Thalasseus bergii Crested Tern [83000]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Natural		
Mermaid Reef - Rowley Shoals	WA	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat likely to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur

Name	Threatened	Type of Presence
		within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Breeding known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Larus novaehollandiae Silver Gull [810]		Breeding known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	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
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Breeding known to occur within area
Papasula abbotti Abbott's Booby [59297]	Endangered	Species or species habitat may occur within area
Phaethon lepturus White-tailed Tropicbird [1014]		Breeding likely to occur within area
Phaethon rubricauda Red-tailed Tropicbird [994]		Breeding known to occur within area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Species or species habitat may occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Species or species habitat may occur within area
Puffinus pacificus Wedge-tailed Shearwater [1027]		Breeding known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species

Name	Threatened	Type of Presence
		habitat may occur within area
Sterna albifrons Little Tern [813]		Breeding known to occur within area
Sterna anaethetus Bridled Tern [814]		Breeding known to occur within area
Sterna bengalensis Lesser Crested Tern [815]		Breeding known to occur within area
Sterna bergii Crested Tern [816]		Breeding known to occur within area
Sterna caspia Caspian Tern [59467]		Breeding known to occur within area
Sterna dougallii Roseate Tern [817]		Breeding known to occur within area
Sterna fuscata Sooty Tern [794]		Breeding known to occur within area
Sterna nereis Fairy Tern [796]		Breeding known to occur within area
Sula dactylatra Masked Booby [1021]		Breeding known to occur within area
Sula leucogaster Brown Booby [1022]		Breeding known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Fish		
Acentronura larsonae Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area
Bhanotia fasciolata Corrugated Pipefish, Barbed Pipefish [66188]		Species or species habitat may occur within area
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
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 known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat known to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		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	Foraging, feeding or related behaviour 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	Foraging, feeding or related behaviour 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
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans

[Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera bonaerensis Antarctic Minke Whale, Dark-shoulder Minke Whale [67812]		Species or species habitat likely to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	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
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Indopacetus pacificus Longman's Beaked Whale [72]		Species or species habitat may occur within area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area
Kogia simus Dwarf Sperm Whale [58]		Species or species habitat may occur within area
Lagenodelphis hosei Fraser's Dolphin, Sarawak Dolphin [41]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Mesoplodon densirostris Blainville's Beaked Whale, Dense-beaked Whale		Species or species

Name	Status	Type of Presence
[74]		habitat may occur within area
Mesoplodon ginkgodens Gingko-toothed Beaked Whale, Gingko-toothed Whale, Gingko Beaked Whale [59564]		Species or species habitat may occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat 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 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)
Dampier	Habitat Protection Zone (IUCN IV)
Eighty Mile Beach	Multiple Use Zone (IUCN VI)
Gascoyne	Multiple Use Zone (IUCN VI)
Mermaid Reef	National Park Zone (IUCN II)
Montebello	Multiple Use Zone (IUCN VI)

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Bedout Island	WA
Montebello Islands	WA
North Turtle Island	WA
Unnamed WA40828	WA
Unnamed WA41080	WA
Unnamed WA44672	WA

Nationally Important Wetlands [Resource Information]

Name	State
Mermaid Reef	EXT

Key Ecological Features (Marine) [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region
Ancient coastline at 125 m depth contour	North-west
Continental Slope Demersal Fish Communities	North-west
Exmouth Plateau	North-west
Glomar Shoals	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

-21.1544 114.742,-20.5965 115.4649,-20.1991 117.3857,-19.7948 119.9391,-19.3997 120.8036,-18.2232 121.2524,-17.1128 120.9765,-16.2705 119.7846,-15.7177 117.8772,-15.6792 116.1423,-16.9137 114.5156,-18.2066 113.846,-19.6903 113.4371,-20.7154 113.3912,-21.3271 113.8289,-21.1544 114.742

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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APPENDIX D CONSULTATION LOG

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
Australian Fisheries Management Authority (AFMA) • Western Tuna and Billfish Fishery Manager • Southern Bluefin Tuna Fishery Manager • North West Slope Trawl Fishery Manager	2.1.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.1.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.1.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.1.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Australian Hydrographic Service (AHS)	2.2.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.2.2	25/10/2019	Email/Letter from stakeholder	Email received from AHS acknowledging the information provided on 24/10/2019. The information supplied will be registered, assessed, prioritised and validated in preparation for updating Navigational Charting products.	No	N/A
	2.2.3	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	2.2.4	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.2.5	30/06/2020	Email/Letter from stakeholder	Email received from AHS acknowledging the update and requesting information on the timing of acquisition this year.	No	Stakeholder requested additional information. No objections or concerns were raised.
	2.2.6	30/06/2020	Email/Letter to stakeholder	TGS advised AHS that the Capreolus-2 3D MSS will potentially start in Q4 2020, however is more likely to commence in Q1 2021. TGS will be in touch with any updates on timing.	No	N/A
	2.2.7	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
	2.2.8	13/08/2020	Email/Letter from stakeholder	Email acknowledgement received from AHS.	No	N/A
Australian Marine Oil Spill Centre (AMOSC)	2.3.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.3.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.3.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of	Yes – Location Map and Survey Timing Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.		
	2.3.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Australian Maritime Safety Authority (AMSA)	2.4.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.4.2	25/10/2019	Email/Letter from stakeholder	Email received from AMSA advising TGS to notify AMSA's Joint Rescue Coordination Centre (JRCC) by e-mail for promulgation of radio-navigation warnings at least 24-48 hours before operations commence. JRCC will also need to be advised when operations start and end. Additionally, TGS will need to contact the Australian Hydrographic Office (AHO) no less than four working weeks before operations. The AHO will promulgate the appropriate Notice to Mariners (NTM), which will ensure other vessels are informed of your activities.	No	Stakeholder has provided information and/or requested additional information. No objections or concerns were raised. Section 5.7 has been updated to include ongoing consultation requirements for AMSA and AHO.
	2.4.3	29/10/2019	Email/Letter to stakeholder	TGS advised that the Vessel Master will notify AMSA's JRCC at least 24-48 hours before operations commence for the promulgation of radio-navigation warnings. TGS will also notify the AHO no less than four weeks before operations commence for the promulgation of Notice to Mariners.	No	N/A
	2.4.4	30/10/2019	Email/Letter from stakeholder	AMSA responded acknowledging receipt of the previous email.	No	N/A
	2.4.5	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.4.6	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.4.7	30/06/2020	Email/Letter from stakeholder	Email received from AMSA advising TGS to notify AMSA's Joint Rescue Coordination Centre (JRCC) by e-mail for promulgation of radio-navigation warnings at least 24-48 hours before operations commence. JRCC will also need to be advised when operations start and end. Additionally, TGS will need to contact the Australian Hydrographic Office (AHO) no less than four working weeks before operations. The AHO will promulgate the appropriate Notice to Mariners (NTM), which will ensure other vessels are informed of your activities.	No	Stakeholder has provided information and/or requested additional information. No objections or concerns were raised.
	2.4.8	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Australian Southern Bluefin Tuna Industry Association (ASBTIA)	2.5.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.5.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.5.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020	Yes – Location Map and Survey Timing Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.		
	2.5.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
BP	2.6.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.6.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.6.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.6.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Carnarvon Petroleum Limited	2.7.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities;	Y - Information Sheet	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				• types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.		
	2.7.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.7.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.7.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
CGG Services (Australia) Pty Ltd	2.8.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.8.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.8.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020	Yes – Location Map and Survey Timing Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.		
	2.8.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Chevron	2.9.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.9.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.9.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.9.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Commonwealth Fisheries Association (CFA)	2.10.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities;	Y - Information Sheet	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				• types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.		
	2.10.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.10.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.10.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Department of Agriculture, Water and the Environment – Biosecurity (Marine Pests)	2.11.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.11.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.11.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020	Yes – Location Map and Survey Timing Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.		
	2.11.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Department of Agriculture, Water and the Environment – Fisheries	2.12.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.12.2	28/10/2019	Email/Letter from stakeholder	Department of Agriculture responded acknowledging receipt of the previous email, and advised that they will respond within 10 business days (if relevant).	No	N/A - No further response was received at the time of EP submission.
	2.12.3	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.12.4	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.12.5	02/07/2020	Email/Letter from stakeholder	Email received from Petroleum & Fisheries acknowledging the information received on the Capreolus-2 3D MSS.	No	N/A
	2.12.6	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.12.7	17/08/2020	Email/Letter from stakeholder	Email received from Petroleum & Fisheries acknowledging the information received on the Capreolus-2 3D MSS. The Department has no concerns on the proposed activity. The Department requests that TGS maintain regular engagement with AMFA and the NWST operators throughout the preparation of the EP and operations.	No	N/A – TGS has engaged AFMA and NWST fishing operators throughout the EP preparation, comment and assessment process.
Department of Biodiversity, Conservation and Attractions (DBCA)	2.13.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.13.2	13/11/2019	Email/Letter from stakeholder	DBCA advised that based on the information provided the DBCA has no further comments to provide in relation to its responsibilities under the Biodiversity Conservation Act 2016 and the Conservation and Land Management Act 1984. DBCA requested for TGS to continue to provide DBCA with updates on the proposed survey.	No	N/A – DBCA requested to continue to receive notifications / updates on the Capreolus-2 3D MSS. Stakeholder register updated to ensure DBCA continues to receive updates on the Capreolus-2 3D MSS.
	2.13.3	5/12/2019	Email/Letter to stakeholder	Email sent to DBCA acknowledging that the DBCA has no further comments to provide. TGS will continue to provide DBCA with notifications regarding the proposed activity.	No	N/A
	2.13.4	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.13.5	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.13.6	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
Department of Communications and the Arts (DoCA)	2.14.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.14.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.14.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.14.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Department of Defence (Defence)	2.15.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.15.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	2.15.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.15.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Department of Industry, Science, Energy and Resources (DISER)	2.16.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.16.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.16.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.16.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
Department of Mines, Industry Regulation and Safety (DMIRS)	2.17.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.17.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.17.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.17.4	27/07/2020	Email/Letter from stakeholder	Email received from DPIRD acknowledging the information on the Capreolus-2 3D MSS. DMIRS has no comments or concerns regarding the seismic survey.	No	N/A
	2.17.5	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Department of Primary Industries and Regional Development (DPIRD) - Fisheries	2.18.1	31/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; • potential impacts and control measures; • timing of key socio-economic sensitivities; • relevant commercial fisheries; and • cumulative assessment.	Y - Information Sheet and Information Presentation	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				TGS requested any feedback to be provided by 6 December 2019.		
	N/A	16/12/2020	Phone call to stakeholder	Phone call to DPIRD requesting feedback on the proposed seismic survey. No response. Message left requesting call-back.	N/A	N/A
	2.18.2	15/01/2020	Email/Letter to stakeholder	Follow up email sent to DPIRD requesting any comments or feedback on the proposed survey. TGS advised that the EP will be submitted to NOPSEMA in February and that they would appreciate receiving any feedback as soon as possible to allow TGS time to review, respond and incorporate the response into the EP.	No	N/A – No response was received at the time of EP submission.
	N/A	10/02/2020	Phone call to stakeholder	Phone call to DPIRD requesting feedback on the proposed seismic survey. No response. Message left requesting call-back.	N/A	N/A
	2.18.3	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.18.4	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.18.5	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Department of Transport (DoT) - Marine Pollution	2.19.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.19.2	11/11/2019	Email/Letter from stakeholder	Email received from DoT advising that if there is a spill risk impacting State waters, the DoT is required to be consulted as outlined in the Department of Transport's Offshore Petroleum Industry Guidance	No	Stakeholder has provided information and/or requested additional information. No

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				Note – Marine Oil Pollution: Response and Consultation Arrangements (September 2018).		objections or concerns were raised.
	2.19.3	07/02/2020	Email/Letter to stakeholder	Email sent to DoT advising that TGS is consulting with DoT as required by DoT's Offshore Petroleum Industry Guidance Note. There is a risk of a spill impacting on State waters from the proposed Capreolus-2 3D MSS. TGS provided DoT with the information requested in Appendix 6 of the Guidance Note. Key points noted: • The petroleum activity (a seismic survey) is a vessel-based activity located entirely in Commonwealth waters. As such, in the event of a spill from a vessel, TGS understands that AMSA would be the Control Agency. In the event that a spill moves into State waters, a cross-jurisdiction arrangement may apply or AMSA may transition Control Agency responsibility to DoT. TGS would provide assistance in incident response and operational monitoring at the direction of the Control Agency. • The worst case spill scenario is considered to be a release of 1,062 m^3 of marine diesel oil (MDO), equivalent to the largest single vessel fuel tank. • Based on stochastic spill modelling of 300 different wind and current conditions, shoreline contact was predicted at Bedout Island from the closest release site (approximately 9.3 km from Bedout Island), which has a 7% probability at the low threshold (10-100 g/m^2). The minimum time before oil contact was approximately 8 hours and the maximum volume of oil ashore was 72.3 m3.	Y – 1) Location Map of Capreolus-2 3D MSS, 2) Copy of the oil spill risk assessment in the Environment Plan (EP), and 3) Copy of the emergency management and response arrangements in the EP 4) Stochastic Oil Spill Modelling Report	N/A – TGS provided DoT with the information requested in Appendix 6 of the Guidance Note.
	2.19.4	17/02/2020	Email/Letter from stakeholder	Email received from DoT acknowledging the information provided and advising that the DoT has deemed a full review as unnecessary due to the low risk posed to State waters from a vessel-based spill. DoT requested that TGS provide a copy of the accepted version of the EP/OPEP for its records once finalised.	No	Stakeholder has provided information and/or requested additional information. No objections or concerns were raised. DoT requested that TGS provided DoT with a copy of the accepted EP/OPEP for its records, once approved. Section 5.7 has been updated to include the requirement to provide DoT with a copy of the accepted EP, once finalised.
	2.19.5	18/02/2020	Email/Letter to stakeholder	TGS acknowledged the response from DoT and agreed to provide DoT with a copy of the approved EP once finalised.	No	N/A
	2.19.6	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	2.19.7	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.19.8	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Director of National Parks (DNP)	2.20.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.20.2	15/11/2019	Email/Letter from stakeholder	Email received from the Director of National Parks, acknowledging the information provided by TGS. DNP noted that the Operational Area does not overlap any Australian Marine Parks, however the Operational Area is less than 1km from Eighty Mile Beach AMP. DNP advised that in preparing the EP, TGS should consider the AMP in the context of the management plan objectives and values. TGS should ensure that • identifies and manages all impacts and risks on Australian marine park values (including ecosystem values) to an acceptable level and has considered all options to avoid or reduce them to as low as reasonably practicable • clearly demonstrates that the activity will not be inconsistent with the management plan. DNP noted that the area is of ecological significance, and noted the specific values of the Eighty Mile Beach AMP: • Shallow shelf habitats, including terraces, banks and shoals	No	Stakeholder has provided information and/or requested additional information. No objections or concerns were raised. TGS will undertake the activity in a manner consistent with the relevant AMP management plans. DNP does not require any further notifications of progress made in relation to this activity unless details regarding the activity change and result in an overlap with or new impact tor a marine park, or for emergency responses.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				• Threatened, migratory, marine and cetacean species, including ○ Humpback whales; ○ Seabirds; ○ Marine turtles; ○ Sawfish. DNP does not require any further notifications of progress made in relation to this activity unless details regarding the activity change and result in an overlap with or new impact tor a marine park, or for emergency responses. 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. Further details of the notification process and information required were provided.		Section 5.7 has been updated to include a notification to DNP in the event of a spill impacting on an AMP.
	2.20.3	28/11/2019	Email/Letter to stakeholder	Email sent to DNP acknowledging the response. TGS noted that the DNP does not require any further notification of progress made in relation to this activity unless details regarding the activity change and result in an overlap with or new impact to a marine park, or for emergency responses. The DNP will be advised of any oil/gas pollution incidences that are likely to impact on a marine park, as soon as possible (as per the information below). TGS advised that the EP will consider the Australian Marine Parks (in the context of management plan objectives and values), to ensure impacts and risks on marine parks are reduced to ALARP and to an acceptable level. The activity will be undertaken in a manner consistent with the relevant management plans.	No	N/A
	2.20.4	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.20.5	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.20.6	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
Equinor Australia	2.21.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.21.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.21.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.21.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
FAR Limited (Lightmark Enterprises Pty Ltd)	2.22.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.22.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	2.22.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.22.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Finder Exploration	2.23.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.23.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.23.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.23.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
King Bay Game Fishing Club (Dampier)	2.24.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.24.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.42.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.42.3	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Mackerel Managed Fishery (MMF) (Area 2) • All Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Marine Tourism WA	2.25.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.25.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.25.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.25.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
National Native Title Tribunal (NNTT)	2.26.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.26.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.26.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.26.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Nickol Bay Prawn Managed Fishery • All Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
North West Slope Trawl Fishery • All Active Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
Pearl Producers Association of WA (PPA) • Pearl Oyster Managed Fishery	2.27.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.27.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.27.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.27.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
PGS Australia Pty Ltd	2.28.1	21/01/2020	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. • TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.28.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	2.28.3	23/03/2020	Email/letter from stakeholder	PGS advised of the intention to undertake the Archer 3D Seismic Survey, under the approved Rollo Marine Seismic Survey EP. The survey will take up to 38 acquisition days and will be undertaken during the period of 1 May 2020 to 30 July 2020. PGS requested information on proposed survey timings from TGS.	Y – PGS Rollo: Archer 3D Information Sheet	N/A – Stakeholder has requested further information. No concerns or claims have been raised. Section 7.2 has been updated to include information on possible survey timings for PGS under the approved Rollo EP.
	2.28.4	30/03/2020	Email/Letter to stakeholder	TGS advised PGS that TGS does not currently have plans to undertake seismic acquisition in the Capreolus-2 Acquisition Area during the period of 1 May 2020 to 31 July 2020.	No	N/A
	2.28.5	13/08/2020	Email/Letter to stakeholder	TGS provided PGS with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP is required to undergo a repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Pilbara Line Managed Fishery • All Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020	Yes – Location Map and Survey Timing Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.		
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Pilbara Trap Managed Fishery • All Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Pilbara Trap Managed Fishery	2.42.1	19/11/2019	Email/Letter from stakeholder	Email received from Brown Dog Fishing Co noting that the Acquisition Area overlaps a significant fishing area, which is of considerable value. The licence holder noted that in the absence of a compensation agreement that the company is not willing to forego its activities and revenue.	No	Stakeholder has raised an objection, claim or concern. The objection or claim has merit and is addressed in the EP. Stakeholder has been advised of the outcome.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
• Brown Dog Fishing Company (Individual Licence Holder)				Brown Dog Fishing Co noted that they will not move out of the way or relocate to accommodate the survey. TGS will need to work around us. TGS expectation that we will continue uninterrupted is incorrect. There are ways that TGS can de risk the project by negotiating clear access to these waters in advance. The fact that the value of production from part of the area you wish to shoot is so high means that it is quite unreasonable to assume that we are prepared to forego this revenue to facilitate your survey. It is quite likely that your survey may take place with no interaction whatsoever with our vessels. But in the event of us being in the area at the time of the survey or an entanglement with our fishing gear, TGS will need to accept that, as a consequence of not taking any steps in good faith to mitigate that risk.		Brown Dog Fishing Co raised concerns of being displaced during the survey, and lack of a compensation process. TGS acknowledges that the survey is located within an area of fishing activity. It is TGS's intention to carry out the survey in a manner that does not interfere with your fishing activities or the resources of the sea. TGS cannot restrict access to the Operational Area and will undertake concurrent operational planning with commercial fisheries, in advance of each survey phase. TGS agrees a 'make-good' process can be an appropriate mechanism for fishers who are impacted by a seismic survey. TGS will consider compensation claims from commercial fishing licence holders on a case-by-case basis and in the following circumstances: • Where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of survey operations; and • A temporary loss of catch from within the Operational Area due to damaged or lost fishing equipment as a direct result of survey operations.
	2.42.2	11/12/2019	Email/Letter to stakeholder	Email sent from TGS acknowledging that the survey is located within an area of fishing activity, and notes concerns about having clear access to these waters. It is TGS's intention to carry out the survey in a manner that does not interfere with your fishing activities or the resources of the sea.	No	N/A – Response to Brown Dog Fishing Co addressing concerns raised regarding displacement from fishing grounds during the survey.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				TGS cannot restrict access to the Operational Area and will undertake concurrent operational planning with commercial fisheries, in advance of each survey phase. TGS will implement the following measures to mitigate potential impacts on the commercial fishing industry: • Advanced notification prior to the commencement of the survey (i.e. minimum 4 weeks), indicating the exact location and expected timing of the survey. • Contact details of the seismic survey vessel and support vessel(s) involved in the survey operation. • Radar and AIS detection systems and ongoing radio communications, which will be maintained on all vessels. VHF Channel 16 will be monitored, and a specific working channel for the survey operation will be communicated to fishers. • Notification to Australian Hydrographic Office for promulgation of Notice to Mariners and daily notification to Joint Rescue Coordination Centre for promulgation of navigational warnings. • Daily look-ahead reports during survey operations, detailing upcoming activities and planned seismic vessel location within the next 72 hours. • Access to seismic survey vessel tracking information via Google Earth. • A support vessel will accompany the seismic vessel at all times to help manage on-the-water interactions with marine users. • TGS will work collaboratively with fishers in order to minimise interactions offshore. During the survey, TGS will record bathymetry, temperature and salinity data. TGS is happy to provide these datasets to you, following completion of each survey phase, if you are interested. TGS has provided these datasets to commercial fishers from previous surveys in Australian waters. TGS agrees a ‘make-good’ process can be an appropriate mechanism for fishers who are impacted by a seismic survey. TGS will consider compensation claims from commercial fishing licence holders on a case-by-case basis and in the following circumstances: • Where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of survey operations; and • A temporary loss of catch from within the Operational Area due to damaged or lost fishing equipment as a direct result of survey operations. If required, TGS will, in consultation with the commercial fishing licence holder, engage an independent expert to review each claim for compensation. TGS is currently in the process of preparing a compensation policy/procedure that will further outline the requirements for		

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				compensation during survey operations. The policy/procedure is being developed in consultation with TGS Norway, taking into consideration the compensation scheme adopted by the Norwegian Government. The policy/procedure will be incorporated into the EP and provided to yourself once finalised.		
	2.42.3	18/02/2020	Email/Letter to stakeholder	Email sent to licence holder advising that TGS has been in the process of developing a compensation framework to further outline the requirements for compensation during TGS survey operations in Australia. TGS will consider compensation claims from fishery licence holders and vessel crews (i.e. the claimant) on a case-by-case basis, and in the following circumstances: • where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of TGS survey operations in Australia; and • a temporary loss of fish catch due to damaged or lost fishing equipment as a direct result of TGS survey operations in Australia. TGS will, in consultation with the claimant, engage an independent third-party to review claims for compensation. TGS is planning to submit the EP to NOPSEMA at the end of this week. If you have further questions, please do not hesitate to get in contact.	Y – TGS Fisheries Compensation Process	N/A
	2.42.4	18/02/2020	Email/Letter from stakeholder	Email received from licence holder with concerns that the compensation process does not appropriately compensate for loss of catch for displacing fishers from their fishing grounds. Brown Dog Fishing Co stated that to compensation for fishing gear damaged by a survey is underwhelming.	No	Stakeholder has raised an objection, claim or concern. The objection or claim has merit and is addressed in the EP. Stakeholder has been advised of the outcome. Brown Dog Fishing Co has raised concerns regarding the compensation process and lack of compensation for displacement and loss of catch. TGS acknowledges that there is a possibility that commercial fishing vessels may experience operational inconvenience and temporary displacement from an area, whilst the seismic survey vessel is conducting seismic acquisition. These disruptions are anticipated to be temporary and not significant. The transient nature of the seismic survey

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
						vessel means that the area where the seismic activities are undertaken is significantly smaller than the Acquisition Area and is only temporarily unavailable to fishing. The compensation process developed by TGS has been based on a proven and accepted compensation scheme adopted by the Norwegian Government with the Norwegian fishing sector.
	2.42.5	24/02/2020	Email/Letter to stakeholder	Email sent to licence holder advising that TGS is committed to working with relevant commercial fishers to enable fair and reasonable concurrent operations and to minimise potential displacement. The seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so, provided that there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. TGS acknowledges that there is a possibility that commercial fishing vessels may experience operational inconvenience and temporary displacement from an area, whilst the seismic survey vessel is conducting seismic acquisition. These disruptions are anticipated to be temporary and not significant. The transient nature of the seismic survey vessel means that the area where the seismic activities are undertaken is significantly smaller than the Acquisition Area and is only temporarily unavailable to fishing. The compensation process developed by TGS has been based on a proven and accepted compensation scheme adopted by the Norwegian Government with the Norwegian fishing sector.	No	N/A – Response from TGS to licence holder outlining the mitigation measures to be implemented to avoid displacing commercial fishers from fishing grounds.
	2.42.6	24/02/2020	Email/Letter from stakeholder	Email received from licence holder advising that there is differences between Norwegian fisheries and an Australian tropical snapper fishery. An offer of compensation for lost gear is insulting and displays a fundamental ignorance of the fishing industry. The risk of a fisherman losing gear to a survey is minimal while the risk of being displaced from viable fishing grounds and interruption to fishing patterns is large.	No	Brown Dog Fishing Co has raised concerns regarding the compensation process and lack of compensation for displacement and loss of catch. TGS has determined that compensation for commercial fishers is not an appropriate control or mitigation measure for the Capreolus-2 3D MSS, given the nature and scale of the activity. TGS will implement a range of communication controls to mitigate the potential of

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
						displacement from viable fishing grounds.
	2.42.7	03/05/2020	Email/Letter to stakeholder	Email sent to licence holder acknowledging that there are differences in the way fishing is carried out between Norwegian fisheries and an Australian snapper fishery. The compensation scheme adopted by the Norwegian Government was used as a guide for the compensation process developed by TGS. TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A – Response to ongoing concerns raised by Brown Dog Fishing Co regarding the compensation process adopted by TGS.
	2.42.8	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.42.9	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Pilbara Fish Trawl Interim Managed Fishery • All Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Pilbara Ports Authority	2.29.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.29.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.29.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.29.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
Pilot Energy Limited	2.30.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.30.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.30.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.30.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Port Hedland Game Fishing Club	2.31.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.31.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.31.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.31.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Recfishwest	2.32.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.32.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.32.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.32.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
Santos Limited	2.33.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.33.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.33.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS understands that the Santos Keraudren Extension 3D MSS EP was recently accepted by NOPSEMA. If possible, could you please let us know of Santos' plans to acquire the survey? Santos' response will not be made public, but will be included in the Sensitive Matters Report submitted to NOPSEMA. TGS will not disclose any specifics, but will present a credible cumulative scenario in the EP, which will state has been determined based upon consultation with other petroleum titleholders. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.33.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Shell Australia	2.34.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures.	Y - Information Sheet	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				TGS requested any feedback to be provided by 6 December 2019.		
	2.34.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.34.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.34.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Specimen Shell Managed Fishery • All Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	No further consultation was undertaken with individual licence holders in the Specimen Shell Managed Fishery due to receiving no responses and feedback received from WAFIC.					
The Wilderness Society	2.35.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.35.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
	2.35.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.35.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Vocus Communications	2.43.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y – Information Sheet	N/A
	2.43.2	15/01/2020	Email/Letter to stakeholder	Follow up email sent to Vocus requesting for any feedback to be provided as soon as possible for incorporation into the EP. TGS advised that the EP will be submitted to NOPSEMA in February.	No	N/A
	2.43.3	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.43.4	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.43.5	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Western Australian Fishing Industry Council (WAFIC)	N/A	03/10/2019	Email/Letter to stakeholder	Email sent to WAFIC advising that TGS is in the early stages of preparing an EP for a marine seismic survey on the NW Shelf. TGS enquired into WAFIC's availability to assist with consultation (as per WAFIC fee-for-service).	No	N/A
	N/A	04/10/2019	Email/Letter from stakeholder	Email received from WAFIC advising that the timing of engagement will depend on which Service WAFIC is able to provide. WAFIC is keen to see TGS incorporate a make-good / adjustment process into the EP for affected commercial fishers.	No	N/A
	N/A	04/10/2019 – 07/10/2019	Email/Letter to/from stakeholder	Email correspondence with WAFIC organising for an initial meeting to discuss the proposed Caproelus-2 3D MSS and approach to consultation with commercial fishers.	No	N/A
	N/A	07/10/2019	Meeting with stakeholder	An initial meeting with WAFIC to discuss the proposed Capreolus-2 3D MSS. TGS also discussed potential to use WAFIC fee-for-service approach to consultation with commercial fisheries. WAFIC was unable to commence the consultation process for TGS until early November, due to other commitments. WAFIC requested that the information provided to commercial fishers be specific to the fishing industry.	No	N/A – No immediate concerns raised from WAFIC during the meeting. WAFIC requested for TGS to include a make-good arrangement in the EP.
	2.36.1	31/10/2019	Email/Letter to stakeholder	TGS advised WAFIC of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; • potential impacts and control measures; • timing of key socio-economic sensitivities; • relevant commercial fisheries; and • cumulative assessment. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet and Information Presentation	N/A
	2.36.2	15/11/2019	Email/Letter from stakeholder	Email received from WAFIC acknowledging the detailed bespoke information provided on the proposed Capreolus-2 3D MSS. WAFIC noted that commercial fishing licence holders are the only 'relevant potentially affected parties' to this EP. WAFIC provided information on the Western Tuna and Billfish, Specimen Shell and the North West Slope Trawl. WAFIC queried why TGS contacted Specimen Shell.	No	Stakeholder has raised an objection, claim or concern. The objection or claim has merit and is addressed in the EP. Stakeholder has been advised of the outcome.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				WAFIC notes that this survey will potentially significantly disrupt commercial fishing activities and the commercial fishing resource. WAFIC seeks clarity regarding how much responsibility TGS will acknowledge, recognise, mediate and compensate the impacts to commercial fishing activities and potential impacts to the commercial fishing resource. WAFIC noted that the same commercial fisheries which will be exposed to TGS's multi-year multi-survey seismic program have already been exposed to seismic surveys, with adverse results, from recent seismic EPs. This will mean that potentially commercial fishing operations will be continually disrupted over multiple years by TGS and other proposed and or confirmed seismic surveys operating over this same broad region. This is completely unacceptable and is not As Low As Reasonably Practicable for commercial fishing operations and the commercial fishing resource. WAFIC requested clarity on the number of years that acquisition of seismic data may occur under the EP. WAFIC noted that the commercial fishing sector does not support any seismic survey activities during peak spawning periods. Noting impacts on the resource is a global issue and there is significant gaps in the science. WAFIC queried whether TGS had any intention of funding/facilitating long-term research into impacts from underwater noise (from seismic). WAFIC does not agree on your definition of "cumulative impacts". We note you appear to view this as repeat surveys over the same area in past years. A true assessment of cumulative impacts (on actual fishing activity and the resource) is the number of surveys that have taken place over an actual fishery over past years and proposed to take place over the same fishery in the coming years. WAFIC also requests that in the published penultimate EP that TGS advises WAFIC where in the EP they addressed all of the above issues and mitigation details. Issues raised deemed not part of the environment plan but still requiring feedback, please provide follow-up documentation.		WAFIC raised concerns regarding impacts to commercial fisheries, commercial fishing resource, fish spawning, cumulative impacts and lack of an agreed compensation process. TGS agrees a 'make-good' process can be an appropriate mechanism for fishers who are impacted by a seismic survey. TGS will consider compensation claims from commercial fishing licence holders on a case-by-case basis and in the following circumstances: • Where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of our survey operations; and • A temporary loss of catch from within the Operational Area due to damaged or lost fishing equipment as a direct result of our survey operations. It is acknowledged that multiple seismic surveys are planned to occur on the North West Shelf, which overlap with the boundaries of the fisheries that occur in the Acquisition Area. TGS is committed to working collaboratively with fishers and other seismic survey operators in order to minimise the potential for interactions between commercial fishers and seismic surveys. TGS cannot restrict access to the Operational Area and will undertake concurrent

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						operational planning with commercial fisheries, in advance of each phase of the survey. TGS will implement the following measures to mitigate potential impacts on the commercial fishing industry: • Advanced notification prior to the commencement of the survey (i.e. minimum 4 weeks), indicating the exact location and expected timing of the survey. • Contact details of the seismic survey vessel and support vessel(s) involved in the survey operation. • Radar and AIS detection systems and ongoing radio communications, which will be maintained on all vessels. VHF Channel 16 will be monitored, and a specific working channel for the survey operation will be communicated to fishers. • Notification to Australian Hydrographic Office for promulgation of Notice to Mariners and daily notification to Joint Rescue Coordination Centre for promulgation of navigational warnings. • Daily look-ahead reports during survey operations, detailing upcoming activities and planned seismic vessel location within the next 72 hours. • Access to seismic survey vessel tracking information via Google Earth.

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						• A support vessel will accompany the seismic vessel at all times to help manage on-the-water interactions with marine users. TGS also agrees to change sail lines to accommodate commercial fisher's requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. The spawning times for commercial fish species cover a 12-month period. Therefore, it is not possible for the survey to be scheduled entirely outside of all spawning periods. The southern zone will be acquired during April to May, which reduces the number of days of acquisition during the spawning times of key commercial fish species (within the species principal range). TGS will advise WAFIC of the EP sections that address the concerns raised by WAFIC during consultation, once the EP is publically available for review and comment.
	2.36.3	21/11/2019	Email/Letter to stakeholder	Email sent to WAFIC acknowledging the detailed response and advising that TGS would provide a response within 2 weeks.	No	N/A
	2.36.4	19/12/2019	Email/Letter to stakeholder	TGS provided a full response to each comment/query/concern raised by WAFIC. TGS acknowledges that the survey is located within an area of fishing activity. It is TGS's intention to carry out the survey in a manner that does not interfere with commercial fishing or the resources of the sea. TGS is committed to working collaboratively with fishers in order to minimise interactions offshore. TGS agrees a 'make-good' process can be an appropriate mechanism for fishers who are impacted by a seismic survey. TGS will consider	Y - Response to WAFIC	N/A – Response to WAFIC addressing concern/queries raised regarding impacts to commercial fishing resources, commercial fisheries, cumulative impacts and lack of compensation process. TGS will advise WAFIC of the EP sections that address the concerns raised by WAFIC

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				compensation claims from commercial fishing licence holders on a case-by-case basis and in the following circumstances: • Where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of our survey operations; and • A temporary loss of catch from within the Operational Area due to damaged or lost fishing equipment as a direct result of our survey operations. TGS is currently in the process of preparing a compensation process that will further outline the requirements for compensation during survey operations. The process is being developed in consultation with TGS Norway, taking into consideration the compensation scheme adopted by the Norwegian Government. The process will be incorporated into the EP and will share the process with WAFIC and other interested stakeholders once finalised. TGS confirms the EP covers a four-year period (assuming the EP is accepted in 2020). The EP will allow for seismic acquisition to occur in stages between 2020 and 2023. TGS will acquire a maximum of 10,000 km^2 per year, within the Acquisition Area (up to a total of 27,649 km^2). If TGS was to acquire the maximum 10,000 km^2, this would take a maximum of 190 days. This timeframe includes contingency time. The defined Acquisition Area represents the maximum area where TGS will apply for permission to acquire seismic. The actual area that will be acquired will depend on the level and areas of interest received from potential clients. It is possible that some areas of the Acquisition Area will not be acquired at all. However, if TGS was to proceed with acquiring the Acquisition Area in its entirety, it would take a maximum of 510 days (including contingency time). The option to include 'periods of down-time' was given careful consideration, but was not considered practicable or feasible. It is acknowledged that multiple seismic surveys are planned to occur on the North West Shelf, which overlap with the boundaries of the fisheries that occur in the Acquisition Area. TGS is committed to working collaboratively with fishers and other seismic survey operators in order to minimise the potential for interactions between commercial fishers and seismic surveys. The spawning times for commercial fish species cover a 12-month period. Therefore, it is not possible for the survey to be scheduled entirely outside of all spawning periods. The southern zone will be acquired during April to May, which reduces the number of days of acquisition during the spawning times of key commercial fish species (within the species principal range).		during consultation, once the EP is publically available for review and comment.

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				TGS cannot restrict access to the Operational Area and will undertake concurrent operational planning with commercial fisheries, in advance of each phase of the survey. TGS will implement the following measures to mitigate potential impacts on the commercial fishing industry: • Advanced notification prior to the commencement of the survey (i.e. minimum 4 weeks), indicating the exact location and expected timing of the survey. • Contact details of the seismic survey vessel and support vessel(s) involved in the survey operation. • Radar and AIS detection systems and ongoing radio communications, which will be maintained on all vessels. VHF Channel 16 will be monitored, and a specific working channel for the survey operation will be communicated to fishers. • Notification to Australian Hydrographic Office for promulgation of Notice to Mariners and daily notification to Joint Rescue Coordination Centre for promulgation of navigational warnings. • Daily look-ahead reports during survey operations, detailing upcoming activities and planned seismic vessel location within the next 72 hours. • Access to seismic survey vessel tracking information via Google Earth. • A support vessel will accompany the seismic vessel at all times to help manage on-the-water interactions with marine users. TGS also agrees to change sail lines to accommodate commercial fisher's requests if it is feasible to do so, providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. TGS acknowledges that the Specimen Shell fishery is a dive and wade fishery and collection typically occurs in shallow waters. FishCube data confirmed collection has historically occurred within the Operational Area (nearby to Bedout Island). As such, licence holders in the fishery have been contacted. No feedback has been received to date. Underwater sound from two concurrent seismic sources is not anticipated to combine to significantly raise the sound pressure levels to which receptors may be exposed. This is because, for example, where sound levels from two sources combine through constructive interference, a doubling of sound pressure corresponds with an increase in SPL of 6 dB (Hass 2013). A minimum separation distance of 40 km between two operational sources has been considered appropriate to manage the impacts. TGS can confirm that no fishing activities will occur from support vessels during the proposed survey. TGS will include an environmental performance standard in the EP to ensure no		

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				recreational fishing activities occur during the survey. Any breach in an environmental performance standard constitutes a recordable incident (requiring reporting to NOPSEMA). TGS will advise WAFIC of the EP sections that address the concerns raised by WAFIC during consultation, once the EP is publically available for review and comment.		
	2.36.5	20/12/2019	Email/Letter from stakeholder	Email received from WAFIC acknowledging the response from TGS. WAFIC does not agree with TGS's review regarding "minimising" exposure during peak fish spawning. We acknowledge that by and large spawning potentially occurs across the full calendar year. WAFIC stresses that due to the availability of some science (noting impacts of seismic on fish spawning) we still have concerns that minimising is not enough and will continue to hold these genuine industry concerns until there is sufficient science to confirm (one way or the other) the risk level. WAFIC seeks support from TGS, other seismic operators, the IAGC to support research into key areas where there is enough science to say there potentially is a problem (such as impacts on fish spawn / spawning) but not enough science to 100% confirm this – we need the seismic industry to support independent research on its own "research black holes". We thank TGS for confirming they will on a case by case basis consider / review compensation considerations. We have some reservations that this is not being managed by an independent party. We also note for a fisher to bring together the precise information required by TGS (multiple year back history of catch and return information), to have a numerically based claim takes considerable time (like asking you or me to dig back multiple years of tax assessments). We do not agree with you that it is ALARP to potentially have seismic surveys operating a minimum of 40 km apart. It does NOT minimise potential impacts to commercial fishing activities - this is a huge impost on commercial fishery, juggling seismic surveys from two different entities operating parallel over the same fishery (s). The corridor system works to keep seismic vessels apart, it does not work at all to reduce the cumulative impact and the complete costly inconvenience on commercial fishing activities. Stakeholder fatigue is significant. Reiterate the query as to why you consulted with Specimen Shell fishers - a dive and wade fishery typically occurring in shallow waters.	No	Stakeholder has raised an objection, claim or concern. The objection or claim has merit and is addressed in the EP. Stakeholder has been advised of the outcome. WAFIC raised further concerns regarding potential impacts to commercial fishing, resource, fish spawning and cumulative impacts. TGS responded to the comments and concerns raised by WAFIC in its correspondence on the 20/12/2019; having finalised the TGS Fisheries Compensation Process, which was attached to the email. TGS acknowledges that multiple seismic surveys are planned to occur on the North West Shelf, which overlap with the boundaries of the same fisheries that occur in the Capreolus-2 Acquisition Area. TGS is committed to working collaboratively with fishers and other seismic survey operators in order to minimise the potential for interactions. TGS will engage with petroleum titleholder/operators of potential concurrent seismic activities during the pre-survey planning phase of Capreolus-2. If concurrent surveys are planned to occur, TGS will develop a

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						concurrent operations plan or SIMOPS (in collaboration with petroleum operators and commercial fishers). TGS will undertake operational planning with commercial fisheries. This will involve engaging with commercial fishers on the proposed survey area, timing and duration (during the pre-survey phase).TGS has agreed to change sail lines to accommodate commercial fisher's requests if it is feasible to do so and providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. WAFIC's ongoing concerns have been noted in the EP. TGS has undertaken a comprehensive impact assessment demonstrating the impacts/risks from the Capreolus-2 3D MSS are ALARP and to acceptable levels. Based on the 40 km 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. This is because, for example, where sound levels from two sources combine through constructive interference, a doubling of sound pressure corresponds with an increase in sound pressure level (SPL) of 6 dB (Hass, 2013). Modelling of the seismic source for theCapreolus-2 3D MSS demonstrates that sound levels will be below 150 dB re 1µPa at 20 km from the source (half way

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						between two seismic sources at their minimum separation distance) and in many cases will be below 140 dB re 1µPa. A combination of seismic sound from two similar seismic sources at this distance would therefore be expected to result in an SPL of below known behavioural response thresholds for marine fauna. TGS will no longer consult with licence holders in the Specimen Shell Managed Fishery.
	2.36.6	04/02/2020	Email/Letter from stakeholder	Email received from WAFIC following-up on previous email sent on 20/12/2019.	No	N/A
	2.36.7	06/02/2020	Email/Letter to stakeholder	Email sent to WAFIC advising that TGS has delayed providing WAFIC with a response whilst TGS was in the process of finalising the compensation fisheries process. TGS noted that they would respond next week and provide WAFIC with a copy of the process.	No	N/A
	2.36.8	18/02/2020	Email/Letter to stakeholder	TGS responded to the comments and concerns raised by WAFIC in its correspondence on the 20/12/2019; having finalised the TGS Fisheries Compensation Process, which was attached to the email. TGS acknowledges that multiple seismic surveys are planned to occur on the North West Shelf, which overlap with the boundaries of the same fisheries that occur in the Capreolus-2 Acquisition Area. TGS is committed to working collaboratively with fishers and other seismic survey operators in order to minimise the potential for interactions. TGS will engage with petroleum titleholder/operators of potential concurrent seismic activities during the pre-survey planning phase of Capreolus-2. If concurrent surveys are planned to occur, TGS will develop a concurrent operations plan or SIMOPS (in collaboration with petroleum operators and commercial fishers). TGS will undertake operational planning with commercial fisheries. This will involve engaging with commercial fishers on the proposed survey area, timing and duration (during the pre-survey phase).TGS has agreed to change sail lines to accommodate commercial fisher's requests if it is feasible to do so and providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. WAFIC's ongoing concerns have been noted in the EP. TGS has undertaken a comprehensive impact assessment demonstrating the	Y – Specimen Shell Managed Fishery Map and the TGS Fisheries Compensation Process	N/A – Response to WAFIC addressing queries/concerns raised on 20/12/2019 regarding impacts to commercial fishing, resource, spawning and cumulative impacts.

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				impacts/risks from the Capreolus-2 3D MSS are ALARP and to acceptable levels. It is NOPSEMA's role to assess and determine whether the assessment in the EP is appropriate for the nature and the scale of the activity, and management measures are appropriate for the nature and scale of potential impacts/risks. TGS has been in the process of preparing a compensation framework to further outline the requirements for compensation during our survey operations in Australia. This framework has now been finalised and is attached for your information. The Bureau of Ocean Energy Management (BOEM 2014) published a final environmental review of geological and geophysical survey activities off the mid and South Atlantic coast. Based on the review, the BOEM recommenced a 40 km geographic separation distance between two seismic sources to create a 'corridor' for marine life. As a precautionary approach, TGS has adopted the 40 km separation distance. Based on the 40 km 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. This is because, for example, where sound levels from two sources combine through constructive interference, a doubling of sound pressure corresponds with an increase in sound pressure level (SPL) of 6 dB (Hass, 2013). Modelling of the seismic source for theCapreolus-2 3D MSS demonstrates that sound levels will be below 150 dB re 1µPa at 20 km from the source (half way between two seismic sources at their minimum separation distance) and in many cases will be below 140 dB re 1µPa. A combination of seismic sound from two similar seismic sources at this distance would therefore be expected to result in an SPL of below known behavioural response thresholds for marine fauna. As previously mentioned, historic data (obtained from FishCube) confirmed that collection has historically occurred within the Operational Area (nearby to Bedout Island). Bedout Island is located approximately 9.3 km from the Operational Area. Water depths within the Operational Area (nearby to Bedout Island) range from 22 m to 60 m. Please see the attached figure, which demonstrates that collection has occurred within the 60 NM CAES block overlapping the Operational Area in 2014, 2015 and 2017. No activity was reported in this block in 2016 and 2018. We acknowledge that the area of effort is likely to be overestimated, as collection is typically limited spatially to discrete locations rather than over the entire area of the 60 NMCAES block. Following your feedback above and given no response has been received to date from individual licence holders, TGS will no longer consult with licence holders in the Specimen Shell Managed Fishery.		

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	2.36.9	18/02/2020	Email/Letter from stakeholder	Email received from WAFIC acknowledging the information provided by TGS. WAFIC noted that TGS takes eight weeks to reply and WAFIC has less than four days to respond. TGS clearly does not recognise the significant disruptions and potential significant impacts the Capreolus-2 3D MSS will have on the commercial fishing sector. WAFIC noted that in the original feedback regarding compensation from TGS (19 December dated reply) in additional to replacing damaged gear and catch loss due to damaged gear also included “Estimated loss of catch compared to historic catch records from the Operational Area”. The self-authored with zero consultation compensation “process” received makes no provision at all for potential loss of catch due to displacement. TGS does not recognise cumulative impacts either on the resource or that fact that there is / will be potentially multiple surveys in one calendar year – not overlapping each other – possibly parallel with another survey - but over multiple commercial fisheries. There are considerable outstanding concerns which WAFIC does not believe have been addressed by TGS in the EP. WAFIC does not agree with TGS’ view regarding ‘minimising’ exposure during peak spawning periods. WAFIC does not agree with TGS’ assessment of ALARP to have seismic surveys operating a minimum of 40 km apart.	No	Stakeholder has raised an objection, claim or concern. The objection or claim has merit and is addressed in the EP. Stakeholder has been advised of the outcome. WAFIC raised ongoing concerns regarding potential impacts to commercial fishing, resource, fish spawning and cumulative impacts from multiple surveys. TGS will consider compensation claims on a case-by-case basis, and in the following circumstances: • where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of TGS survey operations in Australia; and • a temporary loss of fish catch due to damaged or lost fishing equipment as a direct result of TGS survey operations in Australia TGS acknowledges that the Operational Area overlaps with a number of Commonwealth and WA managed fisheries and that there is a possibility that commercial fishing vessels may experience operational inconvenience and temporary displacement from an area, whilst the seismic vessel is conducting seismic acquisition. These disruptions are anticipated to be temporary and not significant. The transient nature of the seismic survey vessel means that the area

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						where the seismic activities are undertaken is significantly smaller than the Acquisition Area and is only temporarily unavailable to fishing. In most circumstances, we understand that alternative fishing grounds will be available to commercial fishers. All concerns raised by WAFIC to date have been responded to and incorporated into the EP. TGS will advise WAFIC of the EP sections that address the concerns raised by WAFIC during consultation, once the EP is finalised and publicly available for review and comment.
	2.36.10	24/02/2020	Email/Letter to stakeholder	Email sent to WAFIC addressing ongoing concerns raised by WAFIC. TGS appreciate WAFIC's ongoing cooperation throughout the consultation process and for providing comments in a timely manner. TGS was delaying our response until we have finalised the compensation process, to provide you with a complete response on all queries/concerns raised. Our response to WAFIC was further delayed due to the office shut-down period over Christmas. As you may be aware, it is also important to note that consultation is an ongoing process and does not end at the time the EP is submitted to NOPSEMA. TGS's intention to submit the EP was not a requisite or timeline for you to digest the information we provided or reply to us prior to the submission. We will continue to engage with stakeholders (including WAFIC) throughout the public comment period and NOPSEMA's assessment of the EP. All feedback received from stakeholders will be assessed for merit and incorporated into the EP (where appropriate). TGS acknowledges that the Operational Area overlaps with a number of Commonwealth and WA managed fisheries and that there is a possibility that commercial fishing vessels may experience operational inconvenience and temporary displacement from an area, whilst the seismic vessel is conducting seismic acquisition. These disruptions are anticipated to be temporary and not significant. The transient nature of the seismic survey vessel means that the area where the seismic activities are undertaken is significantly smaller than the Acquisition Area and is only temporarily unavailable to fishing. In most circumstances, we understand that alternative fishing grounds will be available to commercial fishers.	No	N/A – Response to WAFIC addressing outstanding concerns regarding impacts to commercial fishing, fishing resource, fish spawning and cumulative impacts from multiple surveys.

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				The main fisheries active within the Operational Area are the three Pilbara demersal fisheries (Trap, Line and Trawl), which fish consistently throughout the year and, therefore, survey timing cannot accommodate this. TGS has already made efforts to minimise the overlap of the survey with the seasonality of the Mackerel Managed Fishery in nearshore waters. TGS acknowledges that there may be localised and short-term disturbances to commercially targeted fish species, but there will be no mortality of these fish, no impacts to the regional-scale spawning, recruitment and therefore sustainability of the fish stocks. Limiting the timing of the survey to avoid or further minimise the overlap with fish spawning is not practicable given that the different species spawn throughout most of the year and would provide limited additional environmental benefit given the limited predicted impacts on the stocks (refer to our response dated 19/12/2019, which provided detail on survey phasing and where there are reduction in overlap with fish spawning periods). TGS clearly stated TGS will consider compensation claims on a case-by-case basis, and in the following circumstances: • where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of TGS survey operations in Australia; and • a temporary loss of fish catch due to damaged or lost fishing equipment as a direct result of TGS survey operations in Australia All concerns raised by WAFIC to date have been responded to and incorporated into the EP. TGS will advise WAFIC of the EP sections that address the concerns raised by WAFIC during consultation, once the EP is finalised and publicly available for review and comment. All concerns raised by WAFIC to date have been responded to and incorporated into the EP. TGS will advise WAFIC of the EP sections that address the concerns raised by WAFIC during consultation, once the EP is finalised and publicly available for review and comment.		
	2.36.11	24/02/2020	Email/Letter from stakeholder.	Email received from WAFIC raising ongoing concerns regarding impacts to commercial fisheries, commercial fish stocks and cumulative impacts from multiple seismic surveys. WAFIC disagrees with TGS point to not copy in third parties on activity specific matters. WAFIC advised that the issues being discussed for this activity have broader relevance and the proposed NERA Collaborative Seismic EP. Treating an EP in isolation and for a specific activity receives constant negative feedback from WAFIC to proponents and NOPSEMA.	No	WAFIC raised ongoing concerns regarding potential impacts to commercial fishing, resource, fish spawning and cumulative impacts from multiple surveys. TGS will only acquire up to a maximum of 10,000 km^2 per calendar year, within the defined Acquisition Area. If TGS was to

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				WAFIC advised that if TGS acquires a maximum 10,000 km2 per year for 190 days each year, this will mean that every year (2020 – 2023) that TGS will be actively acquiring data for 6.3 months of each year. WAFIC queried what would be involved in the pre-survey consultation with fisheries, as WAFIC holds little faith that proponents will work with commercial fishers. WAFIC disagrees with TGS' statement 'disruptions are anticipated to be temporary and not significant'. WAFIC advised that the disruptions are not temporary and not insignificant. The disturbances are not short-term. The disturbances are not occasional disturbances, they last and it takes time for fish to return to normal behaviours. WAFIC queries why TGS doesn't include an evidence-based compensation process if TGS is so sure that the four-year survey will not negatively financially impact the commercial fishing sector. WAFIC and commercial fishing stakeholders do not believe that TGS has addressed the seismic EP and potential consecutive year seismic for 6.3 months per year.		acquire the maximum 10,000 km^2, this would take a maximum of 190 days (including contingency time). A maximum of 27,649 km^2 is permitted to be acquired under the EP (if approved, which represents the entire Acquisition Area). If the entire Acquisition Area was to be acquired, this would take a maximum of 510 days (including contingency time). A maximum of 510 days (including contingency time) may be acquired over the 4 year period (between 2020 – 2023), with a limit of 190 days in any calendar year. TGS will not undertake seismic acquisition for 190 days each calendar year between 2020 – 2023. In addition, TGS will not acquire 10,000 km^2 each year between 2020 – 2023, as TGS is only permitted to acquire up to a maximum of 27,649 km^2 over the 4 year period. Therefore, TGS will not be acquiring seismic data for 6.3 months of each year (between 2020 – 2023), as you have outlined in your response below. TGS will undertake operational planning with commercial fisheries, in advance of each survey phase. This will involve engaging with commercial licence holders on the proposed survey area, duration and timing. If required, TGS will develop a concurrent operations plan or SIMOPS. This will require input from commercial fishing licence holders (or skippers of commercial fishing vessels). As mentioned, the seismic survey vessel will change sail lines to

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
						accommodate commercial fisher's requests if it is feasible to do so and providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. TGS acknowledges WAFIC's ongoing concerns on the impacts of seismic activity on commercial fisheries and commercial fish stocks. These concerns have been noted in this EP.
	2.36.12	03/03/2020	Email/letter to stakeholder	TGS requests that WAFIC does not copy in third parties, who TGS has not identified as being relevant persons. It would be appreciated if WAFIC could please respect this request. The NERA Collaborative Seismic EP does not have any relevance to the Capreolus-2 3D MSS. TGS will not provide any further comments on the NERA Collaborative Seismic EP or NERA Compensation Framework, during the consultation process for this activity. As mentioned in our response dated 19/12/2019, TGS will only acquire up to a maximum of 10,000 km^2 per calendar year, within the defined Acquisition Area. If TGS was to acquire the maximum 10,000 km2, this would take a maximum of 190 days (including contingency time). A maximum of 27,649 km^2 is permitted to be acquired under the EP (if approved, which represents the entire Acquisition Area). If the entire Acquisition Area was to be acquired, this would take a maximum of 510 days (including contingency time). A maximum of 510 days (including contingency time) may be acquired over the 4 year period (between 2020 – 2023), with a limit of 190 days in any calendar year. TGS will not undertake seismic acquisition for 190 days each calendar year between 2020 – 2023. In addition, TGS will not acquire 10,000 km2 each year between 2020 – 2023, as TGS is only permitted to acquire up to a maximum of 27,649 km^2 over the 4 year period. Therefore, TGS will not be acquiring seismic data for 6.3 months of each year (between 2020 – 2023), as you have outlined in your response below. It is important to note, the defined Acquisition Area represents the maximum area where TGS will apply for permission to acquire seismic. The actual area that will be acquired will depend on the level	No	N/A – Response to WAFIC addressing ongoing concerns regarding survey parameters and cumulative impacts from the Capreolus-2 3D MSS.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				and areas of interest received from potential clients. It is possible that some areas of the Acquisition Area will not be acquired at all. TGS will undertake operational planning with commercial fisheries, in advance of each survey phase. This will involve engaging with commercial licence holders on the proposed survey area, duration and timing. If required, TGS will develop a concurrent operations plan or SIMOPS. This will require input from commercial fishing licence holders (or skippers of commercial fishing vessels). As mentioned, the seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so and providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. As mentioned in our response dated 18/02/2020, the main fisheries active within the Operational Area are the Pilbara Tap Managed Fishery, Pilbara Line Managed Fishery and Pilbara Fish Trawl (Interim) Managed Fishery, which fish consistently throughout the year. Therefore, the timing of the seismic survey cannot be scheduled to occur outside of commercial fishing activities. It is important to note, TGS has minimised the overlap of the survey with the seasonality of the Mackerel Managed Fishery (MMF) in nearshore waters. TGS will only acquire the southern zone (refer to figure attached) (depths between 50m – 80m) between April and May, primarily outside of the main fishing period for the MMF. It is not possible to entirely avoid acquisition during the peak mackerel fishing period due to other environmental sensitivities (i.e. humpback whale migration period (June to October) and internesting period for flatback turtles (October to March)). TGS will implement a number of control measures (as outlined in our response dated 18/02/2020) to minimise the potential for commercial fishers to be displaced from viable fishing grounds. TGS acknowledges WAFIC's ongoing concerns on the impacts of seismic activity on commercial fisheries and commercial fish stocks. These concerns have been noted in the EP, which has been submitted to NOPSEMA for completeness check, ahead of the public comment/review period.		
	2.36.13	03/03/2020	Email/letter from stakeholder	WAFIC has dropped everything to reply straight away, as you are wanting to submit the EP for NOPSEMA review at the earliest. It would be appreciated if all WAFIC communication is included in the correspondence appendix (and as always, addressed within the EP). If TGS has the ability to shoot up to a maximum of 10,000 km^2 per calendar year within the defined Acquisition Area taking up to 190 days, then TGS will have the ability to do just that. These are the	No	Ongoing concerns raised by WAFIC regarding potential impacts to commercial fishing, resource, fish spawning and cumulative impacts from multiple surveys as part of the Capreolus-2 3D MSS.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				numbers we are discussing because these are the numbers TGS has provided. We cannot "assume" and trust TGS that even though you've applied for this amount you won't be shooting this amount or for this duration – if that is what's in the EP, we have to "assume" that there is just as much of a chance that, based on demand and vessel availability etc. that TGS may end up shooting the maximum each year. 190 days is approximately 6.3 months. Again you have noted above that TGS will only acquire up to a maximum of 10,000 km^2 per calendar year taking a maximum of 190 days. Noting that TGS is only permitted to acquire 27,649 km^2 over the 4 year period does this mean you will split it evenly across 4 years? What's stopping TGS for doing very little / nothing in one year but the maximum 190 days in the next? There is every chance that some, not all of the 4 years will potentially result in a maximum 6.3 month seismic shooting schedule if it suits TGS. We stress the impact on commercial fishing activities should a TGS survey come through around peak catching periods. Not catching fish is not only a loss, it is a significant disruption to the supply chain. Notwithstanding overarching resource issues and cumulative impacts.		TGS acknowledges WAFIC's ongoing concerns has addressed these concerns in this EP.
	2.36.14	04/03/2020	Email/letter from stakeholder	WAFIC advised TGS that WAFIC tried to access NOPSEMA's website to view the Capreolus-2 EP, however received an error message.	No	N/A – WAFIC advised that there was an error with the NOPSEMA website. TGS responded to WAFIC advising that NOPSEMA was in the process of updating their website ahead of the public comment period.
	2.36.15	05/03/2020	Email/Letter to stakeholder	TGS would like to propose a meeting with WAFIC, at a time/date convenient for WAFIC, to clarify the restrictions in the EP on seismic acquisition and discuss any outstanding concerns. TGS advised WAFIC that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website. TGS understands that NOPSEMA was still in the process of updating their website – hence the error messages received. TGS also provided WAFIC with a table outlining the concerns raised by WAFIC during consultation and the location of where TGS has addressed each concern in the EP.	No	N/A – Request to organise a meeting with WAFIC to discuss outstanding concerns.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.36.16	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.36.17	14/07/2020	Email/letter from stakeholder	Email received from WAFIC acknowledging the update provided by TGS on the Capreolus-2 3D MSS. WAFIC notes that this has been an extremely lengthy, time-consuming and debilitating process. The TGS consultation alone has and continues to be a significant burden on WAFIC. It is untenable that TGS, as a member of the NERA's Collaborative Seismic EP and NERA Compensation Framework, is not including an agreement on an evidence-based compensation / adjustment protocol into this EP. A quality EP with the appropriate on-the-water due diligence and all-encompassing considerations should result in no requirement for payment of commercial loses (catch and displacement) to commercial fishers. Therefore, if your EP is complete, thorough and all-encompassing, TGS should with great confidence include the agreement for evidence-based compensation / adjustment process knowing that the TGS survey will not / should not impact the commercial fishing industry.	No	WAFIC raised concerns regarding the lack of an evidence-based compensation / adjustment protocol in the TGS Capreolus-2 3D MSS. TGS has determined that a compensation framework for compensating commercial fishers who are impacted by a seismic survey, either by displacement or from a loss of catch, is not justified for the Capreolus-2 3D MSS. Potential impacts to commercial fish stocks and fishing catch rates are not likely to be significant based on the following reasons: • 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). • 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

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						tolerance levels, with catches in 2017/18 exceeding the acceptable catch tolerance range, indicating an increased level of fish abundance, as well as increased catch rates (CPUE). • The stock assessment for key indicator commercial fish species (e.g. mackerel, red emperor) indicates adequate stock status, breeding stock and fishery catch levels (Gaughan and Santoro 2018). • Fish recovery from TTS or behavioural effects is expected in hours or days. 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 effect for the assessed species is a low proportion of the area they are likely to inhabit and where they are

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
						targeted by commercial fishers. TGS is committed to working with relevant commercial fishers to enable fair and reasonable concurrent operations and to minimise potential displacement. TGS will implement a range of communications measures to mitigate the potential impacts on the commercial fishing industry, including advanced notifications, daily notifications, access to seismic survey vessel tracking information, notice to mariners and daily navigational warnings (as outlined above). In addition, the seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so, provided that there is open and advanced communication between the seismic survey vessel and commercial fishing vessel.
	2.36.18	22/07/2020	Email/Letter to stakeholder	TGS appreciates WAFIC's ongoing engagement and cooperation throughout the consultation process for this survey. TGS acknowledges WAFIC's ongoing concerns on the impacts of seismic activities on commercial fisheries and commercial fish stocks. These concerns have been noted in the EP. TGS is committed to working with relevant commercial fishers to enable fair and reasonable concurrent operations. TGS will implement a number of control measures (as outlined in response dated 24/02/2020) to minimise the potential for commercial fishers to be displaced from viable fishing grounds. To provide effective on-the-water communication and coexistence between the seismic survey vessel and commercial fishers, TGS requests that fishery licence holders sign-up to the daily look-ahead reports, and to provide contact details for their vessels and shore managers. The seismic survey vessel will change sail lines to accommodate commercial fisher's requests if it is feasible to do so and providing there is open and advanced communication between the seismic survey vessel and commercial fishing vessel. As part of the daily look-	No	N/A – Response to WAFIC addressing ongoing concerns regarding compensation.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				ahead reports, TGS will request information from commercial fishers on their upcoming fishing activities for the next 24-72 hours. This will allow the seismic survey vessel to consider alternative sail lines, where practicable. As previously communicated, TGS has developed a compensation framework for the survey (which was provided to WAFIC on 18/02/2020). TGS has determined that a compensation framework for compensating commercial fishers who are impacted by a seismic survey, either by displacement or from a loss of catch, is not justified for the Capreolus-2 3D MSS, based on the outcomes of the impact assessment (refer to the EP) and the proposed control measures for the survey. If WAFIC wishes to discuss the NERA Collaborative Seismic EP or NERA Compensation Framework, please contact TGS outside of the consultation process for this activity. As always, TGS is happy to organise a meeting with WAFIC to discuss any outstanding concerns. If you have any further queries, please do not hesitate to get in contact.		
	2.36.19	22/07/2020	Email/letter from stakeholder	WAFIC notes that TGS's concept of a compensation protocol is insufficient. This does not meet an appropriate standard. WAFIC's expectation is for a protocol covering loss of gear, loss of gear/loss of catch and loss of catch. This would be an evidence based approach based on CPUE comparison over the previous ten years. It will not lead to vexatious or unsubstantiated claims. If TGS is confident that this impact assessment is correct and the proposed control measures are open and fair and allow appropriate "ocean sharing", then TGS will have zero concerns regarding any evidence based adjustment protocol covering loss of gear, loss of gear impacting catch and loss of catch.	No	WAFIC raised ongoing concerns regarding the lack of an evidence-based compensation / adjustment protocol in the TGS Capreolus-2 3D MSS EP. TGS has determined that a compensation framework for compensating commercial fishers who are impacted by a seismic survey, either by displacement or from a loss of catch, is not justified for the Capreolus-2 3D MSS. Refer to assessment of merit above. Concerns raised by WAFIC have been addressed in this EP.
	2.36.20	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.36.21	13/08/2020	Email/letter from stakeholder	WAFIC notes that the TGS Capreolus-2 3D MSS has been uploaded to the NOPSEMA website for public comment. WAFIC informed TGS that the public comment process is for the purpose of public comment, not as a vehicle for potentially affected parties to continued engagement with a proponent. WAFIC is not public. WAFIC requested clarify on why TGS will not include an evidence based protocol for this seismic survey in the EP. It will not lead to vexatious or unsubstantiated claims. WAFIC noted that not having an evidence-based compensation protocol covering loss of gear, loss of gear/loss of catch and loss of catch is untenable. WAFIC does not want to meet with TGS to discuss the above.	No	WAFIC raised ongoing concerns regarding the lack of an evidence-based compensation / adjustment protocol in the TGS Capreolus-2 3D MSS EP. A framework for compensating commercial fishers who are impacted by a seismic survey, either by displacement or from a loss of catch will not be incorporated into the Capreolus-2 3D MSS EP. This decision has been based on the outcomes of the impact assessment (refer to Section 7.1) and the proposed management measures for the survey. TGS has undertaken a comprehensive impact assessment demonstrating the impacts from the Capreolus-2 3D MSS are ALARP and to acceptable levels. It is NOPSEMA's role to assess and determine whether the assessment in the EP is appropriate for the nature and the scale of the activity, and management measures are appropriate for the nature and scale of identified impacts/risks.
	2.36.22	24/08/2020	Email/Letter to stakeholder	TGS appreciates WAFIC's ongoing engagement and cooperation throughout the consultation process for this survey. The public comment process provides members of the community an opportunity to raise any issues about environmental management matters that may not yet have been considered in the EP. It also provides relevant stakeholders with an opportunity to view the EP and provide feedback, should they choose to. This was established to facilitate improved transparency of EPs. TGS notified WAFIC and other relevant stakeholders of the public comment period out of courtesy, in order to keep stakeholders informed about the progress and status of the EP. TGS also made a commitment in the EP to notify relevant stakeholders of the publication of the EP for public review and comment.	No	N/A – Response to WAFIC addressing ongoing concerns regarding compensation.

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				As previously communicated, a framework for compensating commercial fishers who are impacted by a seismic survey, either by displacement or from a loss of catch will not be incorporated into the Capreolus-2 3D MSS EP. This decision has been based on the outcomes of the impact assessment (refer to the EP) and the proposed management measures for the survey. TGS has undertaken a comprehensive impact assessment demonstrating the impacts from the Capreolus-2 3D MSS are ALARP and to acceptable levels. It is NOPSEMA's role to assess and determine whether the assessment in the EP is appropriate for the nature and the scale of the activity, and management measures are appropriate for the nature and scale of identified impacts/risks. The EP submitted to NOPSEMA for assessment will be accompanied by a Sensitive Matters Report, which will include all correspondence with WAFIC for the purpose of transparency. The Sensitive Matters Report will be available to NOPSEMA, but will not be published online in order to preserve confidentiality.		
Western Australian Game Fishing Association	2.37.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.37.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.37.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.37.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public	Y – Location Map	N/A

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				comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.		
Western Tuna and Billfish Fishery • All Active Licence Holders	N/A	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	N/A	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	N/A	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	N/A	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Woodside Energy Limited	2.38.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.38.2	3/12/2019	Email/Letter from stakeholder	Email received from Woodside acknowledging the information provided by TGS on 24/10/2019.	Y - Confidential Response	Woodside provided a confidential response and raised

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
				Woodside provided TGS with a confidential response. Concerns were raised by Woodside, as the Capreolus-2 3D MSS has the potential to interfere with Woodside's proposed development activities in the area. Woodside requested a meeting to discuss the Capreolus-2 3D MSS in more details.		concerns regarding the potential for the proposed seismic survey to interfere with Woodside's proposed development activities in the area.
	2.38.3	5/12/2019	Email/Letter to stakeholder	TGS responded noting Woodside's confidential response.. TGS acknowledges that the proposed seismic survey has the potential to interfere with Woodside's proposed development activities, in particular during construction and installation of the Browse Trunkline (BTL). TGS will ensure Woodside is kept updated on the proposed activity and can develop a simultaneous operations (SIMOPS) plan in collaboration with Woodside, should seismic survey activity be undertaken during installation/construction of the BTL. TGS is unable to provide Woodside with further information on the specific location and timing / duration of the survey, at this time. TGS welcomes the opportunity to meet and discuss Woodside's proposed development activities in the area of the proposed seismic survey.	No	TGS will ensure Woodside is kept updated on the proposed seismic survey and will develop a simultaneous operations (SIMOPS) plan in collaboration with Woodside, should the seismic survey activity be undertaken during installation/construction of the BTL.
	2.38.4 2.38.8	6/12/2019 –	N/A	Additional correspondence occurred with Woodside to organise a meeting to discuss the Capreolus-2 3D MSS.	No	N/A
	2.38.9	19/12/2019	N/A	Meeting with Woodside to discuss the proposed TGS Capreolus-2 3D MSS and the proposed Woodside Browse to North West Shelf (NWS) Project.	No	N/A
	2.38.10	16/01/2020	Email/Letter from stakeholder	Email received from Woodside requesting TGS to provide Woodside with the proposed sequence of the Capreolus-2 3D MSS. Woodside also provided TGS with information on the proposed Browse to North West Shelf (NWS) Project and NWS Project Extension. Woodside advised that the relevant authorities commenced the public comment periods for the NWS Project Extension Proposal's Environmental Review Document (ERD) and the Browse to NWS Project's Draft Environmental Impact Statement (EIS) / Environmental Review Document (ERD). Woodside encourages interested parties' participation in the extended public comment period that starts from 18 December 2019 and runs through to 12 February 2020 and we welcome stakeholder's continued interest in the proposals.	No	N/A – Woodside requested information from TGS on the phasing of the Capreolus-2 3D MSS. In addition, Woodside provided TGS with information on the proposed proposed Browse to North West Shelf (NWS) Project and NWS Project Extension. Section 4.6.11 has been updated to include information on the Browse to NWS Project.
	2.38.11	21/01/2020	Email/Letter to stakeholder	TGS acknowledged the information provided by Woodside on the proposed Browse to North West Shelf (NWS) Project and NWS Project Extension. TGS requesting clarification on whether Woodside is comfortable for TGS to include the information on the Project in the Capreolus-2 3D MSS EP, noting Woodside's initial response was confidential.	No	N/A - TGS seeking clarification from Woodside on whether TGS can include information on the proposed Browse to NWS Project in the Capreolus-2 3D MSS EP.
	2.38.12	23/01/2020	Email/Letter from stakeholder	Woodside advised that TGS can include information on the Browse to NWS Project (extracted from the EIS/ERD) in the Capreouls-2 3D MSS EP, provided that references to specific elements of the EIS/ERD include a link to the full EIS/ERD on the Woodside website, so broader stakeholders have access to further context.	No	N/A

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	2.38.13	23/01/2020	Email/Letter to stakeholder	TGS provided Woodside with a map of the proposed survey areas and sequence/priorities.	Yes – Location Map	N/A - Additional information provided to Woodside.
	2.38.14	18/02/2020	Email/Letter from stakeholder	Woodside requested shapefiles for the proposed survey areas/sequences. Woodside also requested an update on the timing of the public comment period for the EP.	No	N/A – Woodside requested additional information.
	2.38.15	11/03/2020	Email/Letter to stakeholder	TGS provided Woodside with the SHP files for the proposed survey areas. TGS advised Woodside that TGS plans to submit the EP to NOPSEMA at the end of the week. TGS will provide Woodside with a notification advising that the EP is open for public comment.	Yes – SHP files for the proposed survey areas	N/A – Additional information provided to Woodside.
	2.38.16	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.38.17	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.38.18	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
World Wildlife Fund for Nature (WWF)	2.39.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.39.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
	2.39.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.39.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A
Yamatji Land and Sea Council	2.40.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.40.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.40.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.40.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A

Stakeholder	Sensitive Matters Report Ref #	Date of Correspondence	Type of Correspondence	Summary of Correspondence	Attachments	Assessment of Merit (Objection or Claim)
3D Oil Limited	2.41.1	24/10/2019	Email/Letter to stakeholder	TGS advised of proposal to undertake the Capreolus-2 3D MSS in Commonwealth waters. An Information Sheet was attached which provided information on: • the location, schedule and description of activities; • types of vessels to be used and logistical arrangements, as known; and • potential impacts and control measures. TGS requested any feedback to be provided by 6 December 2019.	Y - Information Sheet	N/A
	2.41.2	05/03/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for public comment and review. The public comment period is open until 03 April 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	No	N/A
	2.41.3	29/06/2020	Email/Letter to stakeholder	TGS provided stakeholders with an update on the Capreolus-2 3D MSS. TGS has amended the south-eastern boundaries of the Acquisition Area and Operational Area to include a new area of interest, located to the east of the current Operational Area covering the Dorado field. TGS has also amended the EP timeframe by 12 months, to allow seismic acquisition to occur in phases between 2020 and 2024 (subject to EP approval). These changes do not introduce any new or increased environmental impacts or risks. The EP will undergo a repeat public comment period. TGS will inform stakeholders once the public comment period is open. TGS understands that the 3D Oil Sauropod 3D MSS EP is currently under assessment by NOPSEMA. If possible, could you please let us know of 3D Oil's plans to acquire the survey? 3D Oil's response will not be made public, but will be included in the Sensitive Matters Report submitted to NOPSEMA. TGS will not disclose any specifics, but will present a credible cumulative scenario in the EP, which will state has been determined based upon consultation with other petroleum titleholders. TGS requested any feedback to be provided by 27 July 2020.	Yes – Location Map and Survey Timing Map	N/A
	2.41.4	13/08/2020	Email/Letter to stakeholder	TGS advised stakeholders that NOPSEMA has published the Capreolus-2 3D MSS EP for repeat public comment period. The public comment period is open until 09 September 2020. Comments can be submitted directly to NOPSEMA via the dedicated submission portal on the NOPSEMA website.	Y – Location Map	N/A

APPENDIX E ACOUSTIC MODELLING REPORT

Capreolus-2 3D Marine Seismic Survey

Acoustic Modelling for Assessing Marine Fauna Sound Exposures

Submitted to:

Jared Davidson

ERM

PO: Agreement Dated 8 November 2019

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14 February 2020

P001525-001

Document 01971

Version 1.0

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Suggested citation:

Koessler, M.W. and C.R. McPherson. 2019. *Capreolus-2 3D Marine Seismic Survey: Acoustic Modelling for Assessing Marine Fauna Sound Exposures.* Document 01971, Version 1.0. Technical report by JASCO Applied Sciences for ERM.

Disclaimer:

The results presented herein are relevant within the specific context described in this report. They could be misinterpreted if not considered in the light of all the information contained in this report. Accordingly, if information from this report is used in documents released to the public or to regulatory bodies, such documents must clearly cite the original report, which shall be made readily available to the recipients in integral and unedited form.

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Executive Summary

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned TGS Capreolus-2 3D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, sponges, coral, and plankton. Modelling considered four comparably sized seismic arrays with volumes up to 3480 in^3. These arrays were coupled with single impulse propagation modelling to determine the array most likely to produce the largest ranges to thresholds, which was determined to be a 3480 in^3 seismic source with a 6 m tow depth. Therefore, the modelling considered this 3480 in^3 seismic source in a triple source configuration, towed at 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 nine sites within the Acquisition Area, with water depths between 47 and 567 m. Accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 hours.

The modelling methodology considered source directivity and range-dependent environmental properties in each of the areas assessed. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; L_{pk-pk}), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria. A conservative sound speed profile that would be most supportive of sound propagation conditions for the period of the survey was defined and applied to all modelling.

The analysis considered the distances away from the seismic source at which several effects criteria or relevant sound levels were reached. The results are summarised below for the representative single-impulse sites and accumulated SEL scenarios.

Marine mammal injury and behaviour

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 4.32 and 9.56 km.
- The results for marine mammal injury considered the criteria from the National Marine Fisheries Service (NMFS 2018) technical guidance. NMFS (NMFS 2018) allows for two metrics in the criteria (PK and SEL_{24h}) for the assessment of marine mammal Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS). The longest distance associated with either metric is required to be applied for assessment. Table 1 summarises the maximum distances for PTS, along with the relevant metric associated with the maximum PTS distance; the farthest SEL distances were associated with Scenario 1, in deeper water.
- The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding SEL_{24h} radii for low-frequency cetaceans were larger than those for peak pressure criteria, but they represent an unlikely worst-case scenario. More realistically, marine mammals (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with injury or hearing impairment (either PTS or TTS) if it remained in that location for 24 hours.

Table 1. Summary of maximum marine mammal PTS onset distances for modelled scenarios.

Hearing group	Metric associated with longest distance to PTS onset	R_{max} (km)
Low-frequency cetaceans†	SEL_{24h}	2.34
Mid-frequency cetaceans	—	—
High-frequency cetaceans	PK	0.42

† The model does not account for shutdowns.

Turtles

- The PK turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metric was 60 m for PTS onset and 0.64 km for TTS onset (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- Table 2 summarises the distances to where the NMFS criterion (NSF 2011) for behavioural response of turtles to the 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance summarises the distances to where the NMFS criterion (NSF 2011) for behavioural response of turtles to the 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000b, McCauley et al. 2000a) could be exceeded.

Table 2. Summary of distances to turtle behavioural response criteria.

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Minimum	Maximum
175†	1.02	1.7
166‡	2.3	5.08

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b, McCauley et al. 2000a).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:
    - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
    - Fish with a swim bladder that do not use it for hearing
    - Fish that use their swim bladders for hearing
    - Fish eggs and fish larvae
- Table 3 summarises distances to effect criteria for fish, fish eggs, and fish larvae along with the relevant metric.

Table 3. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios.

Relevant hearing group	Effect criteria	Water column		Seafloor	
		Metric associated with longest distance to criteria	R_{max} (km)	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.06	PK	0.09
	TTS	SEL_{24h}	5.86	SEL_{24h}	5.86
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.24	SEL_{24h}	0.16
	TTS	SEL_{24h}	5.86	SEL_{24h}	5.86
Fish eggs, and larvae	Injury	PK	0.24	PK	0.16

Benthic invertebrates, Sponges, Coral, and Plankton

To assist with assessing the potential effects on these receptors, the following results were determined:

- Bivalves: The distance where a particle acceleration of 37.57 ms^{-2} at the seafloor could occur was determined for comparing to results presented in Day et al. (2016a). The maximum distance to this particle acceleration level was 32 m.
- Crustaceans: The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008) was considered for seafloor sound levels; the sound level was reached at ranges between 446 and 588 m depending on the modelled site.
- Sponges and coral: The PK sound level at the seafloor directly underneath the seismic source was estimated at all modelled sites and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); the threshold was reached within a 8 m horizontal range from the acoustic centre of the source at the shallowest modelled site, at 47 m water depth.
- Plankton: The distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at all modelled sites through full-waveform modelling; the results ranged from 7.90 to 14 km.

1. Introduction

JASCO Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned TGS Capreolus-2 3D Marine Seismic Survey (MSS) to assist in understanding the potential acoustic impact on key regional receptors including marine mammals, fish, turtles, benthic invertebrates, plankton, and corals.

JASCO's specialised Airgun Array Source Model (AASM) was used to predict acoustic signatures and spectra for four comparably sized source arrays under initial consideration for the Capreolus-2 3D MSS. AASM accounts for individual airgun volumes, airgun bubble interactions, and array geometry to yield accurate source predictions. Furthermore, these four arrays were modelled at a single nominal source location within the survey area to compare single-impulse received levels when environmental effects were considered. This allowed the worst-case seismic source to be determined based upon both the source signature and the survey specific environment.

Complementary underwater acoustic propagation models were used in conjunction with the selected array signature to estimate sound levels considering environmental effects. Single-impulse sound fields were predicted at nine defined locations within the Acquisition Area, and accumulated sound exposure fields were predicted for two representative scenarios for likely survey operations over 24 hours with the worst-case source (see Section 2). A conservative sound speed profile that would be most supportive of sound propagation conditions during survey period was defined and applied for all modelled sites. Results are in part presented as maps to assist with understanding the acoustic impact and potential effects spatially. Relevant geospatial areas such as to the Ancient Coastline at 125 m Key Ecological Feature (KEF), the Glomar Shoals (KEF), , the Flatback Turtle Internesting Biologically Important Area (BIA), the Pygmy Blue Whale Migration BIA, and the Humpback Whale Migration BIA are shown to assist with understanding acoustic impacts.

The modelling methodology considered source directivity and range-dependent environmental properties. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p), zero-to-peak pressure levels (PK, L_{pk}), peak-to-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$), and either single-impulse (i.e., per-pulse) or accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria.

Section 3 explains the metrics used to represent underwater acoustic fields and the impact criteria considered. Section 4 details the methodology for predicting the source levels and modelling the sound propagation, including the specifications of the seismic source and all environmental parameters the propagation models require. Section 5 presents the results, which are then discussed and summarised in Section 6.

2. Modelling Scenarios

Nine standalone single impulse sites and two likely scenarios for survey operations over 24 hours to assess accumulated SEL were modelled. The locations of all modelled sites are provided in Table 4, with all sites and the acquisition lines shown in Figure 1 along with the survey boundaries. The modelling assumed that a survey vessel sailed along survey lines at ~4.5 knots, with an impulse interval of 12.5 m. Two representative scenarios (Scenario 1 and 2) for acquisition were considered for 24 hours of operation. Scenario 1 considered survey sail lines in the northern edge of the Acquisition Area, and Scenario 2 considered sail lines in the southern edge of the Acquisition Area near the Glomar shoals KEF.

The single impulse sites and accumulated SEL scenarios were selected based on a proposed survey line plan, whereby the survey will be acquired along survey lines orientated 90/270° within the Acquisition Area. Sites 8 and 9 are located along lines not considered within the two representative scenarios; Site 8 is located at the end of a line run-out closest to Glomar Shoals (therefore outside the Acquisition Area, but potentially within waters where the seismic source may be operated at full volume at the end of a line run-out), and Site 9 at the start of a line at the western boundary of the Acquisition Area. The locations of the single impulse sites and scenarios are considered representative of the range of water depths that will be covered during the Capreolus-2 3D MSS and the potential sound propagation characteristics that may arise at various locations within the Acquisition Area. The orientations of the single impulse sites and line scenarios were selected as they provide for the greatest sound propagation radii broadside from the seismic source towards both shallow water receptors and deep-water receptors relevant to the survey. These receptors include but are not limited to biologically important areas (BIAs) for migrating humpback whales and internesting marine turtles in nearshore waters, and a BIA for migrating pygmy blue whales in deeper, offshore waters.

For Scenario 1, acquisition of one full and one partial line took 19.65 h and 1.02 h (respectively) to traverse with ~3.35 h of turn time required between the lines. For Scenario 2, two lines were also modelled for a 24-hour period, where the first line took 13.12 h to traverse and the second, which was a partial segment of a full acquisition line, took 7.26 h to traverse. The time to complete a turn was ~3.67 h per turn for Scenario 2. These scenarios accounted for 13780 impulses for Scenario 1 and 13590 impulses for Scenario 2 during the respective 24 h periods of acquisition. During line turns, the seismic source was not operating.

Figures 2–3 show static receiver locations spaced along a transect perpendicular to a survey line at:

- 50 m increments between distances of 50 to 1000 m,
- 100 m increments between 1000 m to 5 km,
- 500 m increments between 5 and 10 km, and
- 1000 m increments between 10 and 30 km.

These static receivers were considered for a modelled time history of sound exposure accumulation and for discussing the influence of accumulated sound levels on fish (Section 5.3.3).

Table 4. Location details for the single impulse modelled sites.

Scenario	Site	Latitude (S)	Longitude (E)	MGA* Zone 50		Water depth (m)	Tow direction (°)
				x (m)	*y* (m)		
1	1	18° 37' 47.2237"	116° 51' 40.0265"	485351	7940130	567	90
	2	18° 37' 46.9383"	117° 13' 17.8227"	523376	7940130	444	90
	3	18° 37' 39.9741"	117° 52' 53.3591"	592984	7940130	236	90
	4	18° 34' 24.1059"	118° 11' 58.9744"	626596	7945956	164	90/270
2	5	19° 51' 09.2062"	116° 48' 59.4533"	480789	7804824	66	90
	6	19° 48' 56.7068"	117° 11' 11.0540"	519521	7808897	64	90/270
	7	19° 48' 44.3980"	117° 35' 44.2768"	562381	7809176	60	90/270
	8	19° 37' 29.5311"	116° 51' 53.4680"	485830	7830024	76	90
N/A	9	19° 18' 01.5331"	118° 58' 38.6080"	707776	7864745	47	90

* Map Grid of Australia (MGA)

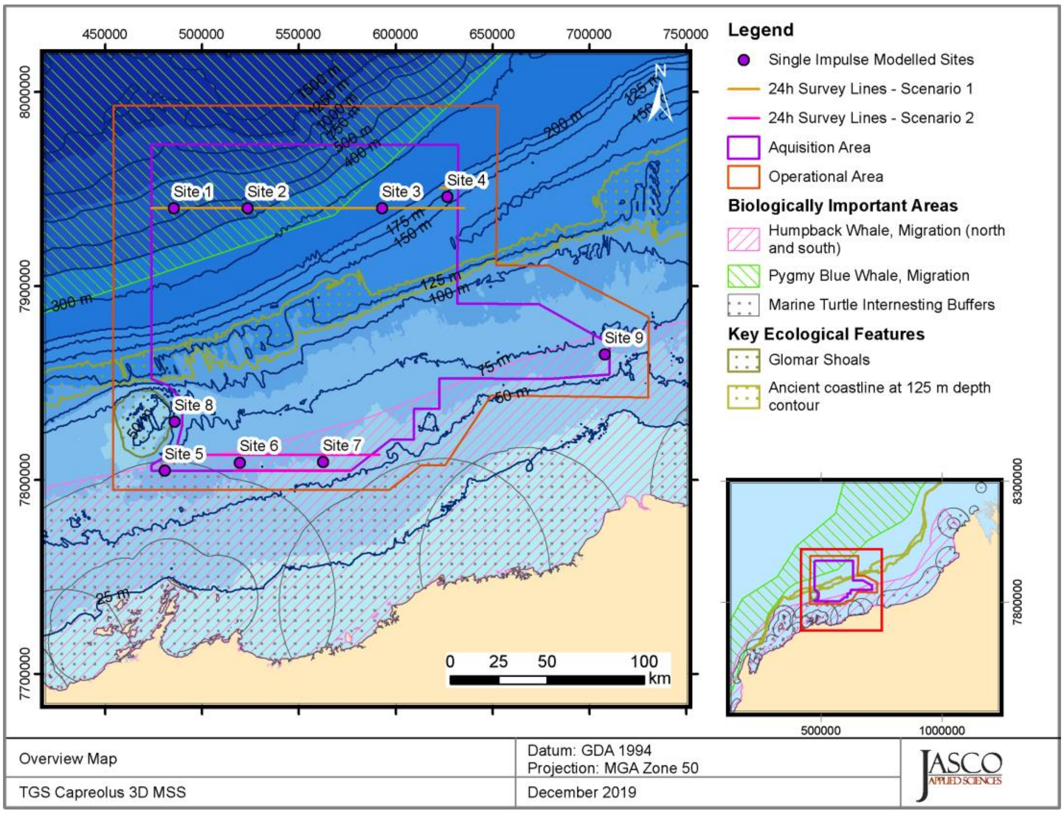

Figure 1. Overview of the modelled sites, acquisition lines, and features for the TGS Capreolus-2 3D MSS modelling.

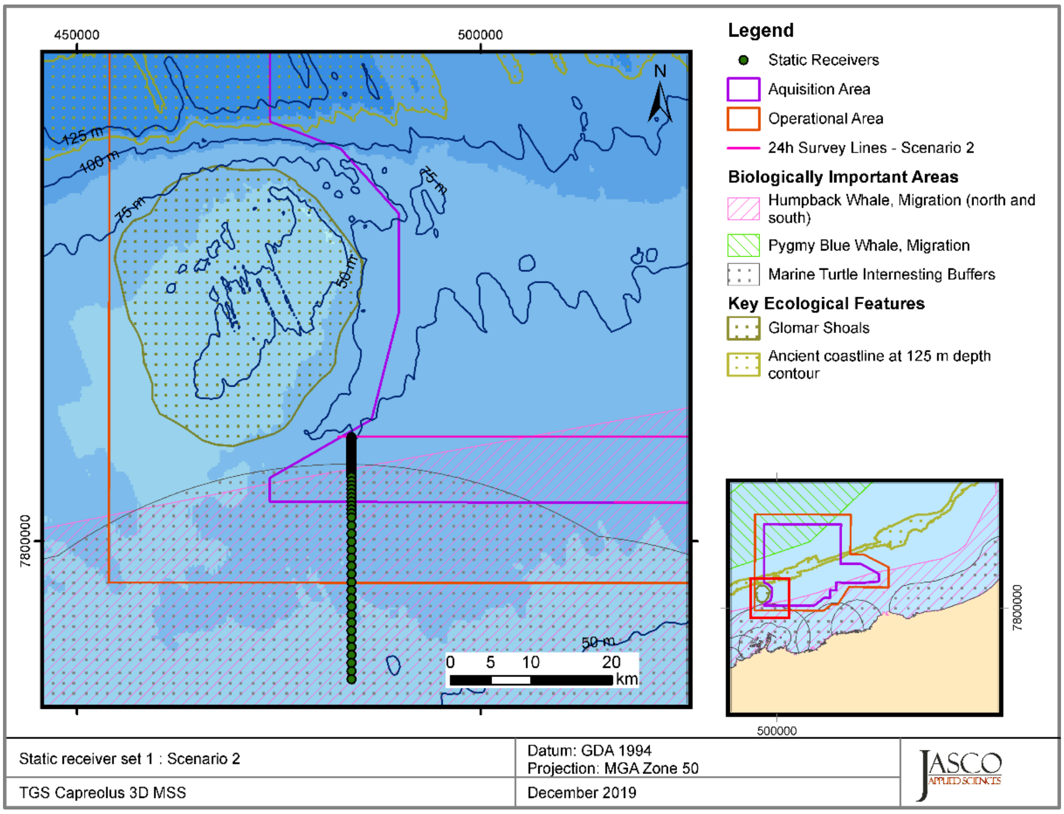

Figure 2. *Static receiver set 1*: Acquisition lines and static receiver locations considered for SEL_{24h} calculations.

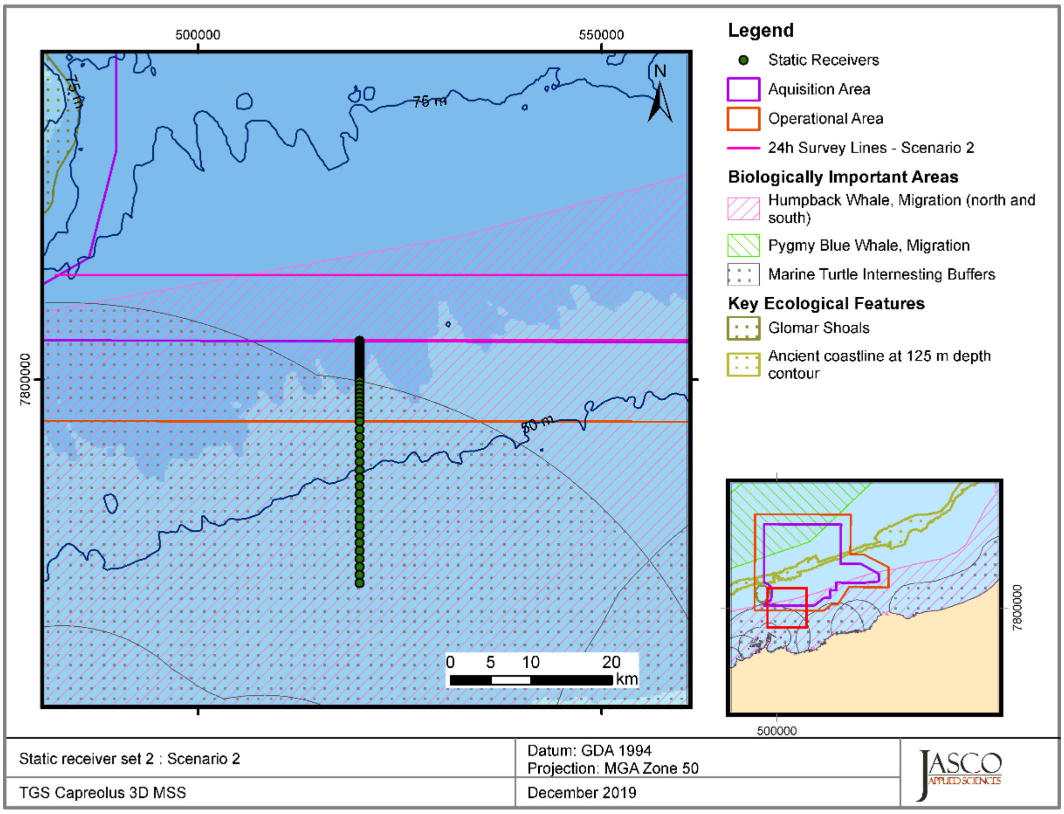

Figure 3. *Static receiver set 2*: Acquisition lines and static receiver locations considered for SEL_{24h} calculations.

3. Noise Effect Criteria

The perceived loudness of sound, especially impulsive noise such as from seismic airguns, is not generally proportional to the instantaneous acoustic pressure. Rather, perceived loudness depends on the pulse rise-time and duration, and the frequency content. Several sound level metrics, such as PK, SPL, and SEL, are commonly used to evaluate noise and its effects on marine life (Appendix A). The period of accumulation associated with SEL is defined, with this report referencing either a “per pulse” assessment or over 24 h. Appropriate subscripts indicate any applied frequency weighting; unweighted SEL is defined as required. The acoustic metrics in this report reflect the updated ISO standard for acoustic terminology, ISO/DIS 18405:2017 (2017).

Whether acoustic exposure levels might injure or disturb marine mammals is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), and United States National Marine Fisheries Service (NMFS 2018). The number of studies that have investigated the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

We chose the following noise criteria and sound levels for this study because they include standard thresholds, thresholds suggested by the best available science, and sound levels presented in literature for species with no suggested thresholds (Sections 3.1–3.3 and Appendix A):

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from the U.S. National Oceanic and Atmospheric Administration (NOAA) Technical Guidance (NMFS 2018) for the onset of Permanent Threshold Shift (PTS) in marine mammals.
2. Marine mammal behavioural threshold based on the current U.S. National Marine Fisheries Service (NMFS) (2014) of 160 dB re 1 µPa SPL (L_p) for impulsive sound sources.
3. Sound exposure guidelines for fish, fish eggs and larvae, and turtles (Popper et al. 2014).
4. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in turtles.
5. Turtle behavioural response threshold of 166 dB re 1 µPa SPL (L_p) (NSF 2011), as applied by the US NMFS, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL) (McCauley et al. 2000b, 2000a).
6. A sound level 178 dB re 1 µPa PK-PK in the water column, reported for comparison to the results in McCauley et al. (2017) for plankton.
7. Peak-peak pressure levels (PK-PK; $L_{pk\text{-}pk}$) and particle acceleration at the seafloor to help assess effects of noise on crustaceans and bivalves through comparing to results in Day et al. (2016a), Day et al. (2019), Day et al. (2016b), Day et al. (2017) and Payne et al. (2008).
8. A sound level of 226 dB re 1 µPa PK (L_{pk}) reported for comparing to Heyward et al. (2018) for sponges and corals.

Additionally, to assess the size of the low-power zone required under the Australian Environment Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1, Department of the Environment, Water, Heritage and the Arts (DEWHA 2008), the distance to an unweighted per-pulse SEL of 160 dB re 1 $\mu Pa^2 \cdot s$ is reported.

The following subsections expand on the thresholds and sound levels for marine mammals, fish, turtles, fish eggs, fish larvae, and benthic invertebrates.

3.1. Marine Mammals

The criteria applied in this study to assess possible effects of airgun noise on marine mammals are summarised in Table 5 and detailed in Sections 3.1.1 and 3.1.2, with frequency weighting explained in Appendix A.4.

Table 5. Unweighted SPL, SEL_{24h}, and PK thresholds for acoustic effects on marine mammals.

Hearing group	NMFS (2014)	NMFS (2018)			
	Behaviour	**PTS onset thresholds* (received level)**		**TTS onset thresholds* (received level)**	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
Low-frequency cetaceans	160	183	219	168	213
Mid-frequency cetaceans		185	230	170	224
High-frequency cetaceans		155	202	140	196

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_{pk}, flat–peak denotes a sound pressure that is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa^{2}s.
Subscripts indicate the designated marine mammal auditory weighting.

3.1.1. Behavioural Response

Southall et al. (2007) extensively reviewed marine mammal behavioural responses to sounds. Their review found that most marine mammals exhibited varying responses between 140 and 180 dB re 1 µPa SPL, but inconsistent results between studies made choosing a single behavioural threshold difficult. Studies varied in their lack of control groups, imprecise measurements, inconsistent metrics, and that animal responses depended on study context, which included the animal's activity state. To create meaningful quantitative data from the collected information, Southall et al. (2007) proposed a severity scale that increased with increasing sound levels.

NMFS has historically used a relatively simple sound level criterion for potentially disturbing a marine mammal. For impulsive sounds, this threshold is 160 dB re 1 µPa SPL for marine mammals (NMFS 2014), which has been applied for this report.

3.1.2. Injury and Hearing Sensitivity Changes

There are two categories of auditory threshold shifts or hearing loss: permanent threshold shift (PTS), a physical injury to an animal's hearing organs and temporary threshold shift (TTS), a temporary reduction in an animal's hearing sensitivity as the result of receptor hair cells in the cochlea becoming fatigued.

To assist in assessing the potential for injuries to marine mammals, this report applies the criteria recommended by NMFS (2018), considering both PTS and TTS, to help assess the potential for injuries to and hearing sensitivity changes in marine mammals. Appendix A.3 provides more information about the NMFS (2018) criteria.

3.2. Fish, Turtles, Fish Eggs, and Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Turtles was formed to continue developing noise exposure criteria for fish and turtles, work begun by a panel convened by NOAA two years earlier. The resulting guidelines included specific thresholds for different levels of effects and for different groups of species (Popper et al. 2014). These guidelines defined quantitative thresholds for three types of immediate effects:

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

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. These effects are not assessed in this report. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure varies depending on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Turtles, fish eggs, and fish larvae are considered separately. Table 6 lists relevant effects thresholds from Popper et al. (2014). In general, any adverse effects of seismic sound on fish behaviour depends on the species, the state of the individuals exposed, and other factors. We note that, despite mortality being a possibility for fish exposed to airgun sounds, Popper et al. (2014) do not reference an actual occurrence of this effect. Since the publication of that work, newer studies have further examined the question of possible mortality. Popper et al. (2016) adds further information to the possible levels of impulsive seismic airgun sound to which adult fish can be exposed without immediate mortality. They found that the two fish species in their study, with body masses in the range 200–400 g, exposed to a single-impulse of a maximum received level of either 231 dB re 1 μPa (PK) or 205 dB re 1 $\mu Pa^2 \cdot s$ (SEL), remained alive for 7 days after exposure and that the probability of mortal injury did not differ between exposed and control fish.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long-lasting exposures, it is required to define a time. Popper et al. (2014) recommend applying a standard period, where this is either defined as a justified fixed period or the duration of the activity; however, Popper et al. (2014) also included caveats about how long the fish will be exposed because they can move (or remain in location) and so can the source. Popper et al. (2014) summarises that in all TTS studies considered, fish that showed TTS recovered to normal hearing levels within 18–24hours. Due to this, a period of accumulation of 24 hours has been applied in this study for SEL, which is similar to that applied for marine mammals in NMFS (2016, 2018).

In the discussion of the criteria, Popper et al. (2014) discuss the complications in determining a relevant period of mobile seismic surveys, as the received levels at the fish change between impulses because the source is moving, and that in reality a revised guideline based on the closest PK or the per-pulse SEL might be more useful than one based on accumulated SEL. This is because exposures at the closest point of approach (CPA) are the primary exposures contributing to a receiver's accumulated level (Gedamke et al. 2011). Additionally, several important factors determine the likelihood and duration a receiver is expected to be in close proximity to a sound source (i.e., overlap in space and time between the source and receiver). For example, accumulation time for fast moving (relative to the receiver) mobile sources is driven primarily by the characteristics of the source (i.e., speed, duty cycle; NMFS 2016, 2018).

As discussed in Popper (2018), many fish species move around, some over large distances. The author suggests that it is reasonable to think that if the sound of a seismic source becomes too loud, the fish will move away from the source because they are able to determine the direction of a sound source. If the fish moves away, the amount of energy to which it is exposed is likely to be one or a few seismic pulses, and these would not likely be loud enough to result in any effect because the fish would move away at a much lower level signal than could cause harm. Data on TTS for fish are very limited, with the only study that examined recovery from seismic impulses being Popper et al. (2005). Popper (2018) states that if this study had been conducted on wild, free-swimming fish instead of caged ones, there would have been no effect whatsoever because they were likely to have moved away from the source as it approached them, as would happen with normally free-moving demersal and pelagic fish species associated with a 3-D seismic survey in northern Australian waters, extrapolating from the Bethany 3-D assessed in Popper (2018).

Therefore, the time over which energy should be accumulated in each individual fish in the survey area should be limited to the time over which fish receives the maximum exposure, and 24 h is likely too long a period for calculating the accumulation of energy in determining potential harm (e.g., damage or TTS) (Popper 2018). Even if fish do show some TTS, recovery will start as soon as the most intense sounds end, and recovery is likely to even occur, to a limited degree, between seismic pulses. Based on very limited data, recovery within 24 h (or less) is very likely. If TTS does occur, the duration of exposure to the most intense sounds that could result in TTS will be over just a few hours. Thus, energy accumulating over longer periods than a few hours is probably inappropriate (Popper 2018).

Following this, the analysis for the Capreolus-2 3D MSS has considered time periods of 1–4 and 24 h for the accumulation of SEL, to examine the time over which the maximum exposure occurs at difference ranges, and the point from which recovery might start to occur. This is to help contextualise the potential effects on both site-attached and pelagic fish species.

Table 6. Criteria for seismic noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish I: No swim bladder (particle motion detection)	>219 dB SEL_{24h} or >213 dB PK	>216 dB SEL_{24h} or >213 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish II: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	>>186 dB SEL_{24h}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish III: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or >207 dB PK	203 dB SEL_{24h} or >207 dB PK	186 dB SEL_{24h}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Fish eggs and fish larvae	>210 dB SEL_{24h} or >207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Notes: Peak sound level (PK) dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s. All criteria are presented as sound pressure, even for fish without swim bladders, since no data for particle motion exist. Relative risk (high, moderate, or low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

3.2.1. Turtles

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. McCauley et al. (2000b) observed the behavioural response of caged turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the turtles increased their swimming activity and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The 166 dB re 1 µPa level has been used as the threshold level for a behavioural disturbance response by NMFS and applied in the Arctic Programmatic Environment Impact Statement (PEIS) (NSF 2011). At that time, and in the absence of any data from which to determine the sound levels that could injure an animal, TTS or PTS onset were considered possible at an SPL of 180 dB re 1 µPa (NSF 2011). Some additional data suggest that behavioural responses occur closer to an SPL of 175 dB re 1 µPa, and TTS or PTS at even higher levels (McCauley et al. 2000b, McCauley et al. 2000a), but the received levels were unknown, and the NSF (2011) PEIS maintained the earlier NMFS criteria levels of 166 and 180 dB re 1 µPa (SPL) for behavioural response and injury, respectively. Popper et al. (2014) suggested injury to turtles could occur for sound exposures above 207 dB re 1 µPa (PK) or above 210 dB re 1 µPa²·s (SEL_{24h}). Sound levels defined by Popper et al. (2014) show that animals are very likely to exhibit a behavioural response when they are near an airgun (tens of metres), a moderate response if they encounter the source at intermediate ranges (hundreds of metres), and a low response if they are far (thousands of meters) from the airgun.

Finneran et al. (2017) presented revised thresholds for turtle injury, considering both PK and frequency weighted SEL, which have been applied in this study, along with the NMFS criterion for behavioural response (SPL of 166 dB re 1 µPa), and a criterion for behavioural disturbance (SPL of 175 dB re 1 µPa) (McCauley et al. 2000b, McCauley et al. 2000a) (Table 7).

Table 7. Acoustic effects of impulsive noise on turtles: Unweighted SPL, SEL_{24h}, and PK thresholds.

Effect type	Criterion	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Behaviour	NSF (2011)	160	NA	
	McCauley et al. (2000a)	175		
PTS onset thresholds* (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds* (received level)			189	226

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_{pk}, flat denotes peak sound pressure that is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa²s.

3.3. Benthic Invertebrates (Crustaceans and Bivalves)

Research is ongoing into the relationship between sound and its effects on crustaceans, including the relevant metrics for both effect and impact. Available literature suggests particle motion, rather than sound pressure, is a more important factor for crustacean and bivalve hearing. Water depth, seabed material, and seismic source size are related to the particle motion levels at the seafloor, with larger arrays and shallower water being related to higher particle motion levels, more likely relevant to effects on crustaceans and bivalves.

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

For crustaceans, a PK-PK sound level of 202 dB re 1 µPa (Payne et al. 2008) is considered to be associated with no impact, and it is therefore applied in this assessment. Additionally for context, the PK-PK sound levels determined for crustaceans in Day et al. (2016a), Day et al. (2016b), and Day et al. (2019) 209–213 dB re 1 µPa are also included. These sound levels were associated with observations of sub-lethal effects, relating to impairment of reflexes, damage to the statocysts and reduction in numbers of haemocytes (possibly indicative of decreased immune response function).

For bivalves, PK-PK sound levels of 212 and 213 are presented to allow comparison to the maximum sound levels measured in Day et al. (2016a) and Day et al. (2017) for scallops and pearl shell oyster. For bivalves, literature does not present a sound level associated with no impact, and as particle motion is the more relevant metric, particle acceleration from the seismic source has been presented for comparing the results in Table 7 of Day et al. (2016b). The maximum particle acceleration assessed for scallops was 37.57 ms^{-2}, considered appropriate for pearl shell oyster.

4. Methods

4.1. Acoustic Source Model

The pressure signature of the individual airguns and the composite 1/3-octave-band point-source equivalent directional levels (i.e., source levels) of the four seismic sources were modelled with JASCO's Airgun Array Source Model (AASM). Although AASM accounts for notional pressure signatures of each seismic source with respect to the effects of surface-reflected signals on bubble oscillations and inter-bubble interactions, the surface-reflected signal (known as surface ghost) is not included in the far-field source signatures. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

AASM considers:

- Array layout.
- Volume, tow depth, and firing pressure of each airgun.
- Interactions between different airguns in the array.

All seismic sources considered were modelled over AASM's full frequency range, up to 25 kHz. Appendix B.1 details this model.

4.2. Parameter Overview

The specifications of the seismic source and the environmental parameters used in the propagation models are described in detail in Appendix D. Two sound speed profiles, one for each scenario, were considered in this modelling study. Two profiles were selected to characterise the different environments associated with each scenario, where scenarios 1 is associated with deeper waters on the continental shelf break and slope and scenario 2 is associated with shallow water on the continental shelf. The month of June was identified as the seasonal period that would provide the farthest propagation (Appendix D.3.2) due to the presence of a slightly upward refracting sound speed profile for both scenarios.

Seabed sediments in the survey area were modelled with two discrete seabed types. On the inner and middle continental shelf, a seabed consisting of a sand layer underlain by cemented limestone was used for sites in water less than 100 m depth (Sites 5–9, Table 4, see profile in Table D-1). On the shelf break and slope (>100 m, Sites 1–4, Table 4) the seabed was modelled as a succession from soft to hard sediments (unconsolidated carbonate sediment to cemented limestone, see profile in Table D-2).

4.3. Sound Propagation Models

Three sound propagation models were used to predict the acoustic field around the seismic source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 5 Hz to 25 kHz).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 5 to 1024 Hz).
- Wavenumber integration model (VSTACK Site 4, 5 to 1024 Hz).
- Wavenumber integration model (VSTACK Sites 6 and 9, 10 to 1024 Hz).

The models were used in combination to characterise the acoustic fields at short and long ranges in terms of SEL, SPL, PK, and PK-PK. Appendix C details each model. MONM-BELLHOP was used to calculate SEL of a 360° area around each source location. FWRAM was used to model synthetic seismic pulses and to generate a generalised range-dependent SEL to SPL conversion function for the considered modelled sites. The range-dependent conversion function was applied to predicted per-pulse SEL results from MONM-BELLHOP to estimate SPL values. FWRAM was also used to calculate water column PK and PK-PK levels.

VSTACK was used to calculate close range PK, PK-PK, and particle motion levels along transects at the seafloor from the loudest direction of the seismic source at the shallowest modelled site (Site 9) as well as two deeper modelled sites (Site 6 and Site 4). VSTACK was also used estimate particle acceleration.

Although MONM accounts for the partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, it is unstable for seabed environments with high seabed shear speed (greater than ~600 m/s) such as those present in parts of the study area due to the presence of a limestone (calcarenite) layer in the seabed. For environments where the seabed contains material with higher shear speed material, such as the shallow water (<100 m) modelled sites considered in this study, a correction is applied to the broadband levels predicted from MONM and FWRAM. The correction consists of using output from the VSTACK model at short ranges and measurement data from an acoustic study (McCauley et al. 2016) at long ranges. VSTACK, which can model high shear speed exactly, was used to adjust at ranges up to a kilometre. At ranges longer than a kilometre, measurement data was used.

4.4. Accumulated SEL

During a seismic survey, new sound energy is introduced into an environment with each pulse from the seismic source. While some impact criteria are based on the per-pulse energy released, others, such as the marine mammal and fish SEL criteria used in this report (Sections 3.1–3.3), account for the total acoustic energy marine fauna is subjected to over a specified duration, defined in this report as 24 h. An accurate assessment of the accumulated sound energy depends not only on the parameters of each seismic impulse but also on the number of impulses delivered in a duration and the relative positions of the impulses.

When there are many seismic pulses, it becomes computationally prohibitive to perform sound propagation modelling for every single event. The distance between the consecutive seismic impulses is small enough, however, that the environmental parameters that influence sound propagation are virtually the same for many impulse points. The acoustic fields can, therefore, be modelled for a subset of seismic pulses and estimated at several adjacent ones. After sound fields from representative impulse locations are calculated, they are adjusted to account for the source position for nearby impulses.

Although estimating the cumulative sound field with the described approach is not as precise as modelling sound propagation at every impulse location, small-scale, site-specific sound propagation features tend to blur and become less relevant when sound fields from adjacent impulses are summed. Larger scale sound propagation features, primarily dependent on water depth, dominate the cumulative field. The accuracy of the present method acceptably reflects those large-scale features, thus providing a meaningful estimate of a wide area SEL field in a computationally feasible framework.

To produce the map of accumulated received sound level distributions and calculate distances to specified sound level thresholds, the maximum-over-depth level was calculated at each sampling point within the modelled region. The radial grids of maximum-over-depth and seafloor sound levels for each impulse were then resampled (by linear triangulation) to produce a regular Cartesian grid. The sound field grids from all impulses were summed (Equation A-5) to produce the cumulative sound field grid with cell sizes of 20 m. The contours and threshold ranges were calculated from these flat Cartesian projections of the modelled acoustic fields. The single-impulse SEL fields were computed over model grids approximately 200 × 200 km in range, which encompasses the full area of the cumulative grid (the entire survey area).

The unweighted (fish) and frequency-weighted SEL_{24h} results were rendered as contour maps, including contours that focus on the relevant criteria-based thresholds. Only contours at ranges larger than the nearfield of the seismic source were rendered.

Additional context on the accumulation of SEL over each considered scenario is presented in Section 5.3.3, detailing how the sound field is sampled at the static receivers, located perpendicular to the modelled survey lines (described in Section 2). At a given static spatial location, the per-pulse and accumulated time history can be plotted using similar methods to estimate the cumulative sound exposure grids as described above. As the seismic source (and vessel) moves along the survey line, different sound fields from the single impulse sites were used to represent the acoustic footprint at that impulse location. Based on the speed of the vessel and the impulse interval between consecutive impulses a time history of the per-pulse and accumulated received SEL can be obtained at a receiver point.

The per-pulse levels at each receiver location were then summed over the assessment time period, 1, 2, 3, and 4 h windows centred on the CPA or 24 h, to provide context on the spatial and temporal dependence of the accumulated sound field.

4.5. Geometry and Modelled Regions

To assess sound levels with MONM-BELLHOP, the sound field modelling calculated propagation losses up to distances of 100 km from the source in each cardinal direction, with a horizontal separation of 20 m between receiver points along the modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta$ = 2.5° for a total of N = 144 radial planes. Receiver depths were chosen to span the entire water column over the modelled areas, from 2 m to a maximum of 2000 m, with step sizes that increased with depth. To supplement the MONM results, high-frequency results for propagation loss were modelled using BELLHOP for frequencies from 2.5 to 25 kHz. The MONM and Bellhop results were combined to produce results for the full frequency range of interest.

FWRAM was run to 100 km, but along only four radials (fore and aft endfire, and port and starboard broadside) for computational efficiency. This was done to compute SEL-to-SPL conversions (Appendix D.2) but also to quantify water column PK and PK-PK. The horizontal range step is dependent on frequency and ranges from 50 m at lower frequencies to 10 m above 800 Hz.

The maximum modelled range for VSTACK was 1000 m, and a variable receiver range increment that increased away from the source was used, which increased from 10 to 25 m. Received levels were computed for receivers at the seafloor.

5. Results

5.1. Acoustic Source Levels and Directivity

AASM (Section 4.1) was used to predict the horizontal and vertical overpressure signatures and corresponding power spectrum levels for the seismic source, with results provided in Appendix B.2 along with the horizontal directivity plots.

Preliminary source modelling was conducted to determine the source with the highest equivalent far-field acoustic output of four comparable source arrays, which were defined as being between 3090–3480 in^3 as required to meet the technical specification and objectives of the Capreolus-2 3D MSS. All four arrays were coupled with single impulse propagation modelling (Appendix E), to determine the array most likely to produce the largest ranges to thresholds. This was determined to be a 3480 in^3 seismic source with a 6 m tow depth (see Appendix D.4 for details on this source)

Table 8 shows the PK and per-pulse SEL source levels in the horizontal-plane broadside (perpendicular to the tow direction), endfire (along the tow direction), and vertical directions. The vertical source level that accounts for the “surface ghost” (the out of phase reflected pulse from the water surface) is also presented to make it easier to compare the output of other seismic source models.

Figure B-1 shows the broadside, endfire, and vertical overpressure signature and corresponding power spectrum levels for the source. The signature consists of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy was produced at frequencies below 400 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among airguns in the source and correspond with the volumes and relative locations of the airguns to each other.

Table 8. Far-field source level specifications for the 3480 in^3 source, for a 6 m tow depth. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Direction	Peak source pressure level ($L_{S,pk}$) (dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$) (dB 1 µPa^{2}m^{2}s)	
		10–2000 Hz	2000–25000 Hz
Broadside	248.6	225.3	185.7
Endfire	247.5	225.2	190.6
Vertical	258.1	230.9	197.9
Vertical (surface affected source level)	258.1	233.5	200.9

5.2. Per-pulse Sound Fields

5.2.1. Tabulated results

Per-pulse results for the 3480 in³ seismic source towed at 6 m are presented for SPL, SEL, PK, and PK-PK, including seafloor PK and PK-PK in Tables 9–14.

5.2.1.1. Entire water column

Table 9. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 3480 in³ source to modelled maximum-over-depth unweighted per-pulse SEL isopleths from the modelled single impulse sites (1–9), with water depth indicated.

Per-pulse SEL (L_E; dB re 1 µPa²·s)	Site 1 (567 m)		Site 2 (444 m)		Site 3 (236 m)		Site 4 (164 m)		Site 5 (66 m)	
	R_{max}	$R_{95\%}$	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	0.10	0.10
180	0.14	0.12	0.14	0.12	0.14	0.12	0.16	0.14	0.34	0.30
170	0.46	0.42	0.51	0.48	0.86	0.70	0.86	0.68	0.88	0.78
160†	2.70	2.15	3.28	2.30	4.38	3.30	4.60	3.78	2.75	2.40
150	14.1	10.8	14.0	11.0	15.1	12.0	14.7	11.4	6.92	5.81
140	51.7	36.7	43.3	31.4	39.0	30.4	41.4	32.1	15.7	11.9
130	>100	/	>100	/	>100	/	90.9	72.0	30.9	23.2
120	>100	/	>100	/	>100	/	>100	/	48.7	48.4

Per-pulse SEL (L_E; dB re 1 µPa²·s	Site 6 (64 m)		Site 7 (60 m)		Site 8 (76 m)		Site 9 (47 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
190	0.08	0.08	0.09	0.08	0.08	0.08	0.09	0.08
180	0.34	0.29	0.36	0.30	0.34	0.29	0.36	0.30
170	0.86	0.76	0.88	0.78	0.86	0.76	0.88	0.78
160†	2.56	2.24	2.74	2.33	2.56	2.24	2.74	2.33
150	7.00	5.67	6.90	5.63	7.00	5.67	6.90	5.63
140	14.9	11.6	14.8	11.4	14.9	11.6	14.8	11.4
130	29.6	22.8	29.8	22.3	29.6	22.8	29.8	22.3
120	58.8	42.9	61.4	46.3	58.8	42.9	61.4	46.3

† Low power zone assessment criteria DEWHA (2008).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 10. Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) from the 3480 in^3 source to modelled maximum-over-depth SPL isopleths from the modelled single impulse sites (1–9), with water depth indicated.

SPL (L_p; dB re 1 µPa)	Site 1 (567 m)		Site 2 (444 m)		Site 3 (236 m)		Site 4 (164 m)		Site 5 (66 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.08
190	0.12	0.11	0.12	0.11	0.12	0.11	0.12	0.11	0.26	0.23
180	0.40	0.34	0.42	0.40	0.78	0.63	0.72	0.59	0.68	0.61
175#	1.36	1.06	1.38	1.12	1.36	1.13	1.70	1.42	1.04	0.97
170	2.30	1.84	2.34	1.89	2.85	2.3	3.38	2.59	1.65	1.50
166†	3.42	2.73	3.76	3.01	4.6	3.72	5.08	4.00	2.60	2.11
160‡	7.46	5.97	8.01	6.36	9.56	7.25	8.96	7.29	4.35	3.90
150	31.9	23.3	32	22.8	27.8	20.6	28.3	21.2	11.2	7.98
140	85.6	59.4	100	61.3	65.9	53.2	72.6	52.7	31.2	23.10
130	>100	/	>100	/	>100	/	>100	/	69.1	45.70

SPL (L_p; dB re 1 µPa)	Site 6 (64 m)		Site 7 (60 m)		Site 8 (76 m)		Site 9 (47 m)	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	0.08	0.07	0.08	0.08	0.07	0.06	0.09	0.09
190	0.26	0.23	0.28	0.23	0.26	0.23	0.28	0.24
180	0.68	0.60	0.70	0.62	0.64	0.58	0.70	0.65
175#	1.02	0.93	1.08	0.97	1.04	0.94	1.18	1.02
170	1.58	1.43	1.66	1.48	1.64	1.42	1.92	1.58
166†	2.48	2.04	2.44	2.08	2.30	2.07	2.66	2.33
160‡	4.52	3.76	4.32	3.80	4.36	3.87	5.12	4.07
150	10.3	7.77	10.2	7.68	10.8	8.30	14.8	11.2
140	29.4	21.9	29.6	21.0	27.2	21.6	39.8	32.6
130	74.7	60.1	83.2	64.1	62.2	53.4	92.5	76.3

Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b).
† Threshold for turtle behavioural response to impulsive noise (NSF 2011).
‡ Marine mammal behavioural threshold for impulsive sound sources (NMFS 2014).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} is greater than the maximum modelling extent.

Table 11. Maximum (R_{max}) horizontal distances (km) from the 3480 in^3 array to modelled maximum-over-depth peak pressure level (PK) thresholds based on the NOAA Technical Guidance (NMFS 2018) for marine mammals, and Popper et al. (2014) for fish and Finneran et al. (2017) for turtles, at four modelling sites (Table 4) , with water depth indicated.

Hearing group	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (km)			
		Site 2 (444 m)	Site 4 (164 m)	Site 6 (64 m)	Site 9 (47 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	0.10
Mid-frequency cetaceans (PTS)	230	—	—	—	—
Mid-frequency cetaceans (TTS)	224	0.02	0.02	0.02	—
High-frequency cetaceans (PTS)	202	0.22	0.19	0.36	0.42
High-frequency cetaceans (TTS)	196	0.41	0.69	0.76	0.76
Turtles (PTS)	232	—	—	—	—
Turtles (TTS)	226	—	—	—	—
Fish: No swim bladder (also applied to sharks)	213	0.06	0.06	0.06	0.10
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	0.13	0.12	0.18	0.24

A dash indicates the threshold is not reached within the limits of the modelling resolution (20 m).

Table 12. Maximum (R_{max}) horizontal distances (in km) from the 3480 in^3 array to modelled maximum-over-depth peak-peak pressure level threshold (178 dB re 1µPa, PK-PK), assessed along the four FWRAM modelling transects (maximum presented) at four modelled sites (Table 4), with water depth indicated.

PK-PK ($L_{pk\text{-}pk}$; dB re 1 µPa)	Distance R_{max} (km)			
	Site 2 (444 m)	Site 4 (164 m)	Site 6 (64 m)	Site 9 (47 m)
178	14.0	7.90	10.3	12.3

5.2.1.2. Seafloor

Table 13. Maximum (R_{max}) horizontal distances (in m) from the 3480 in^3 array to modelled seafloor peak pressure level thresholds (PK) from three single-impulse modelled sites (Table 4), with water depth indicated.

Hearing group/animal type	PK threshold (L_{pk}; dB re 1 µPa)	Distance R_{max} (m)		
		Site 4 (164 m)	Site 6 (64 m)	Site 9 (47 m)
Sound levels for sponges and corals†	226	*	*	8
Fish: No swim bladder (also applied to sharks)	213	60	81	89
Fish: Swim bladder not involved in hearing, Swim bladder involved in hearing Fish eggs, and larvae	207	148	171	159

† Heyward et al. (2018)
An asterisk indicates that the sound level was not reached.

Table 14. Maximum (R_{max}) horizontal distances (in m) from the 3480 in^3 seismic source to modelled seafloor peak-peak pressure levels (PK-PK) from three single-impulse modelled sites (Table 4), with water depth indicated. Results included in relation to benthic invertebrates (Section 3.3).

PK-PK (L_{pk-pk}; dB re 1 µPa)	Distance R_{max} (km)		
	Site 4 (164 m)	Site 6 (64 m)	Site 9 (47 m)
213[a,b,c]	144	151	151
212[b,c]	160	176	166
210[a,b]	197	211	193
209[a,b]	216	225	208
202[d]	588	375	446

[a] Day et al. (2019), lobster
[b] Day et al. (2016a), lobster and scallops
[c] Day et al. (2017), scallops.
[d] Payne et al. (2008), lobster, applied no impact threshold

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 SPL sound fields have been presented at all modelling sites (Table 4), shown in Figures 4–12.

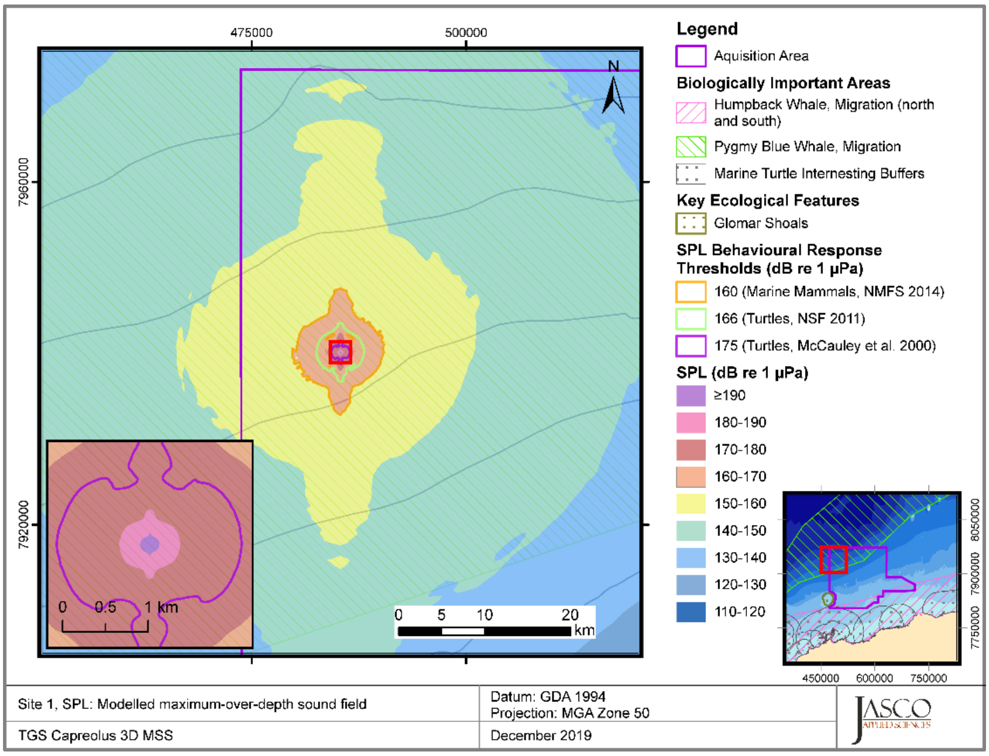

Figure 4. *Site 1, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

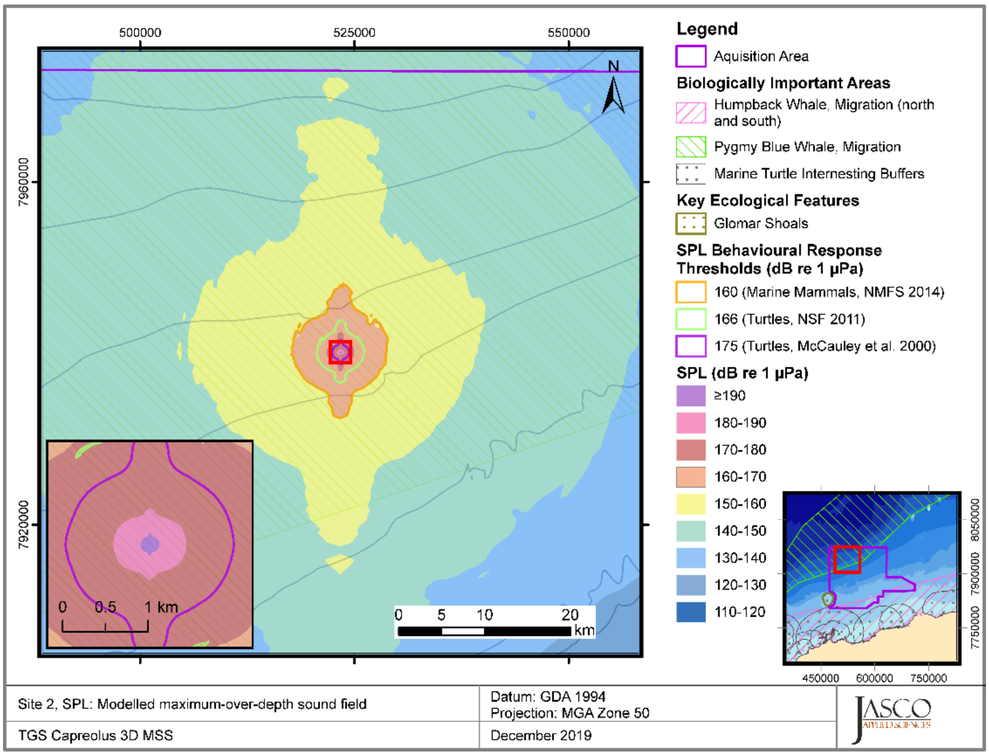

Figure 5. *Site 2, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

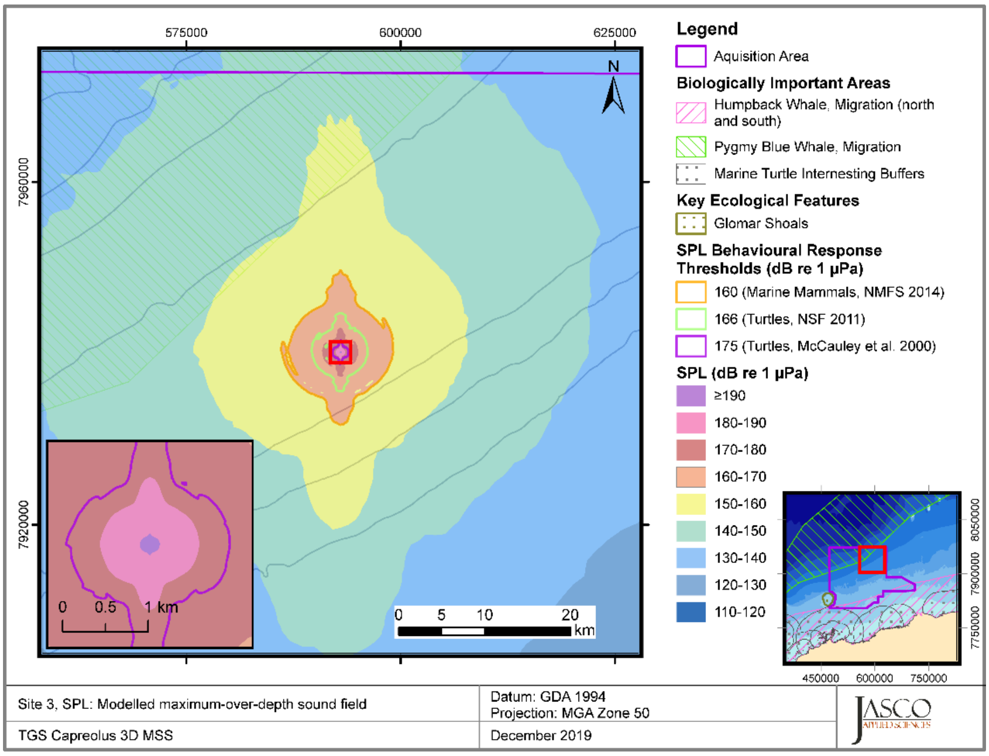

Figure 6. *Site 3, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

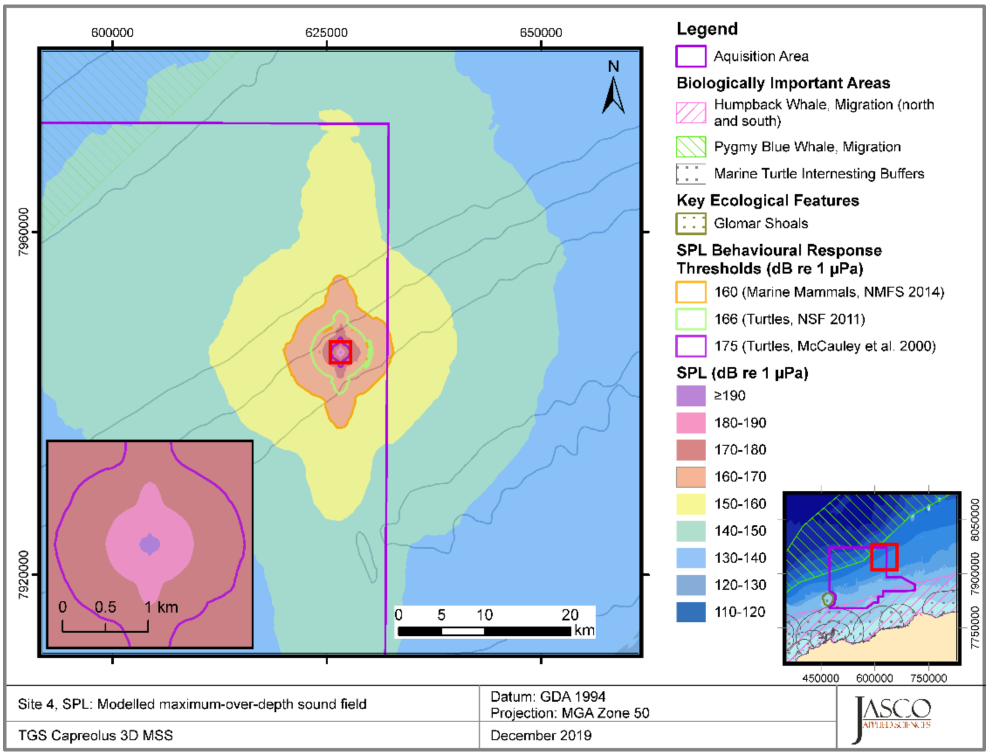

Figure 7. *Site 4, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

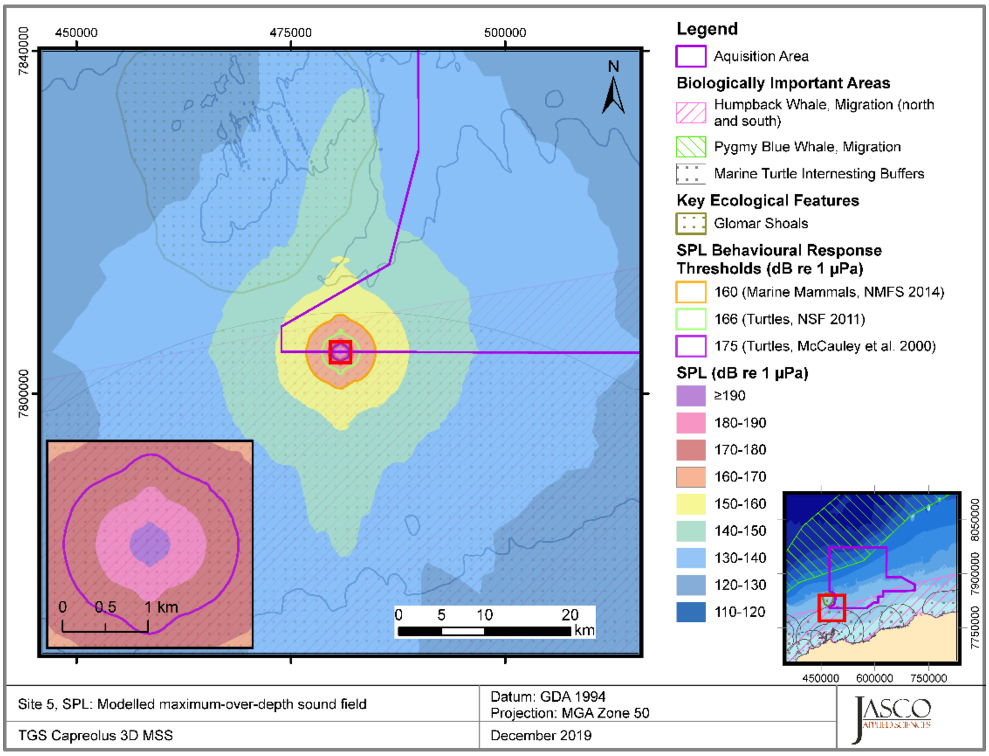

Figure 8. *Site 5, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

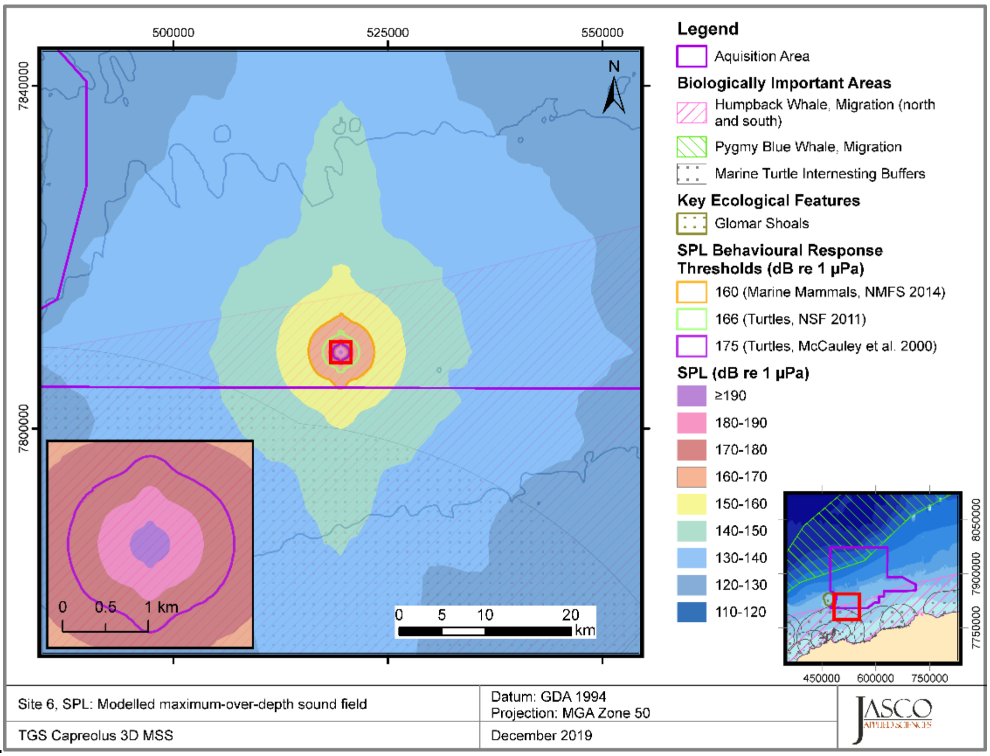

Figure 9. *Site 6, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

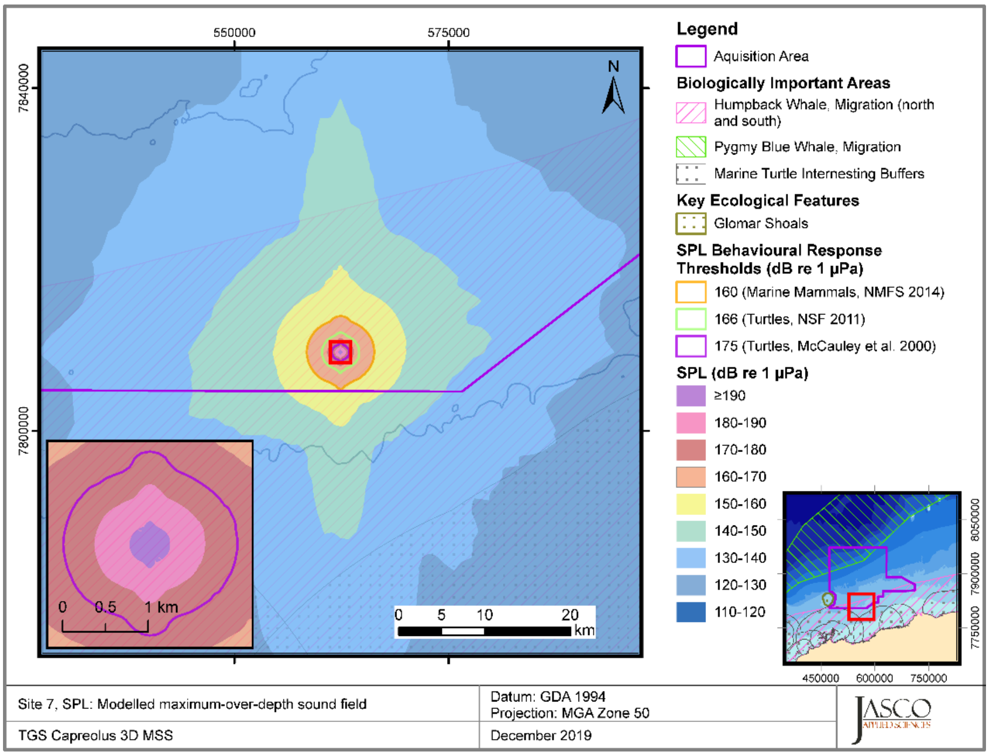

Figure 10. *Site 7, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

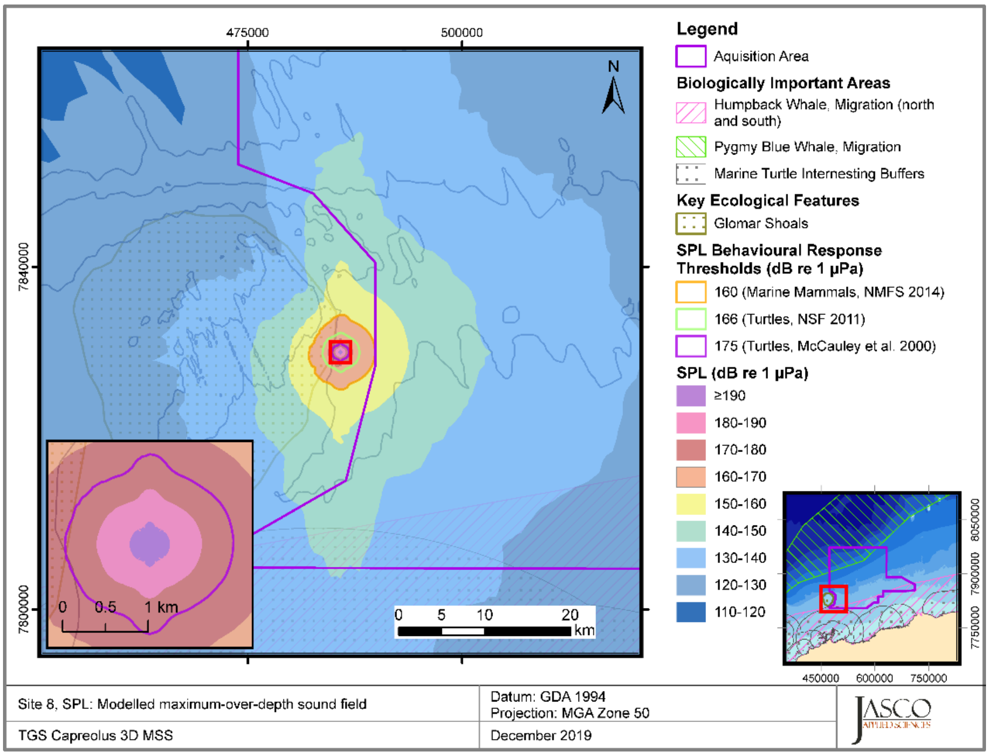

Figure 11. *Site 8, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

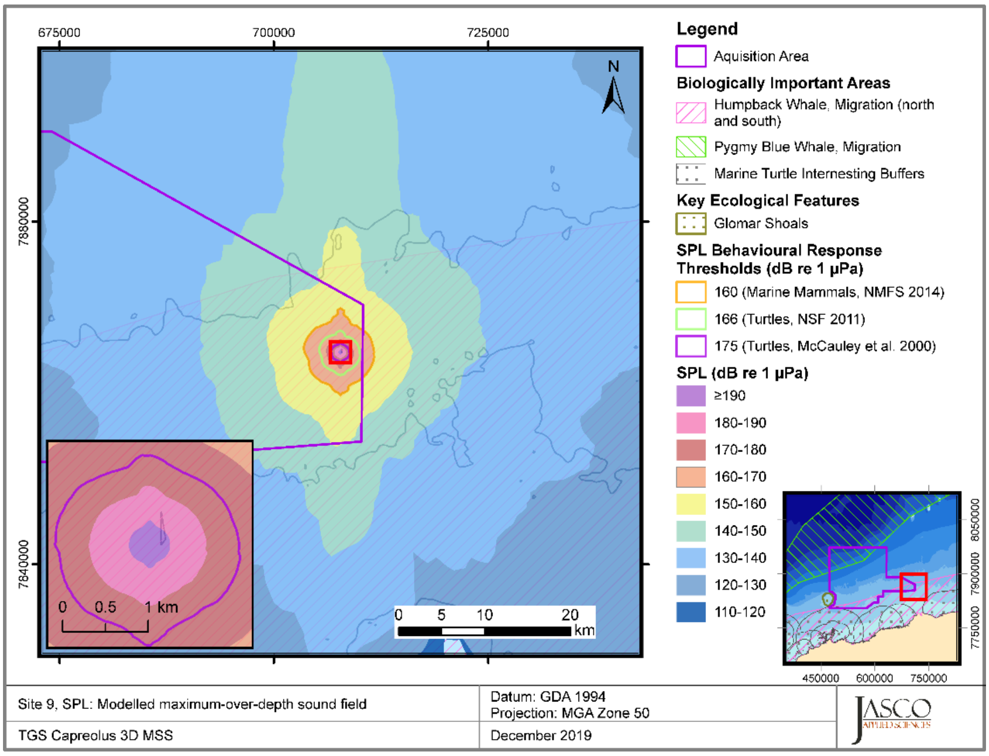

Figure 12. *Site 9, SPL:* Sound level contour map showing unweighted maximum-over-depth results.

5.2.2.2. Vertical slices of modelled sound fields

Vertical slices of the SPL sound fields for the 3480 in^3 seismic source are shown in Figures 13–21.

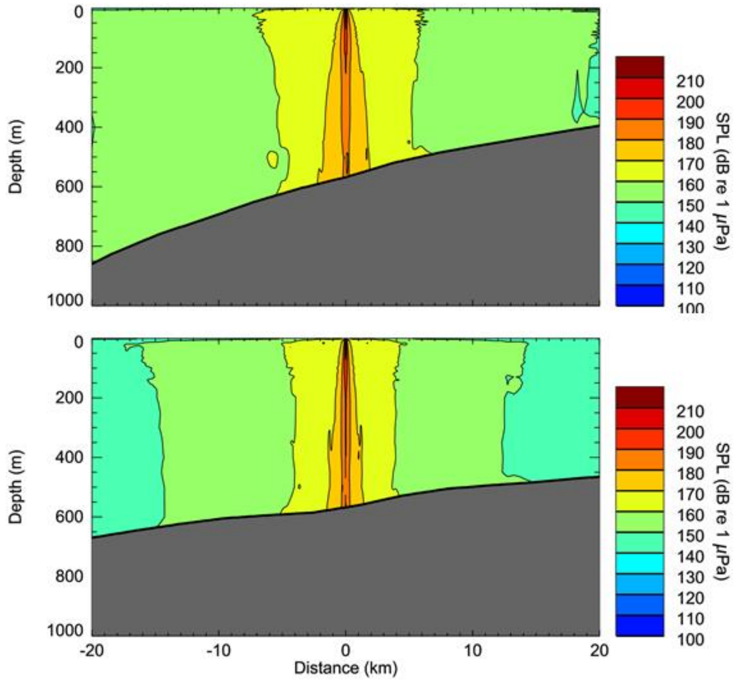

Figure 13. *Site 1, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

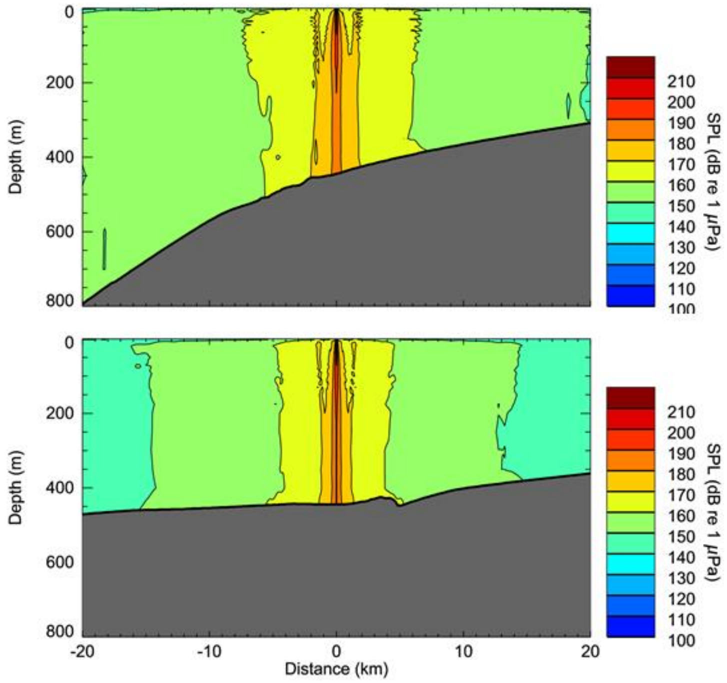

Figure 14. *Site 2, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

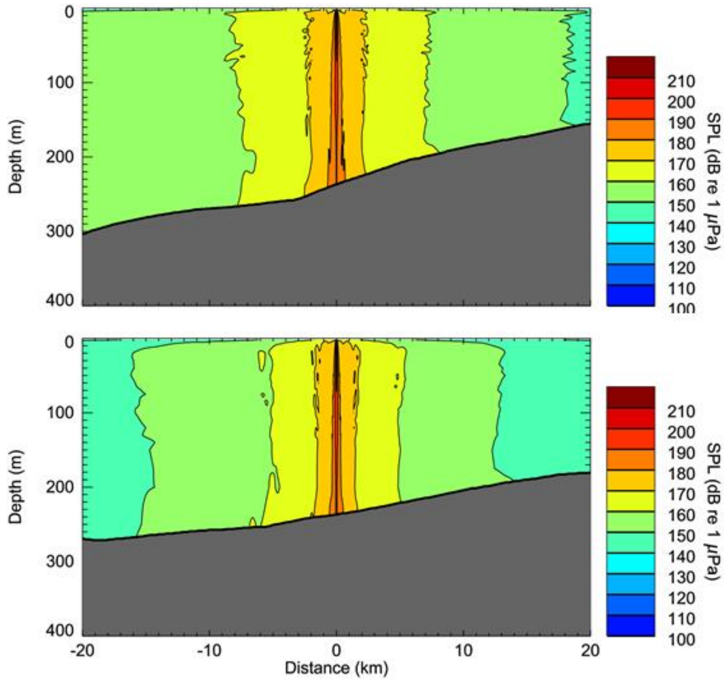

Figure 15. *Site 3 SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

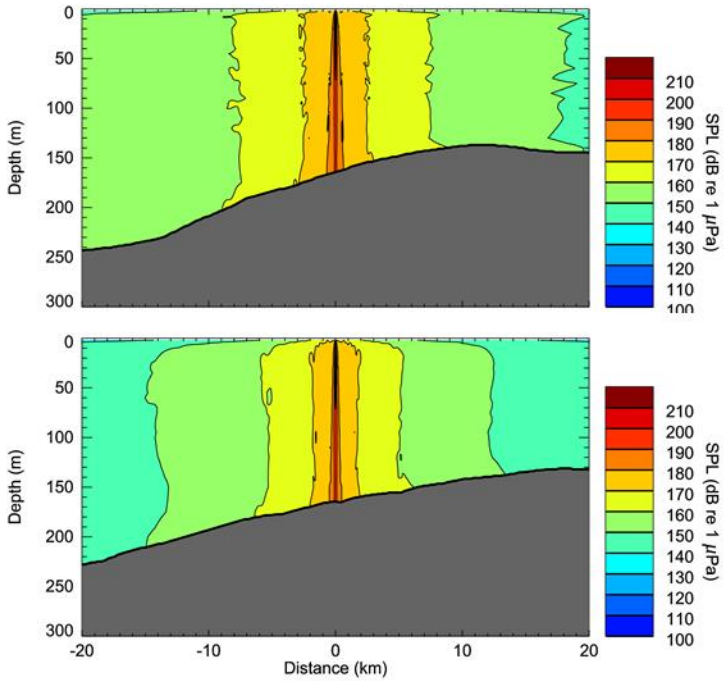

Figure 16. *Site 4, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

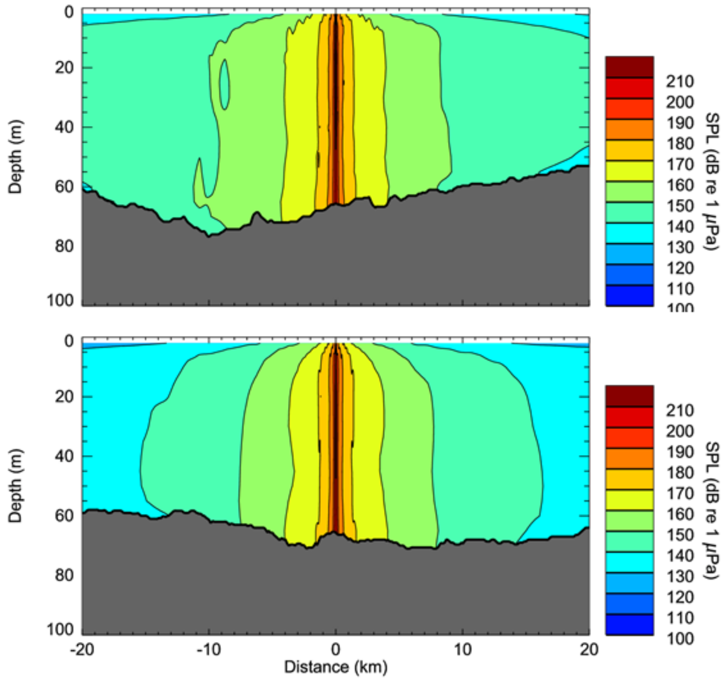

Figure 17. *Site 5, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

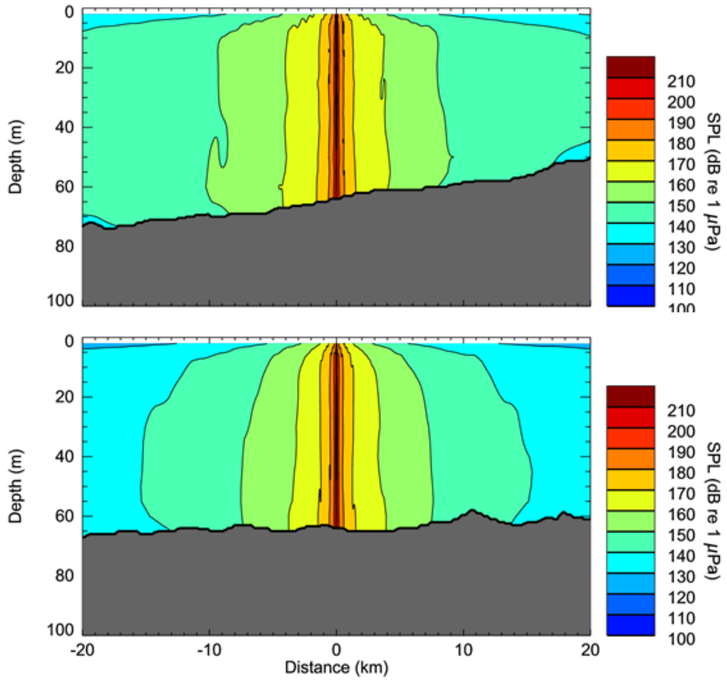

Figure 18. *Site 6, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

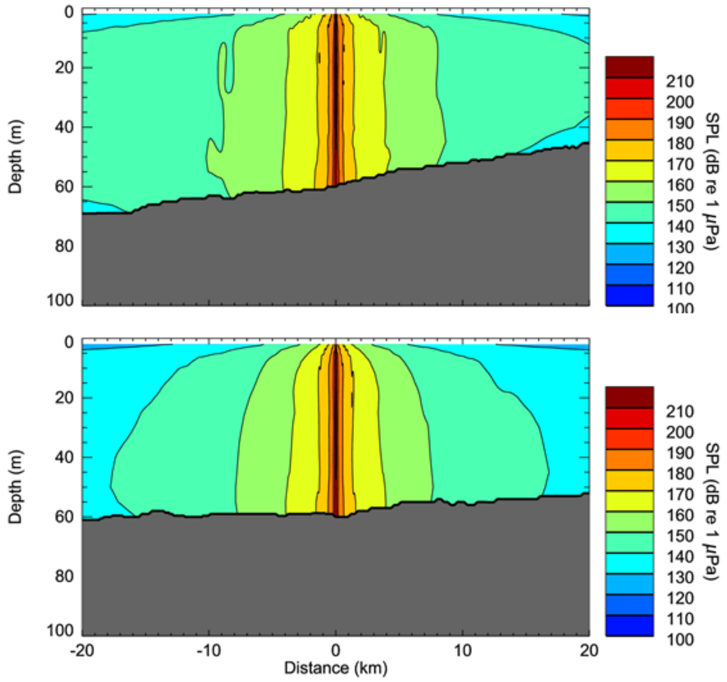

Figure 19. *Site 7, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

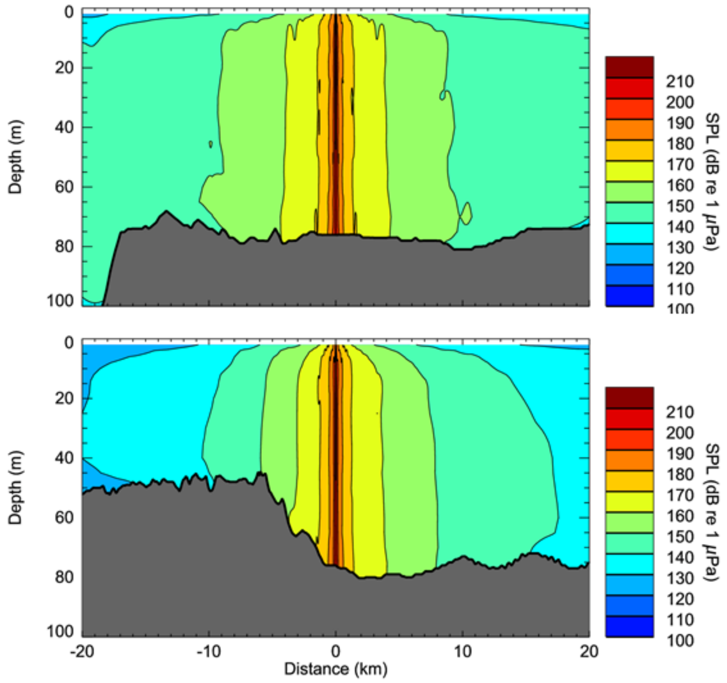

Figure 20. *Site 8, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

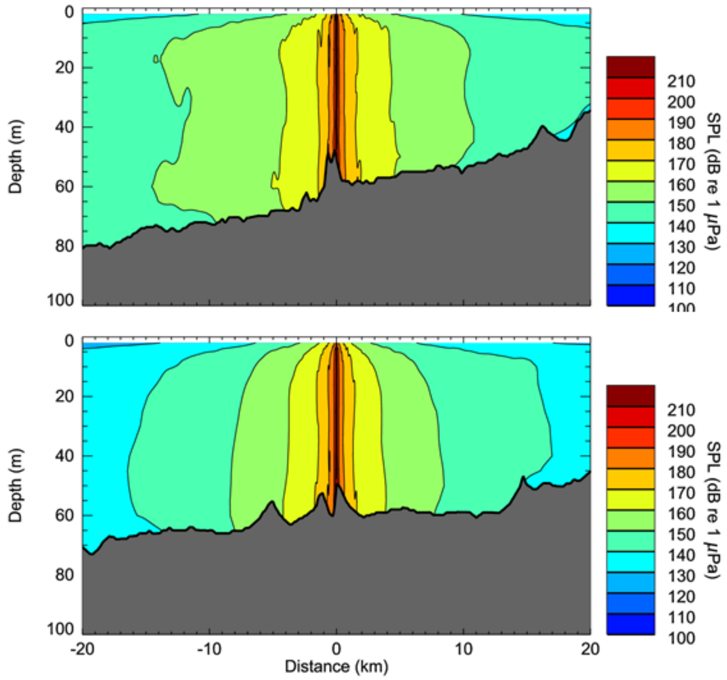

Figure 21. *Site 9, SPL*: Vertical slice of the predicted SPL for the 3480 in^3 source. Levels are shown along the broadside (top) and endfire (bottom) directions.

5.2.3. Particle motion

Figures 22–24 show modelled maximum particle acceleration as a function of horizontal range in four perpendicular directions from the centre of the 3480 in^3 seismic source at the shallowest modelling site (Scenario 2, Site 9, 47 m water depth), along with sites at 64 m and 164 m water depth (Scenario 2, Site 6 and Scenario 1, Site 4). The modelling considered a resolution of 10 m, and the maximum distance to a particle acceleration of the closest value to 37.57 ms^{-2} (Section 3.3, Day et al. (2016a) occurs at approximately 32 m (Figure 22) at Site 9 (47 m water depth), and within 5 m of the array at Site 4 (164 m water depth), while the maximum level at the seafloor at Site 4 was 21 ms^{-2}.

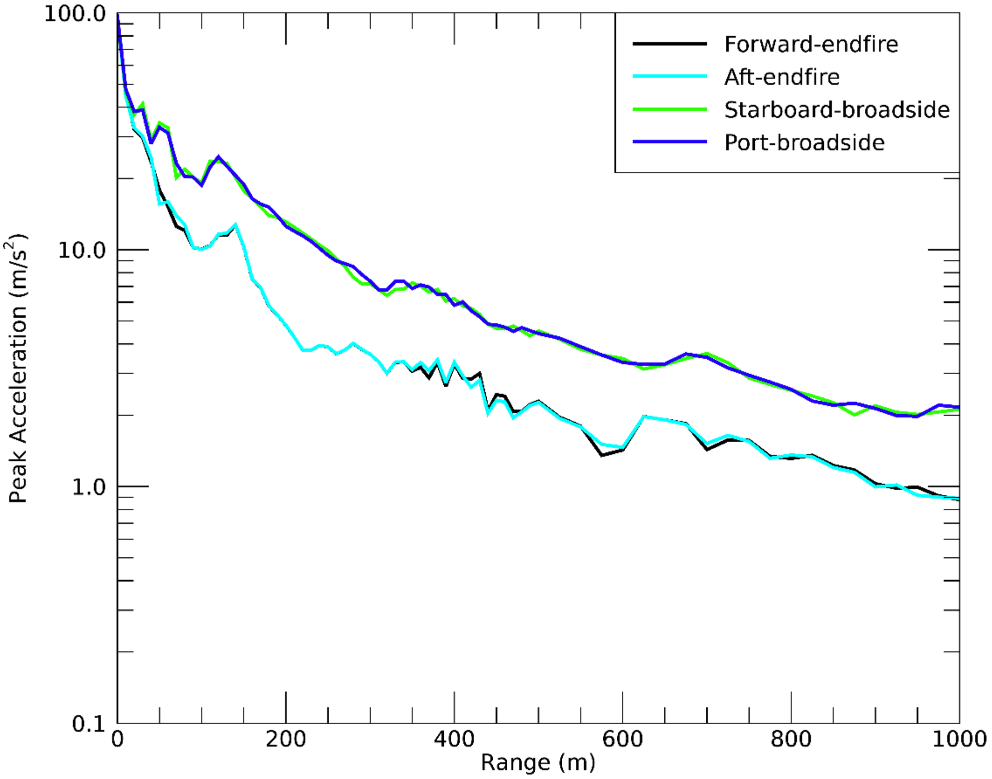

Figure 22. Scenario 1, Site 1 (47 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3480 in^3 seismic source along four directions.

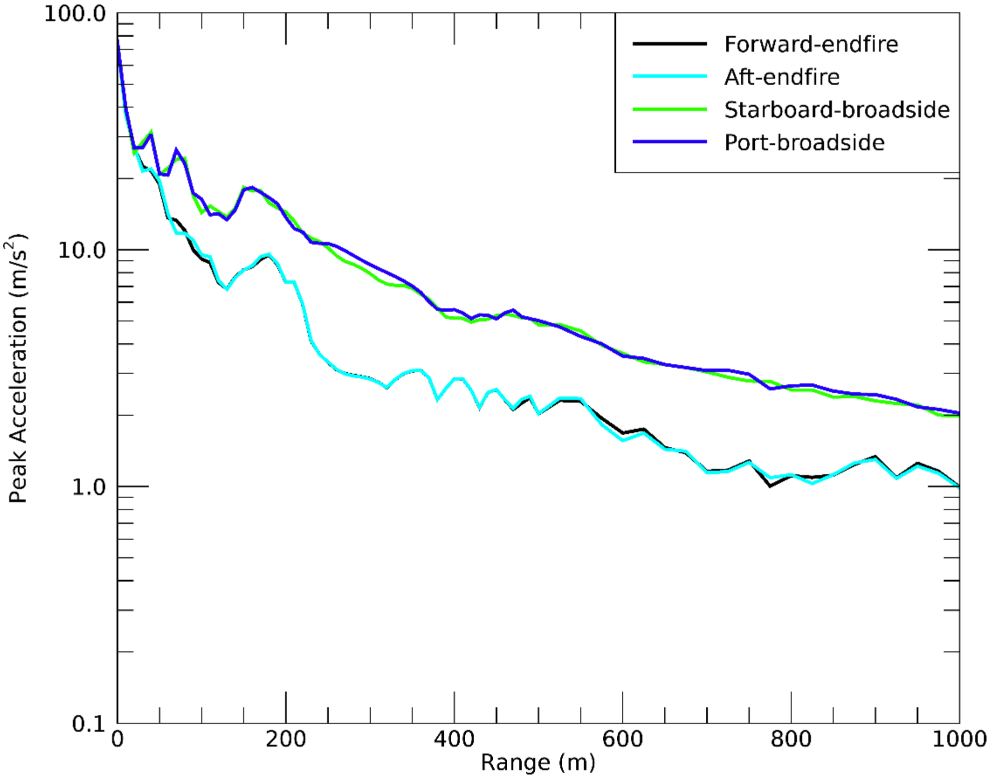

Figure 23. Scenario 1, Site 4 (64 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3480 in^3 seismic source along four directions.

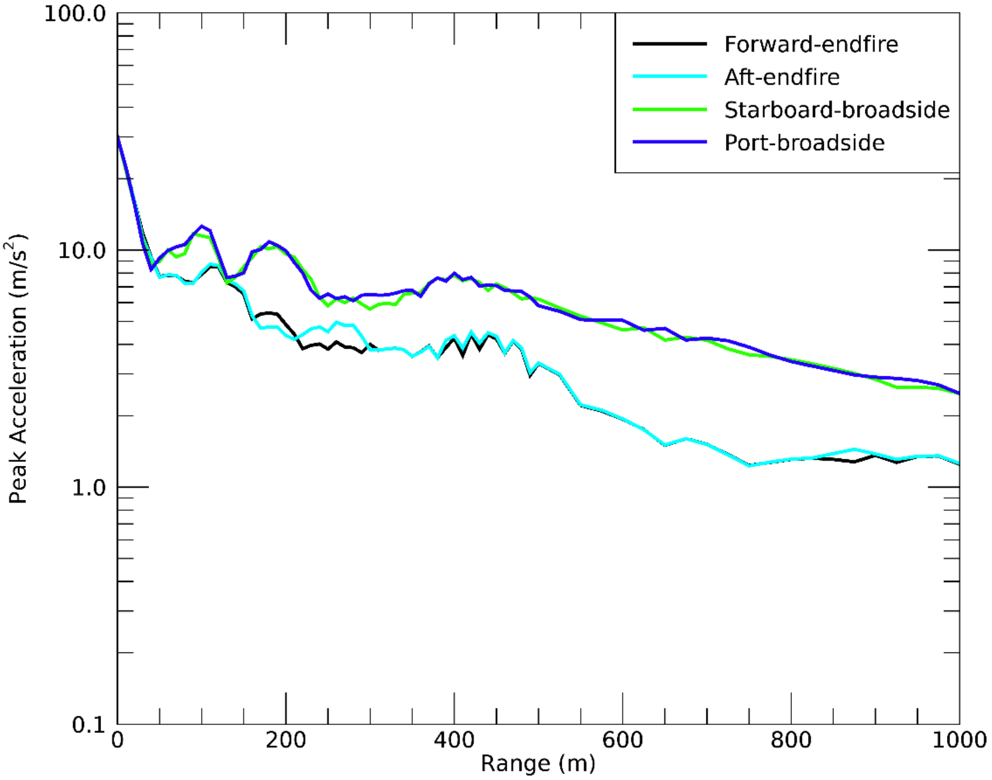

Figure 24. Scenario 1, Site 7 (164 m water depth): Maximum particle acceleration at the seafloor as a function of horizontal range from the centre of a single 3480 in^3 seismic source along four directions.

5.3. Multiple Pulse Sound Fields

The SEL_{24h} results for the proposed survey are presented for Scenario 1 and Scenario 2 within the Acquisition Area. Tables 15 and 16 show the estimated ranges to the appropriate cumulative exposure criterion contour for the various marine fauna groups considered and the corresponding ensonified areas. The ranges in this section are the perpendicular distance from the survey line to the relevant isopleth. Estimates of the maximum-over-depth sound fields, including threshold contours relating to marine mammals and fish, are presented in Figures 25 and 27, while estimates of the sound field at the seafloor and threshold contours relevant to fish are presented in Figures 26 and 28.

5.3.1. Tabulated results

Table 15. Maximum-over-depth distances (in km) to frequency-weighted SEL_{24h} based marine mammal PTS and TTS thresholds NMFS (2018) and turtles (Finneran et al. 2017).

Hearing group	**PTS**				
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	**Scenario 1**		**Scenario 2**	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Low-frequency cetaceans	183	2.34	310	0.76	240
Mid-frequency cetaceans	185	—	—	—	—
High-frequency cetaceans	155	0.02	3.04	0.04	12.7
Turtles	204	0.02	3.93	0.06	13.2
Hearing group	**TTS**				
	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	**Scenario 1**		**Scenario 2**	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Low-frequency cetaceans	168	65.4	13901	13	2916
Mid-frequency cetaceans	170	0.01	1.2	0.02	2.72
High-frequency cetaceans	140	0.62	145	0.38	125
Turtles	189	0.64	139	0.52	174

A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 16. Distances to SEL_{24h} based fish criteria in the water column.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1		Scenario 2	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	0.02	3.04	0.02	2.72
II, fish eggs and fish larvae	210	0.02	3.93	0.04	12.1
III	207	0.02	3.93	0.06	17.0
Fish recoverable injury					
I	216	0.02	3.93	0.02	3.73
II, III	203	0.03	9.19	0.10	33.1
Fish TTS					
I, II, III	186	5.86	1567	3.06	896

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Table 17. Distances to SEL_{24h} based fish criteria at the seafloor.

Marine fauna group	Threshold for SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Scenario 1		Scenario 2	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury					
I	219	*	*	*	*
II, fish eggs and fish larvae	210	*	*	0.04	10.2
III	207	*	*	0.06	16.3
Fish recoverable injury					
I	216	*	*	*	*
II, III	203	*	*	0.1	33.0
Fish TTS					
I, II, III	186	5.86	1552	2.88	862

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.
An asterisk indicates that the threshold was not reached.

5.3.2. Sound field maps

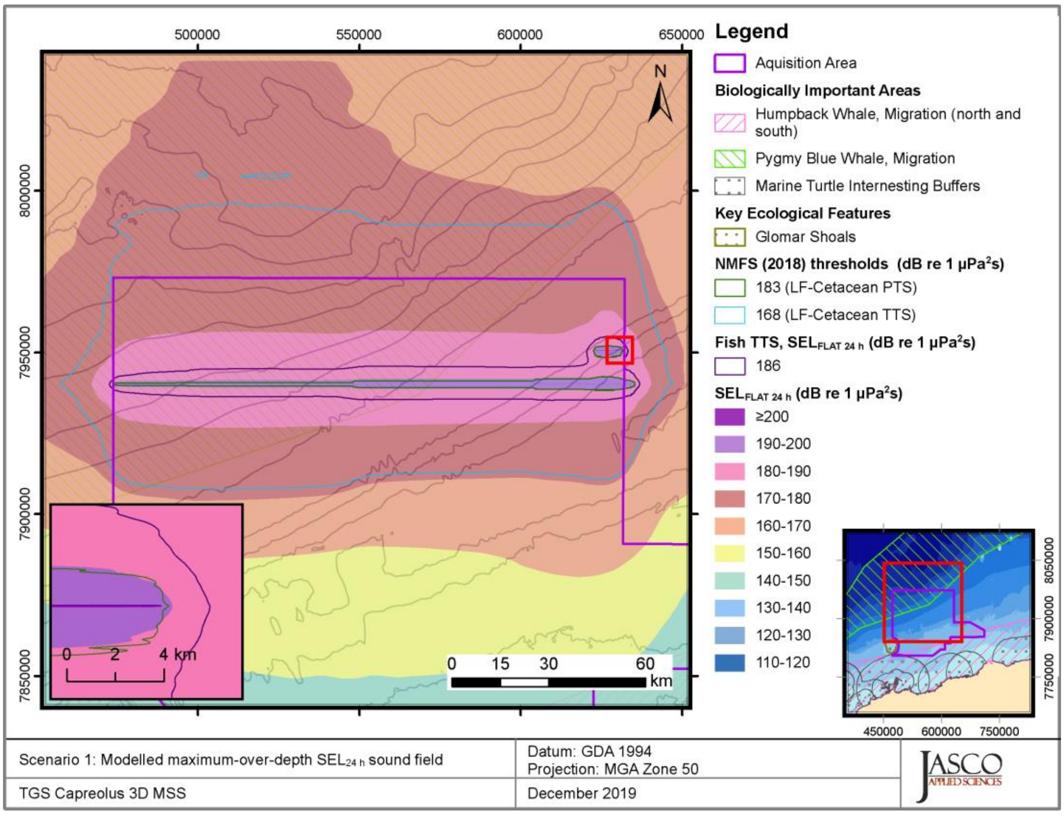

Figure 25. *Scenario 1:* Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetaceans and fish TTS. Thresholds for mid-frequency cetacean PTS were not reached.

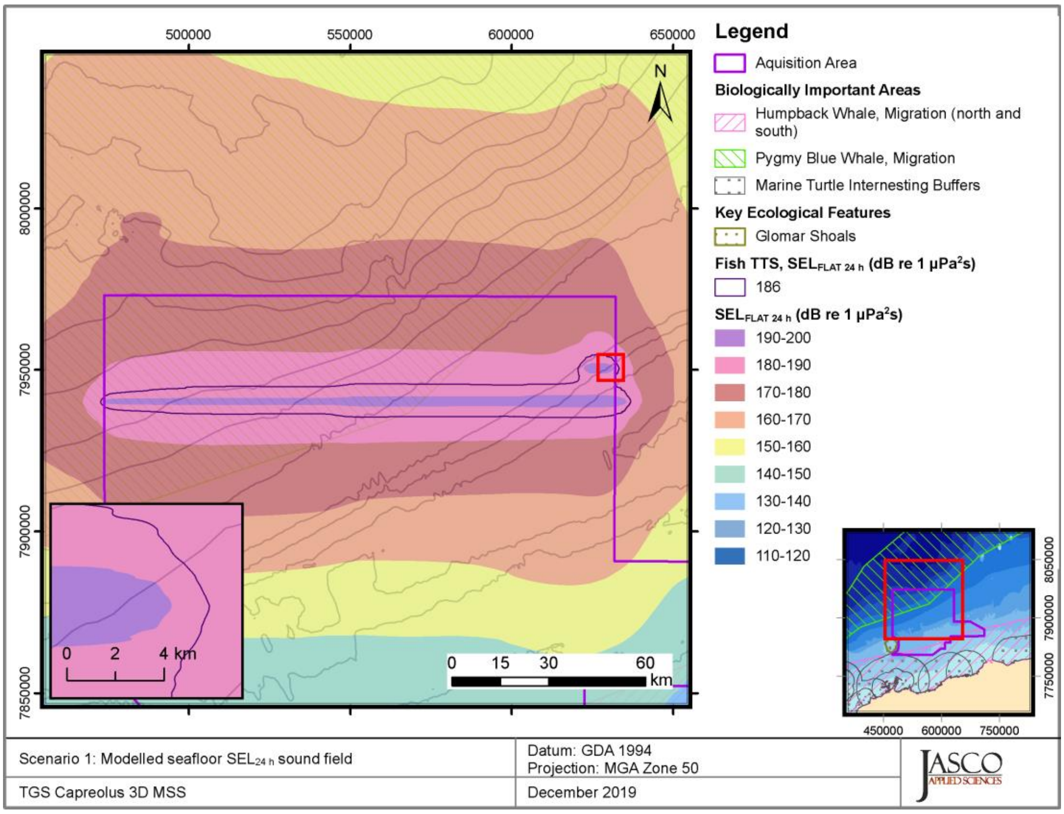

Figure 26. *Scenario 1:* Sound level contour map showing unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS.

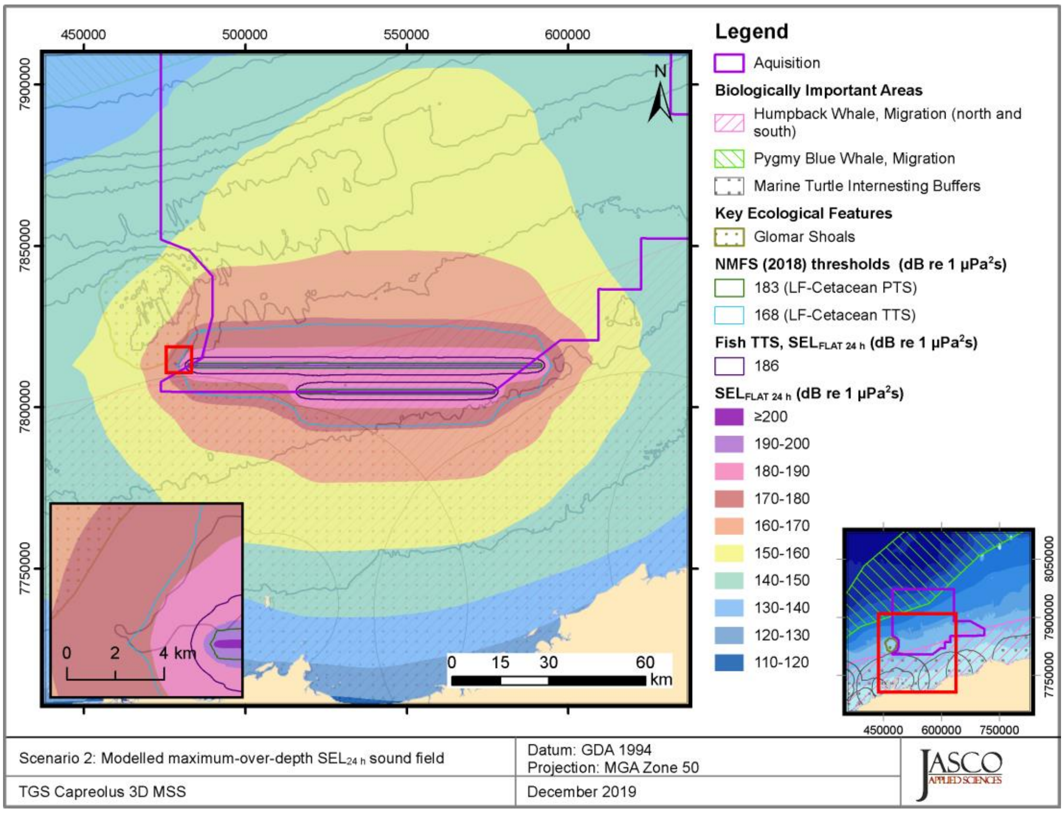

Figure 27. *Scenario 2*: Sound level contour map showing unweighted maximum-over-depth SEL_{24h} results, along with isopleths for low-frequency cetacean PTS, TTS and fish TTS. Thresholds for mid-frequency cetacean PTS were not reached.

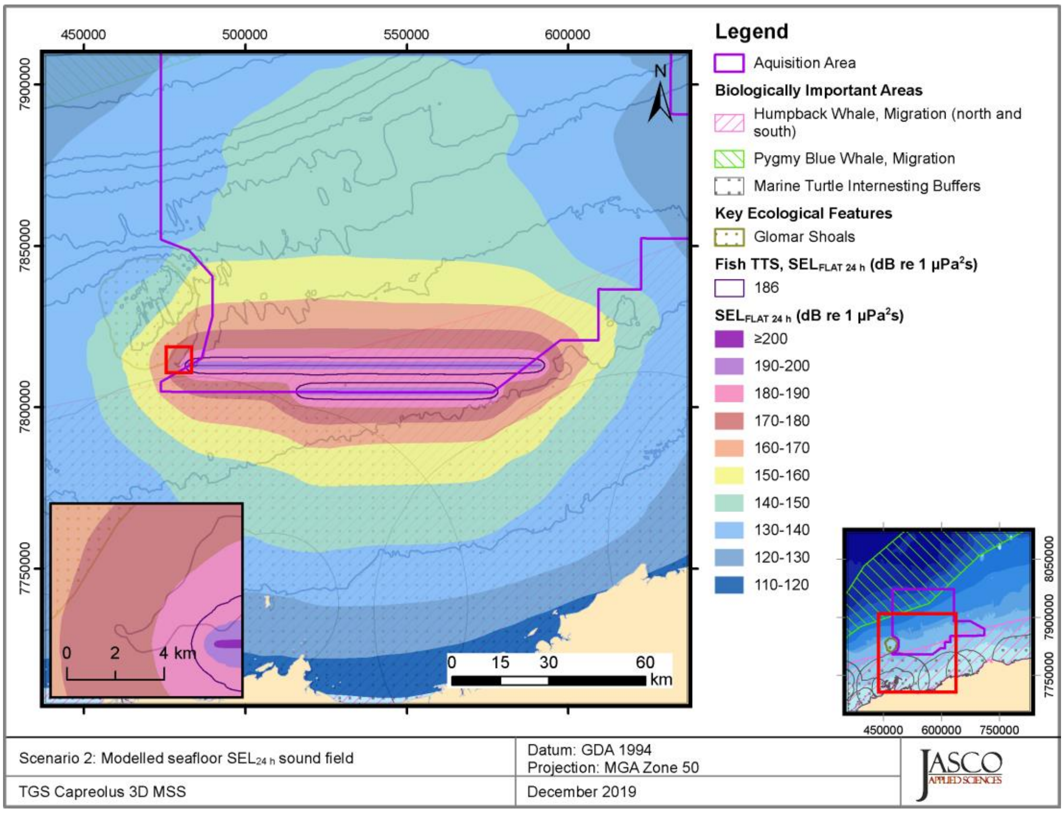

Figure 28. *Scenario 2:* Sound level contour map showing unweighted seafloor SEL_{24h} results, along with the isopleth for fish TTS.

5.3.3. Accumulated levels at static receivers

To provide further assessment of the influence of accumulated sound levels on fish, unweighted sound exposure levels were modelled at static receivers at perpendicular offsets from the closest survey line in each of the two considered 24-hour scenarios, see Figures 2 and 3 for receiver location relative to survey lines. Accumulated and per-pulse SEL were extracted at a subset of considered receiver distances for plotting purposes.

The results are presented in Figure 29 for Scenario 1 and Figure 30 for Scenario 2, fourteen receiver offset distances out of the seventy one considered (0.1, 0.25, 0.5, 1.0, 2.0, 3.0, 5.0, 10.0, 15.0, 20.0, 25.0, and 30.0 km) were plotted as a function of time on a common graph. The notable gaps in per-pulse levels are associated the vessel turning, and run-ins, during which the source was not in operation for modelling purposes.

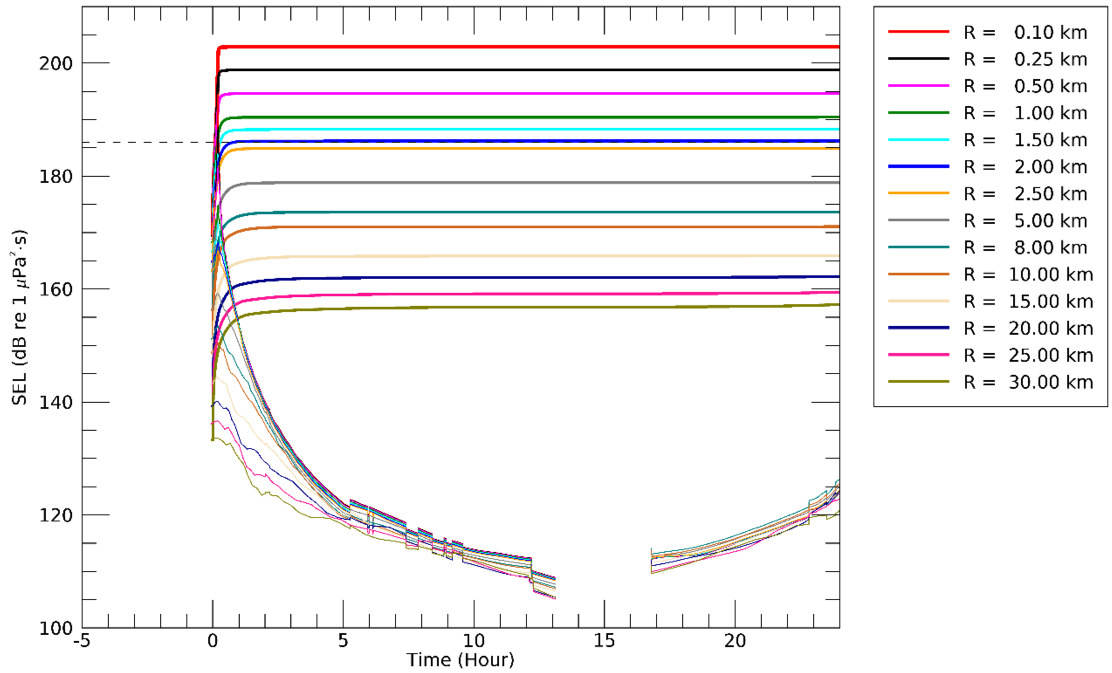

Figure 29. Scenario 2, Receiver Set 1: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 μPa^2·s.

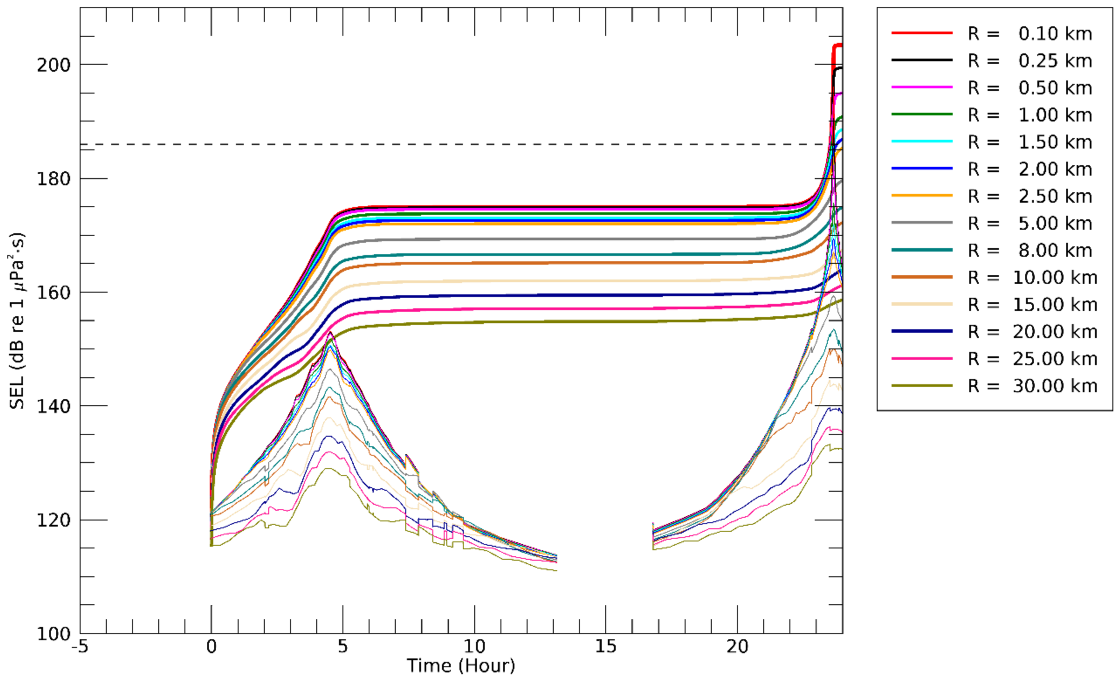

Figure 30. Scenario 2, Receiver Set 2: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 μPa^2·s.

The accumulated SEL results are also presented for several different time windows centred around periods corresponding to CPA. Table 18 shows the estimated isopleth ranges based on the static receiver locations to the fish TTS threshold of 186 dB re 1 μPa^2·s for water column and seafloor receptors for Scenario 1 and Scenario 2. The ranges presented below were estimated by interpolating the receiver range where received levels drop below the threshold. Since all receiver locations were defined as perpendicular to survey lines, they represent an estimate of the perpendicular distance from the survey line to the relevant threshold; however, they are particular to that specific point along the line. The range for the full 24 h accumulated SEL, estimated by the same method, is also provided for comparison.

Figures 31 and 32 show the per-pulse SEL and SEL accumulated in the considered time windows around the CPA maxima as an example of the method described above.

Table 18. Distances to maximum-over-depth and seafloor static receiver SEL_{24h} based fish TTS criteria for the time windows for the considered receiver locations.

Marine fauna group	SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	Static Receiver	Distance (km)				
			1 h	2 h	3 h	4 h	24 h
Scenario 1							
Fish TTS I, II, III	186	Maximum-over-depth	1.97	2.04	2.05	2.05	2.06
		Seafloor	1.96	2.03	2.04	2.04	2.04
Scenario 2							
Fish TTS I, II, III	186	Maximum-over-depth	2.09	2.15	2.16	2.17	2.25
		Seafloor	2.06	2.11	2.12	2.13	2.17

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

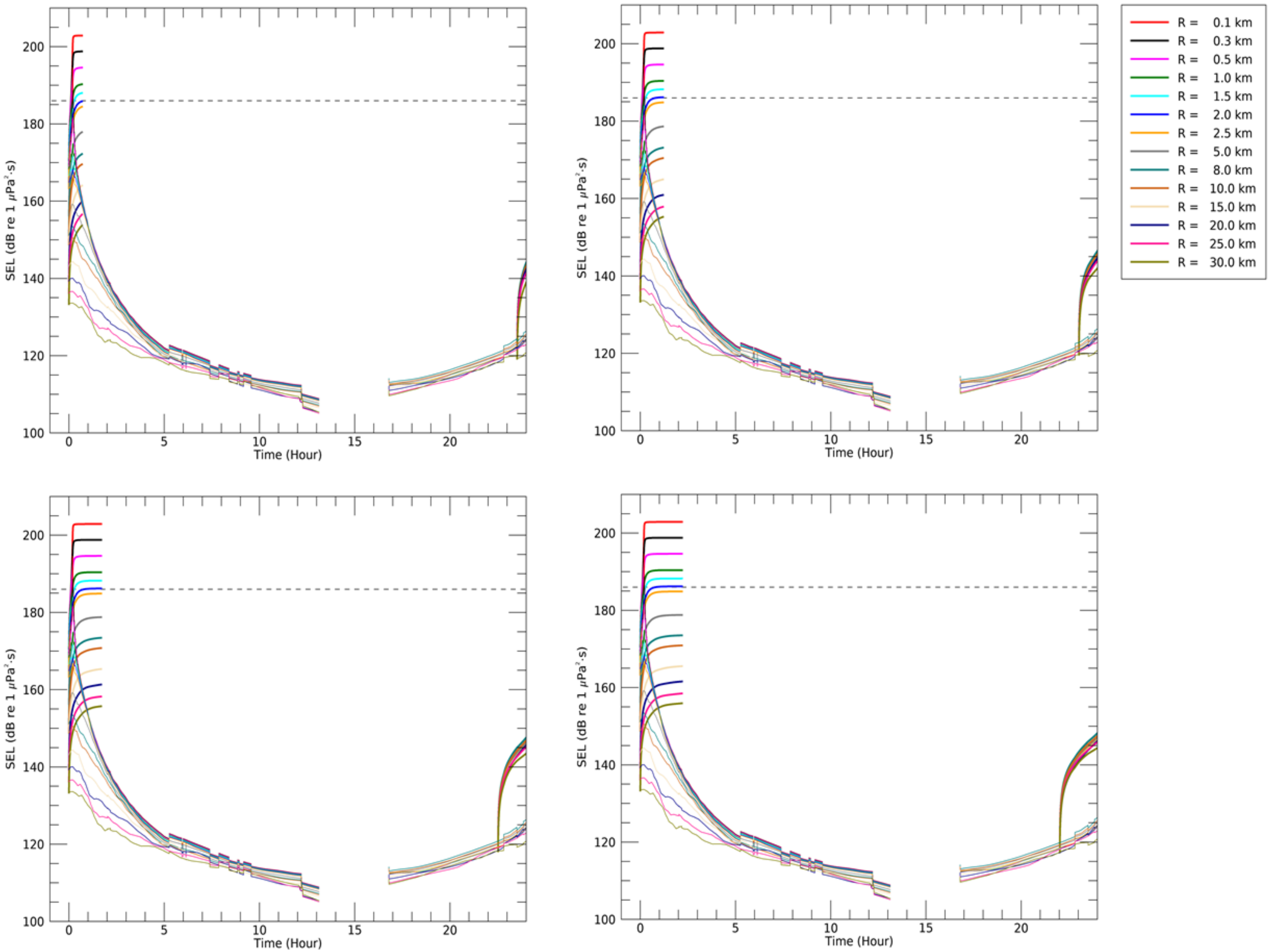

Figure 31. *Scenario 1*: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines (Figure 2). Clockwise from top-left the plots show accumulation over a 1, 2, 3, and 4 h window around the CPA, respectively. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 μPa^2·s.

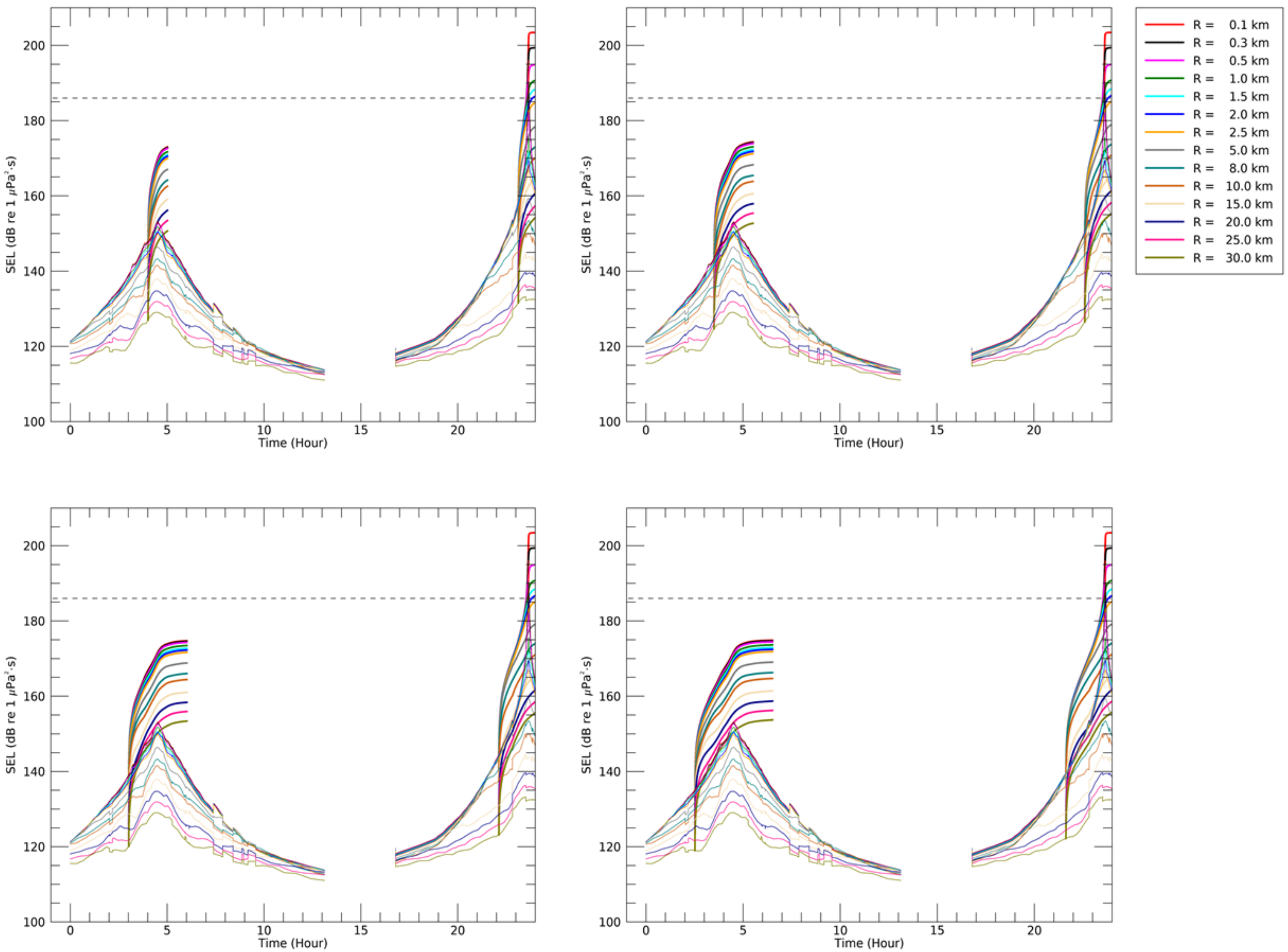

Figure 32. *Scenario 2*: Maximum-over-depth per-pulse unweighted SEL (thin lines) and accumulated unweighted SEL (thick lines) for fourteen receivers (denoted by R) located at increasing distance from the survey lines (Figure 2). Clockwise from top-left the plots show accumulation over a 1, 2, 3, and 4 h window around the CPA, respectively. Gaps in the per-pulse curves correspond to vessel turns. The horizontal black dashed line corresponds to the fish TTS threshold of 186 dB re 1 μPa^2·s.

6. Discussion

This modelling study predicted underwater sound levels associated with the planned Capreolus-2 3D MSS. The underwater sound field was modelled for a 3480 in^3 seismic source (Appendix B), selected as a worst-case option based on a comparison of four seismic sources, which were considered for operation within the survey Operational Area (Appendix E).

An analysis of seasonal sound speed profiles, the results of which are presented in Appendix D.3.2, indicated that June was the month most conducive to sound propagation due to the presence of a upward refracting layer near the sea surface; as such it was used to ensure a conservative estimation of distances to received sound level thresholds over the potential survey periods. Modelling also accounted for site-specific bathymetric variations (Appendix D.3.1) and local geoacoustic properties (Appendix D.3.3).

Most acoustic energy from a seismic source occurs at lower frequencies, in the tens to hundreds of hertz. The modelled 3480 in^3 array had a pronounced broadside directivity for 1/3-octave-bands between ~158 to 251 Hz (Appendix B.2), which caused a noticeable axial bulge in the modelled acoustic footprints.

The overall broadband (10–25000 Hz) unweighted per-pulse SEL source level of the 3480 in^3 seismic source operating at 6 m depth was 225.3 dB 1 μPa^{2}m^{2}s in the broadside direction and 225.2 dB 1 μPa^{2}m^{2}s in the endfire direction. The peak pressure level in the same directions was 248.6 and 247.5 dB re 1 μPa m, respectively (Table 8).

6.1. Per-Pulse Sound Fields

The selected sound speed profiles (Figures D-7 and D-8) for June were primarily downward refracting apart from a slight upward refracting layer, which extended to approximately 60–70 m from the sea surface. This layer has the potential to trap high frequency energy near the sea surface that would otherwise dissipate more rapidly in range due to propagation, absorption, and seabed losses. The slight upward refracting layer in the sound speed profile only has the potential to effective trap frequencies above 320 or 403 Hz based on the thickness of the refracting layer (Jensen et al. 2011).

The Acquisition Area of the Capreolus-2 3D MSS covers a large and significant geographic footprint of the Australian North West Shelf region. Due to this large area, the selected scenarios and associated modelled sites are in two significantly different environments. The per-pulse modelling sites encompassed water depths from 47 to 567 m across two different geological areas and water column profiles. The bathymetry within Acquisition Area varied between 50–1250 m over a 180 km northern transect the southern edge of the Acquisition Area. Furthermore, along a northward transect the environment generally transitions from the shallow waters of the continental shelf into deeper waters of the continental slope.

The array directionality and frequency content coupled with the bathymetry had a considerable effect on propagation at longer distances, with larger lobes of sound energy extending into the deeper waters at all modelling sites. This is particularly evident for modelled Sites 1–4 which are situated near the northern the edge of the survey area, along the continental shelf break and continental slope. The maximum-over-depth sound footprint maps and vertical slice plots (Sections 5.2.2.1 and 5.2.2.2) assist in demonstrating the influence of the bathymetry and seabed composition on the sound field.

For the sites modelled in shallow water (less than 100 m depth, Sites 5–9) where the seabed was modelled as a 5 m thick sand layer underlain by cemented limestone (calcarenite), the predicted levels were generally high near and directly below the seismic source as compared to sites in deeper water over the thicker layers of unconsolidated sediment (Sites 1–4). Sites in shallow water over the sand and cemented limestone seabed generally displayed higher rates of loss at distance away from the source as compared to sites located deep water over thick layers of unconsolidated sediment.

The sand layer underlain by cemented limestone seabed is more reflective at steep grazing angles (short ranges) but more absorptive at shallow grazing angle (long ranges). This resulted in smaller isopleths for lower thresholds but slightly larger isopleths for high level thresholds when compared to a more typical unconsolidated sediment dominated seabed (see single impulse isopleth radii in

Tables 9 and 10). This is mainly a consequence of different water depth and seabed composition (i.e. geoacoustic profiles) for the considered modelled sites.

The distances to PK and PK-PK based criteria (Section 3.2 and 3.3) for fish, benthic crustaceans, and bivalves at the seafloor are provided in Tables 13 and 14. The distances to these criteria did not always consistently change with increasing depth as any correlation between water depth and threshold distance is related to patterns of surface and seabed reflections that affect how sound propagates in shallow water. However, the number of modelled sites and water depths considered within the Acquisition Area, provides a good representation of potential variability for seabed receptors.

6.2. Particle Motion

Section 5.2.3 discuss the relevance of particle motion (acceleration) to benthic invertebrates. Particle acceleration decays rapidly away from the source location within the distance equal to half the water depth. It is then influenced by shallow water propagation effects, such as constructive interference from sea-surface and seabed reflections. This resulted in up to 10 ms^{-2} variation in predicted levels out to two water depths, Beyond this distance, it exhibited an almost linear decay (Figures 22–24).

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

Day et al. (2016a) and Day et al. (2016b) included a regression of particle acceleration versus range for the single 150 in^3 airgun used in their study (minimum range of 6 m) and showed that acceleration at 10 and 100 m range was typically 26 and 5 ms^{-2}, respectively. Day et al. (2016a) and Day et al. (2016b) also referenced an unpublished maximum particle acceleration measurement of 6.2 ms^{-2} from a 3130 in^3 airgun array at 477 m range in 36 m of water. In our study, modelled peak acceleration at 10 m range was predicted to be between 21.8 and 47.5 ms^{-2} depending on the site; corresponding values at 100 m range are between 11.4 and 19.2 ms^{-2}. At ~477 m, our study predicts acceleration ranging between 4.5–6.7 ms^{-2} in the broadside directions. These result aligns with the measurements reported in Day et al. (2016a) and Day et al. (2016b) thus represents what is likely to occur.

The maximum distance to a particle acceleration of the closest value to 37.57 ms^{-2}, determined for comparing literature, (Section 3.3; Day et al. (2016a), Day et al. (2016b)) is 32 m.

6.3. Multiple Pulse Sound Fields

The accumulated SEL over 24 hours of seismic source operation was modelled considering two representative scenarios with realistic acquisition patterns for the Capreolus-2 3D MSS. The modelling predicted the accumulation of sound energy, considering the change in location and the azimuth of the source at each pulse point, which were used to assess possible injury in marine mammals and the SEL_{24h} based fish and marine mammal criteria. The results were presented as maps of the accumulated exposure levels and tabulated values of ranges to threshold levels and exposure areas for the given effects criteria (Section 3).

The footprints and range maxima for all accumulated SEL thresholds are influenced by the different seabed compositions across acquisition lines. The discussion above regarding ranges to isopleths also applies to the accumulated SEL calculations. In general, the largest isopleth radii occur when the broadside direction of the array aligns with deepening waters in the offshore direction, see Figures 25 and 27 for examples.

6.3.1. Time histories and accumulated levels at static receivers

Sound exposure levels were also modelled at static receivers located at various offset distances from the closest survey line in each of the two scenarios (Figures 29 and 30). This provides a sense for the accumulation of acoustic energy as the seismic source acquires multiple lines over a 24 h period. The resulting time histories of accumulated SEL show that the single nearest pass of the seismic source(s) to a receiver (represented by the few hours [1–4 h windows] when sound exposure levels are at their greatest) will account for the majority of exposure over the 24 h period regardless of whether it occurs earlier or later, and additional passes after that one nearest exposure event will not add appreciably to the total level. This is particularly evident in Figure 29, where the static receivers are located near the beginning of 24 h scenario line.

The time history of the accumulated and per-pulse SEL depends on the spatial offset between source and receiver points; as well as, the shape and extent of the isopleths for each single impulse sites, which depend on the local environmental properties. The per-pulse time histories are sensitive to the single impulse site isopleths, which can lead to local 'jumps' in the shape of the curves when the local environmental properties differ between adjacent impulses. This is due to the approach of using a discrete number of modelled sites to represent the 13780 or 13590 individual impulse sites within each scenario. However, for the accumulated SEL time histories, as well as the 24 h SEL assessments, larger scale sound propagation features dominated the accumulated and cumulative field as indicated by the smooth accumulated SEL time history curves.

An examination of the accumulation of sound exposure in 1–4 h windows centred around the CPA for both Scenarios (Table 18 and Figures 31 and 32), illustrates the influence of water depth and receiver location on the results. In all cases, there was no significant difference between the TTS range between the 1–4 h windows around the CPA. Considering how the sound exposure is accumulated as discussed above, due to the line spacing and nominal acquisition plan considering in the modelled scenario, the TTS threshold for fish was only exceeded at receivers when the source was active along the most proximal line. This occurred within the maximum predicted TTS range.

Given the considerations in Popper (2018) for types of fish that are assumed to not move away from a surveying vessel and therefore experience TTS, accumulation of energy over longer periods than a few hours is likely inappropriate. For the receiver locations selected, only one high-level exposure will likely occur per 24 h. For the scenarios considered, the ranges to TTS with only a 1–4 h window is more biologically appropriate, and these distances would therefore relate only to one acquisition line. For these fish, recovery could begin a few hours after exposure (not considering the time between pulses). In the considered scenarios, if these fish remained stationary, they are not predicted to experience another high-level exposure until the next most proximal pass of the source.

6.4. Summary

The study findings pertaining to each metric and criteria for various marine species of interest are summarised below with references to the result location.

Marine mammal injury and behaviour

- The maximum distance where the NMFS (2014) marine mammal behavioural response criterion of 160 dB re 1 µPa (SPL) could be exceeded varied between 4.32 and 9.56 km (Site 7 and Site 3), provided in Table 10.
- The results for the criteria applied for marine mammal Permanent Threshold Shift (PTS), NMFS (2018), consider both metrics within the criteria (PK and SEL_{24h}). The longest distance associated with either metric is required to be applied. Table 19 summarises the maximum distances for PTS, along with the relevant metric and the location of the results within this report; the farthest SEL distances were associated with Scenario 1, in deeper water.
- The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. The corresponding SEL_{24h} radii for low-frequency cetaceans were larger than those for peak pressure criteria, but they represent an unlikely worst-case scenario. More realistically, marine mammals (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius for SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with injury (either PTS or TTS) if it remained in that location for 24 hours.

Table 19. Summary of maximum marine mammal PTS onset distances for modelled scenarios (PK values from Table 11 and SEL_{24h} values from Table 15)

Hearing group	Scenario 1		Scenario 2	
	Metric associated with longest distance to PTS onset	R_{max} (km)	Metric associated with longest distance to PTS onset	R_{max} (km)
Low-frequency cetaceans†	SEL_{24h}	2.34	SEL_{24h}	0.76
Mid-frequency cetaceans	—	—	—	—
High-frequency cetaceans	PK	0.22	PK	0.42

† The model does not account for shutdowns.
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m).

Turtles

- The PK turtle injury criteria of 232 dB re 1 µPa for PTS and 226 dB re 1 µPa for TTS from Finneran et al. (2017) was not exceeded at a distance longer than 20 m (horizontal modelling resolution for FWRAM) from the acoustic centre of the source.
- The maximum distance to the SEL_{24h} metric was 60 m for PTS onset and 0.64 km for TTS onset (Finneran et al. 2017). As is the case with marine mammals, a reported radius for SEL_{24h} criteria does not mean that turtles travelling within this radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- Table 20 summarises the distances to where the NMFS criterion (NSF 2011) for behavioural response of turtles to the 166 dB re 1 µPa (SPL) and the 175 dB re 1 µPa (SPL) threshold for behavioural disturbance (McCauley et al. 2000b, McCauley et al. 2000a) could be exceeded.

Table 20. Summary of distances to turtle behavioural response criteria (from Table 10).

SPL (L_p; dB re 1 µPa)	Distance (km)	
	Minimum	Maximum
175†	1.02	1.7
166‡	2.3	5.08

† Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000b, McCauley et al. 2000a).
‡ Threshold for turtle behavioural response to impulsive noise (NSF 2011).

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for quantitative criteria based on Popper et al. (2014) and considered both PK (seafloor and water column) and SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:
    - Fish without a swim bladder (also appropriate for sharks in the absence of other information)
    - Fish with a swim bladder that do not use it for hearing
    - Fish that use their swim bladders for hearing
    - Fish eggs and fish larvae
- Table 21 summarises the distances to injury criteria for fish, fish eggs, and fish larvae along with the relevant metric and the location of the information within this report. This summary only presents the 24 h SEL results, rather than those considering the alternate time windows presented in Section 5.3.3 and discussed in Section 6.3.

Table 21. Summary of maximum fish, fish eggs, and larvae injury and TTS onset distances for single impulse and SEL_{24h} modelled scenarios (PK values from Tables 11 and 13 and SEL_{24h} values from Tables 16 and 17).

Relevant hearing group	Effect criteria	Water column		Seafloor	
		Metric associated with longest distance to criteria	R_{max} (km)	Metric associated with longest distance to criteria	R_{max} (km)
Fish: No swim bladder	Injury	PK	0.06	PK	0.09
	TTS	SEL_{24h}	5.86	SEL_{24h}	5.86
Fish: Swim bladder not involved in hearing and Swim bladder involved in hearing	Injury	PK	0.24	SEL_{24h}	0.16
	TTS	SEL_{24h}	5.86	SEL_{24h}	5.86
Fish eggs, and larvae	Injury	PK	0.24	PK	0.16

Benthic invertebrates, Coral, and Plankton

To assist with assessing the potential effects on these receptors, the following were determined:

- Bivalves: The distance where a particle acceleration of 37.57 ms^{-2} at the seafloor could occur was determined for comparing to results presented in Day et al. (2016a). The maximum distance to this particle acceleration level was 32 m (Section 5.2.3).
- Crustaceans: The sound level of 202 dB re 1 µPa PK-PK from Payne et al. (2008) was considered for seafloor sound levels; the sound level was reached at ranges between 446 and 588 m depending on the modelled site (Table 14).
- Sponges and coral: The PK sound level at the seafloor directly underneath the seismic source was estimated at all modelled sites and compared to the sound level of 226 dB re 1 µPa PK for sponges and corals (Heyward et al. 2018); the threshold was reached within a 8 m horizontal range from the acoustic centre of the source at the shallowest modelled site, at 47 m water depths (Table 13).
- Plankton: The distance to the sound level of 178 dB re 1 µPa PK-PK from McCauley et al. (2017) was estimated at all modelled sites through full-waveform modelling using FWRAM; the results ranged from 7.90 to 14 km (Table 12).

Glossary

1/3-octave
One third of an octave. Note: A one-third octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec; ISO 2017).

1/3-octave-band
Frequency band whose bandwidth is one one-third octave. Note: The bandwidth of a one-third octave-band increases with increasing centre frequency.

90%-energy time window
The time interval over which the cumulative energy rises from 5 to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

broadside direction
Perpendicular to the travel direction of a source. Compare with endfire direction.

cavitation
A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of noise.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. See also broadside direction.

ensonified
Exposed to sound.

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

hearing group
Groups of marine mammal species with similar hearing ranges. Commonly defined functional hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

geoacoustic
Relating to the acoustic properties of the seabed.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency (HF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for hearing high frequencies.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic airguns and impact pile driving.

low-frequency (LF) cetacean
The functional cetacean hearing group that represents mysticetes (baleen whales) specialized for hearing low frequencies.

mean-square sound pressure spectral density
Distribution as a function of frequency of the mean-square sound pressure per unit bandwidth (usually 1 Hz) of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: $\mu Pa^2/Hz$.

mid-frequency (MF) cetacean
The functional cetacean hearing group that represents those odontocetes (toothed whales) specialized for mid-frequency hearing.

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

parabolic equation method
A computationally efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

particle acceleration
The rate of change of particle velocity. Unit: meters per second squared (m/s^2). Symbol: *a*.

peak pressure level (PK)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak pressure level. Unit: decibel (dB).

peak-to-peak pressure level (PK-PK)
The difference between the maximum and minimum instantaneous pressure levels. Unit: decibel (dB).

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive noise exposure. PTS is considered auditory injury.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

received level (RL)
The sound level measured (or that would be measured) at a defined location.

rms
root-mean-square.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second ($Pa^2 \cdot s$) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 $\mu Pa^2 \cdot s$. SEL is expressed over the summation period (e.g., per-pulse SEL [for airguns], single-strike SEL [for pile drivers], 24-hour SEL).

sound exposure spectral density
Distribution as a function of frequency of the time-integrated squared sound pressure per unit bandwidth of a sound having a continuous spectrum (ANSI S1.1-1994 R2004). Unit: $\mu Pa^2 \cdot s/Hz$.

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound intensity
Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound level measured in the far-field and scaled back to a standard reference distance of 1 metre from the acoustic centre of the source. Unit: dB re 1 µPa m (pressure level) or dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ (exposure level).

spectral density level
The decibel level ($10 \cdot \log_{10}$) of the spectral density of a given parameter such as SPL or SEL, for which the units are dB re 1 $\mu Pa^2/Hz$ and dB re 1 $\mu Pa^2 \cdot s/Hz$, respectively.

spectrum
An acoustic signal represented in terms of its power, energy, mean-square sound pressure, or sound exposure distribution with frequency.

surface duct
The upper portion of a water column within which the sound speed profile gradient causes sound to refract upward and therefore reflect off the surface resulting in relatively long-range sound propagation with little loss.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive noise exposure.

thermocline
The depth interval near the ocean surface that experiences temperature gradients due to warming or cooling by heat conduction from the atmosphere and by warming from solar heating.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also referred to as propagation loss.

wavelength
Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow the American National Standard Institute and International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI R2013), but these standards are not always consistent.

The zero-to-peak sound pressure, or peak sound pressure (PK or $L_{p,\text{pk}}$; dB re 1 µPa), is the decibel level of the maximum instantaneous acoustic pressure in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,\text{pk}} = 10\log_{10}\frac{\max|p^2(t)|}{p_0^2} = 20\log_{10}\frac{\max|p(t)|}{p_0} \qquad \text{(A-1)}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of an acoustic event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure (PK-PK or $L_{p,\text{pk-pk}}$; dB re 1 µPa) is the difference between the maximum and minimum instantaneous sound pressure, possibly filtered in a stated frequency band, attained by an impulsive sound, $p(t)$:

$$L_{p,\text{pk-pk}} = 10\log_{10}\frac{[\max(p(t)) - \min(p(t))]^2}{p_0^2} \qquad \text{(A-2)}$$

The sound pressure level (SPL or L_p; dB re 1 µPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\, p^2(t)\, dt \Big/ p_0^2\right) \qquad \text{(A-3)}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function. For short acoustic events, such as sonar pulses and marine mammal vocalizations, it is important to choose an appropriate time window that matches the duration of the signal. For in-air studies, when evaluating the perceived loudness of sounds with rapid amplitude variations in time, the time weighting function $g(t)$ is often set to a decaying exponential function that emphasizes more recent pressure signals. This function mimics the leaky integration nature of mammalian hearing. For example, human-based fast time-weighted SPL ($L_{p,\text{fast}}$) applies an exponential function with time constant 125 ms. A related simpler approach used in underwater acoustics sets $g(t)$ to a boxcar (unity amplitude) function of width 125 ms; the results can be referred to as $L_{p,\text{boxcar 125ms}}$. Another approach, historically used to evaluate SPL of impulsive signals underwater, defines $g(t)$ as a boxcar function with edges set to the times corresponding to 5% and 95% of the cumulative square pressure function encompassing the duration of an impulsive acoustic event. This calculation is applied individually to each impulse signal, and the results have been referred to as 90% SPL ($L_{p,90\%}$).

The sound exposure level (SEL or L_E; dB re 1 µPa²·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt \middle/ T_0 p_0^2\right) \tag{A-4}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}} \tag{A-5}$$

Because the SPL(T_{90}) and SEL are both computed from the integral of square pressure, these metrics are related numerically by the following expression, which depends only on the duration of the time window T:

$$L_p = L_E - 10\log_{10}(T) \tag{A-6}$$

$$L_{p90} = L_\mathrm{E} - 10\log_{10}(T_{90}) - 0.458 \tag{A-7}$$

where the 0.458 dB factor accounts for the 10% of pulse SEL missing from the SPL(T_{90}) integration time window.

Energy equivalent SPL (L_eq; dB re 1 µPa) denotes the SPL of a stationary (constant amplitude) sound that generates the same SEL as the signal being examined, $p(t)$, over the same time period, T:

$$L_\mathrm{eq} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)\,dt \middle/ p_0^2\right) \tag{A-8}$$

The equations for SPL and the energy-equivalent SPL are numerically identical. Conceptually, the difference between the two metrics is that the SPL is typically computed over short periods (typically of one second or less) and tracks the fluctuations of a non-steady acoustic signal, whereas the L_eq reflects the average SPL of an acoustic signal over time periods typically of one minute to several hours.

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,\mathrm{LF,24h}}$; see Appendix A.4) or auditory-weighted SPL ($L_{p,\mathrm{ht}}$). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

In the present report, audiogram-weighted, fast-averaged SPL ($L_{p,\mathrm{ht,F}}$) is defined by the exponential function from Plomp and Bouman (1959):In the present report, audiogram-weighted, fast-averaged SPL ($L_{p,\mathrm{ht,F}}$) is defined by the exponential function from Plomp and Bouman (1959):

$$L_{p,\mathrm{ht}} = L_{E,\mathrm{ht,per\text{-}pulse}} - 10\log_{10}(d/0.9)\,,$$
$$L_{p,\mathrm{ht,F}} = L_{p,\mathrm{ht}} + 10\log_{10}\frac{1-e^{-d/\tau}}{1-e^{-T/\tau}} \tag{A-9}$$

where d is the duration in seconds, τ is the time constant of 0.125 s representing marine mammal auditory integration time, $L_{p,\mathrm{ht}}$ is the audiogram-weighted SPL over pulse duration, and T is the pulse repetition period. This metric accounts for the hearing sensitivity of specific species through frequency weighting, and results in reduced perceived loudness (i.e., sensation level) for pulses shorter than auditory integration time (τ).

A.2. Particle Acceleration and Velocity Metrics

Since sound is a mechanical wave, it can also be measured in terms of the vibratory motion of fluid particles. Particle motion can be measured in terms of three different (but related) quantities: displacement, velocity, or acceleration. Acoustic particle velocity is the time derivative of particle displacement, and likewise acceleration is the time derivative of velocity. For the present study, acoustic particle motion has been reported in terms of acceleration and velocity.

The particle velocity (v) is the physical speed of a particle in a material moving back and forth in the direction of the pressure wave. It can be derived from the pressure gradient and Euler's linearised momentum equation where ρ_0 is the density of the medium:

$$v = -\int \nabla p(t) dt / \rho_0 \tag{A-10}$$

The particle acceleration (a) is the rate of change of the velocity with respect to time, and it can be obtained from A-13 as

$$a = \frac{dv}{dt} = -\frac{\nabla p(t)}{\rho_0} \tag{A-11}$$

Unlike sound pressure, particle motion is a vector quantity, meaning that it has both magnitude and direction: at any given point in space, acoustic particle motion has three different time-varying components (x, y, and z). Given the particle velocity in the x, y, and z, directions, v_x, v_y, and v_z, the particle velocity magnitude $|v|$ is computed per the Pythagorean equation:

$$|v| = \sqrt{v_x + v_y + v_z} \; . \tag{A-12}$$

The magnitude of particle acceleration is calculated similarly from the particle acceleration in the x, y, and z directions.

A.3. Marine Mammal Impact Criteria

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.4). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 $\mu Pa^2 \cdot s$. 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 $\mu Pa^2 \cdot s$.

As of 2017, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018; with the criteria defined in NMFS (2018) applied in this report.

A.4. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.4.1. Marine mammal frequency weighting functions

Weighting functions are applied to the sound spectra under consideration to weight the importance of received sound levels at particular frequencies in a manner reflective of an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007). Southall et al. (2007) were first to suggest weighting functions and functional hearing groups for marine mammals. The Technical Guidance issued by NOAA (NMFS, 2018) includes weighting functions and associated thresholds, and is used in this report.

A.4.2. Frequency Weighting Functions - Technical Guidance (NMFS 2018)

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:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a \left[1+(f/f_{hi})^2\right]^b}\right)\right] \tag{A-13}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid-, and high-frequency cetaceans, phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses noise impacts on marine mammals (NMFS 2016, NMFS 2018). Table A-1 lists the frequency-weighting parameters for each hearing group; Figure A-1 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by NMFS (2018).

Hearing group	a	b	f_{lo} (Hz)	f_{hi} (kHz)	K (dB)
Low-frequency cetaceans (baleen whales)	1.0	2	200	19,000	0.13
Mid-frequency cetaceans (dolphins, plus toothed, beaked, and bottlenose whales)	1.6	2	8,800	110,000	1.20
High-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*)	1.8	2	12,000	140,000	1.36

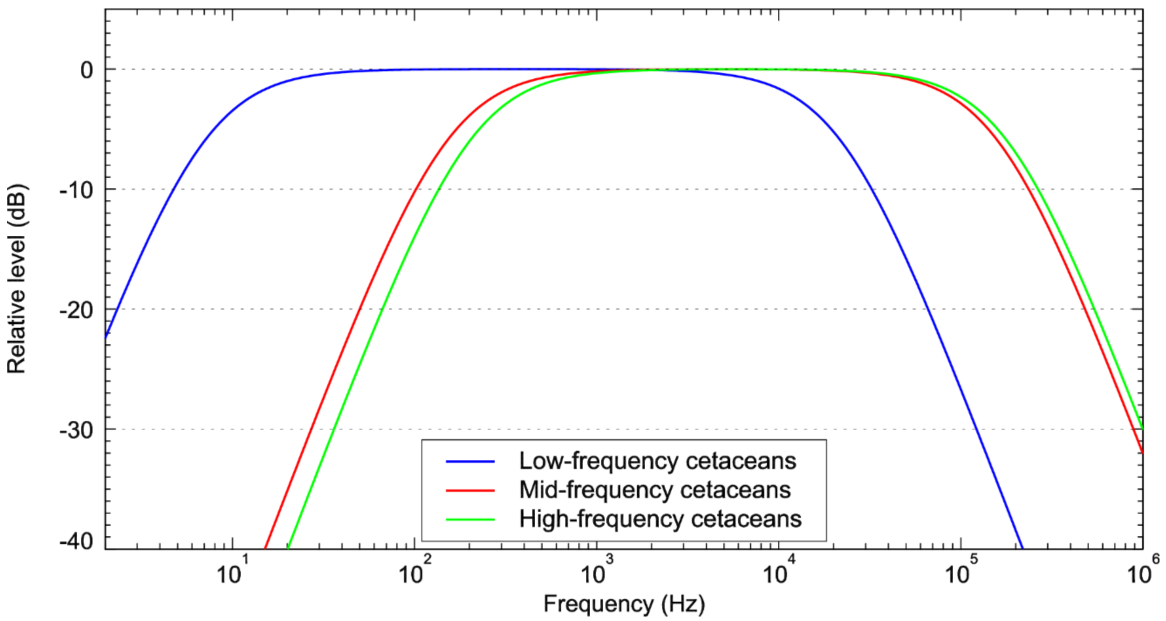


Figure A-1. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by NMFS (2018).

Appendix B. Acoustic Source Model

B.1. Airgun Array Source Model

The source levels and directivity of the seismic source were predicted with JASCO's Airgun Array Source Model (AASM). AASM includes low- and high-frequency modules for predicting different components of the seismic source spectrum. The low-frequency module is based on the physics of oscillation and radiation of airgun bubbles, as originally described by Ziolkowski (1970), that solves the set of parallel differential equations that govern bubble oscillations. Physical effects accounted for in the simulation include pressure interactions between airguns, port throttling, bubble damping, and generator-injector (GI) gun behaviour discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). A global optimisation algorithm tunes free parameters in the model to a large library of airgun source signatures.

While airgun signatures are highly repeatable at the low frequencies, which are used for seismic imaging, their sound emissions have a large random component at higher frequencies that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (800−25,000 Hz) sound emissions of individual airguns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each airgun in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict airgun source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, tow depth, and firing pressure of each airgun
- Interactions between different airguns in the array

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{\mathrm{nf}} < \frac{l^2}{4\lambda} \tag{B-1}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, a seismic source length of l = 21 m yields a near-field range of 147 m at 2 kHz and 7 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modelling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

B.2. Array Source Levels and Directivity

Figure B-1 shows the broadside (perpendicular to the tow direction), endfire (parallel to the tow direction), and vertical overpressure signature and corresponding power spectrum levels for the 3480 in^3 array considered for the survey (Appendix D.4).

Horizontal 1/3-octave-band source levels are shown as a function of band centre frequency and azimuth (Figure B-2).

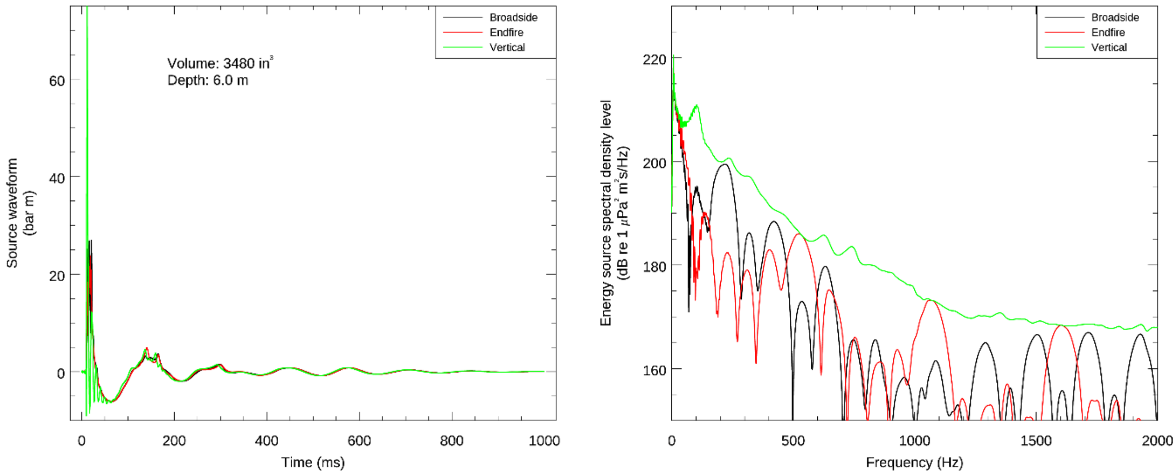


Figure B-1. Predicted source level details for the 3480 in^3 array at 6 m towed depth. (Left) the overpressure signature and (right) the power spectrum for in-plane horizontal (broadside), perpendicular (endfire), and vertical directions.

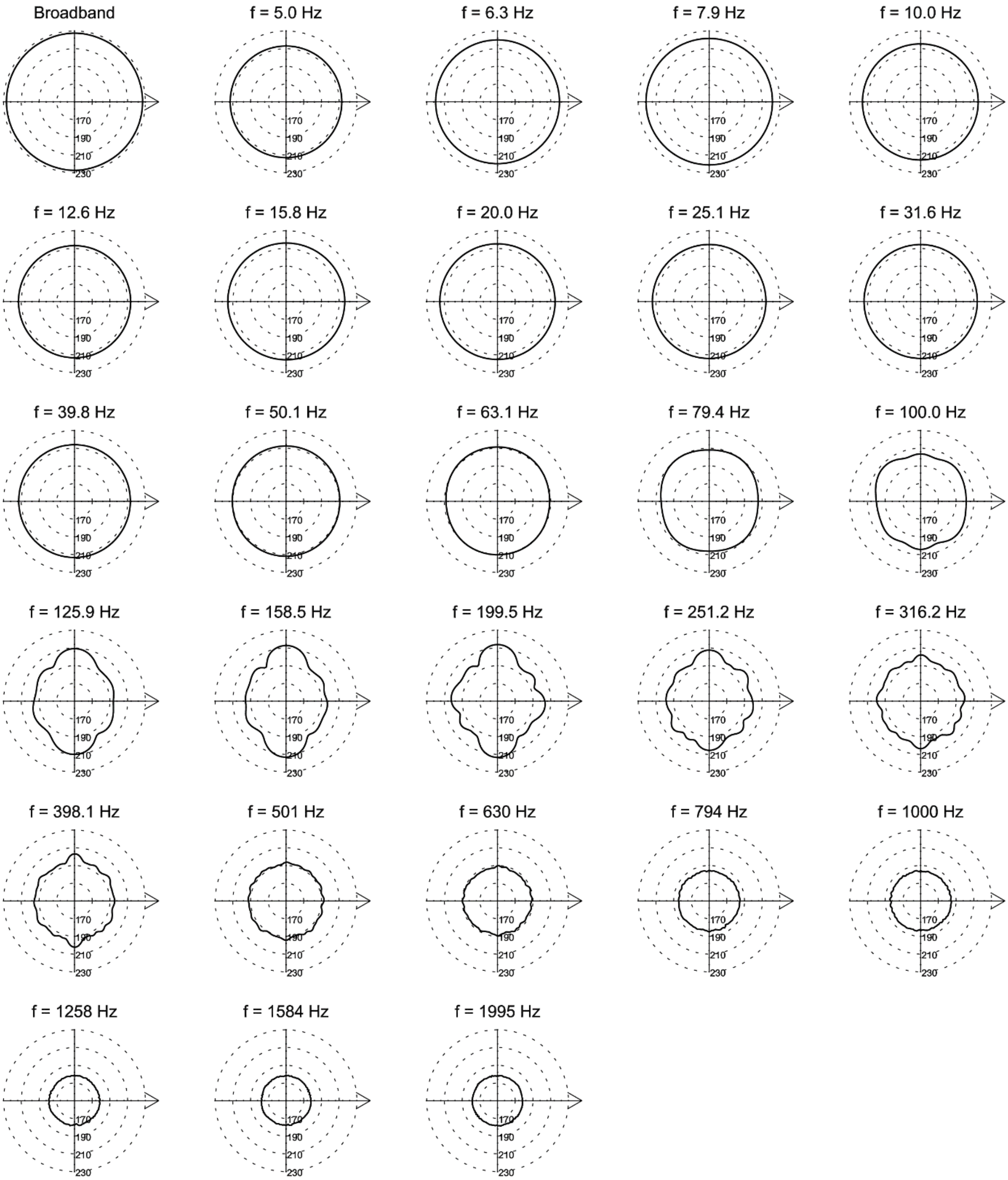


Figure B-2. Directionality of the predicted horizontal source levels for the 3480 in^3 seismic source, 5 Hz to 2 kHz. Source levels (in dB re 1 $\mu Pa^2 \cdot s\ m^2$) are shown as a function of azimuth for the centre frequencies of the 1/3-octave-bands modelled; frequencies are shown above the plots. 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).

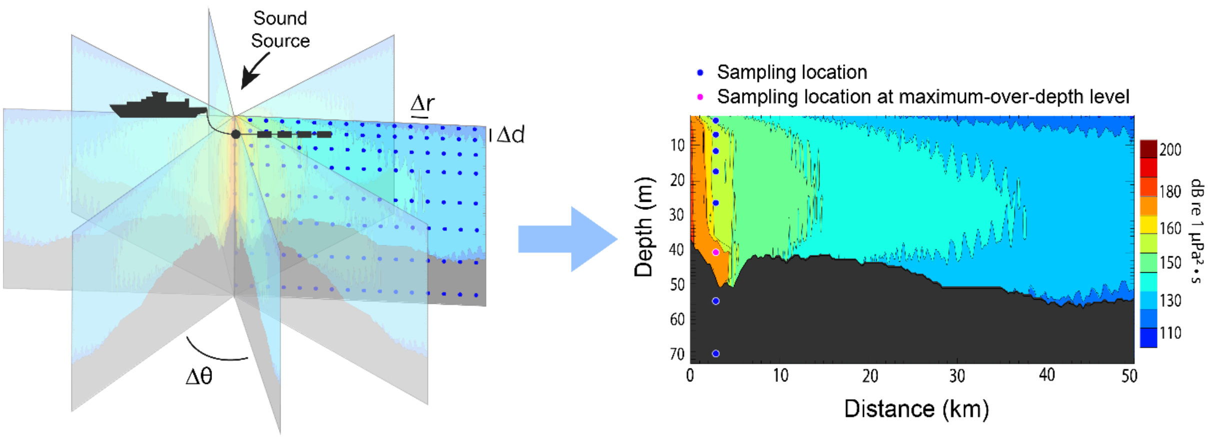


Figure C-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

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).

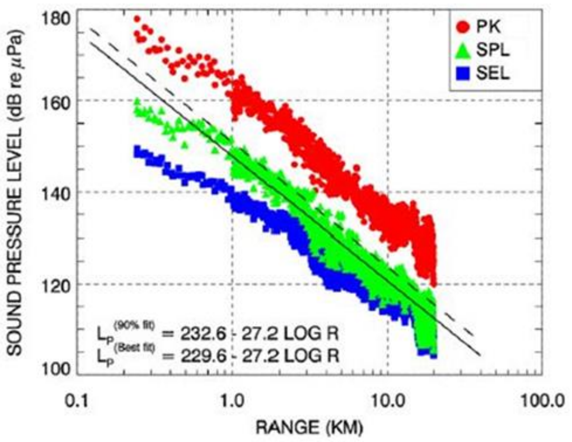


Figure C-2. PK and SPL and per-pulse SEL versus range from a 20 in^3 seismic source. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

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.

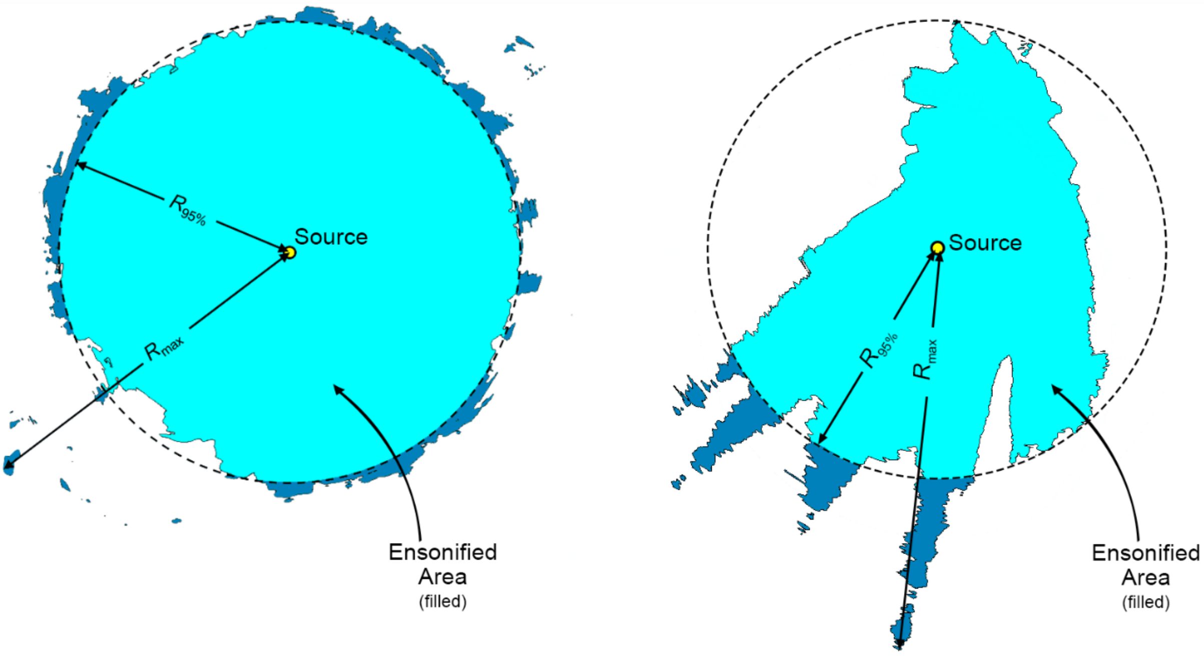
Appendix D. Methods and Parameters

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.



(a) (b)

Figure D-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two different scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

D.2. Estimating SPL from Modelled SEL Results

The per-pulse SEL of sound pulses is an energy-like metric related to the dose of sound received over a pulse's entire duration. The pulse SPL on the other hand, is related to its intensity over a specified time interval. Seismic pulses typically lengthen in duration as they propagate away from their source, due to seafloor and surface reflections, and other waveguide dispersion effects. The changes in pulse length, and therefore the time window considered, affect the numeric relationship between SPL and SEL. This study has applied a fixed window duration to calculate SPL (T_{fix} = 125 ms; see Appendix A.1), as implemented in Martin et al. (2017b). Full-waveform modelling was used to estimate SPL, but this type of modelling is computationally intensive, and can be prohibitively time consuming when run at high spatial resolution over large areas.

For the current study, FWRAM (Appendix C.2) was used to model synthetic seismic pulses over the frequency range 5–1024 Hz. This was performed along all broadside and endfire radials at three sites. FWRAM uses Fourier synthesis to recreate the signal in the time domain so that both the SEL and SPL from the source can be calculated. The differences between the SEL and SPL were extracted for all ranges and depths that corresponded to those generated from the high spatial-resolution results from MONM. A 125 ms fixed time window positioned to maximize the SPL over the pulse duration was applied. The resulting SEL -to-SPL offsets were averaged in 0.02 km range bins along each modelled radial and depth, and the 90th percentile was selected at each range to generate a generalised range-dependent conversion function for each site. The range- dependent conversion function was averaged between the two sites and applied to predicted per-pulse SEL results from MONM to model SPL values. Figure D-2 to D-5 show the conversion offsets for Sites 2, 4, 6 and 9; the spatial variation is caused by changes in the received airgun pulse as it propagates from the source. The conversion to SPL from SEL was conducted using the considering the water depth and seabed geology at a given modelled site as compared Sites 2, 4, 6 and 9.

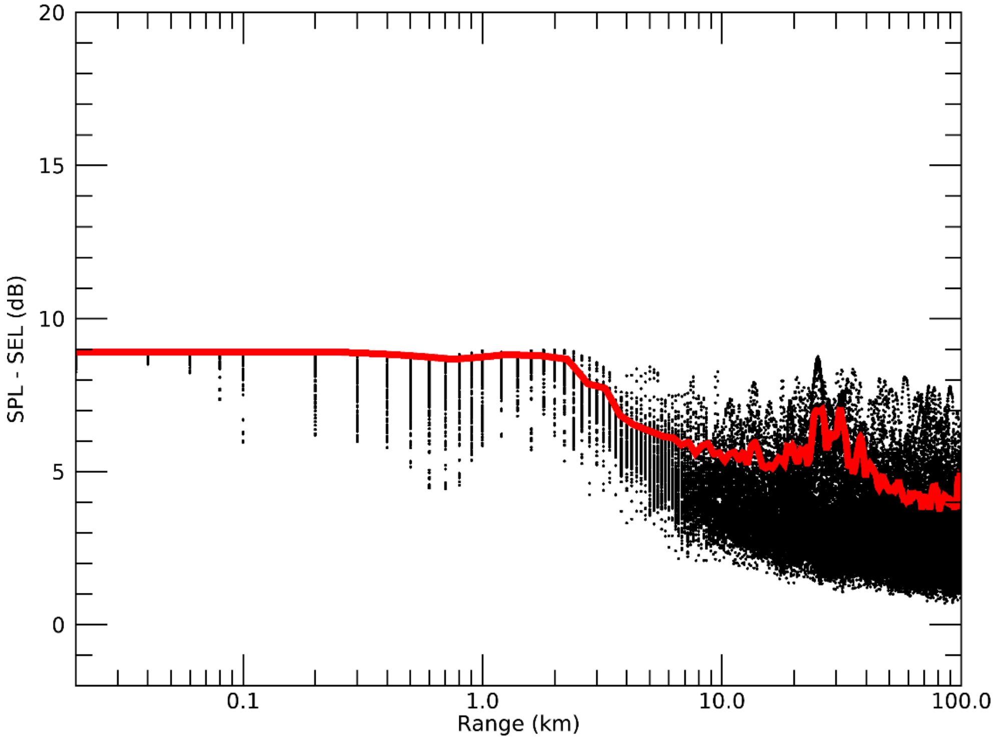


Figure D-2. *Site 2*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3480 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

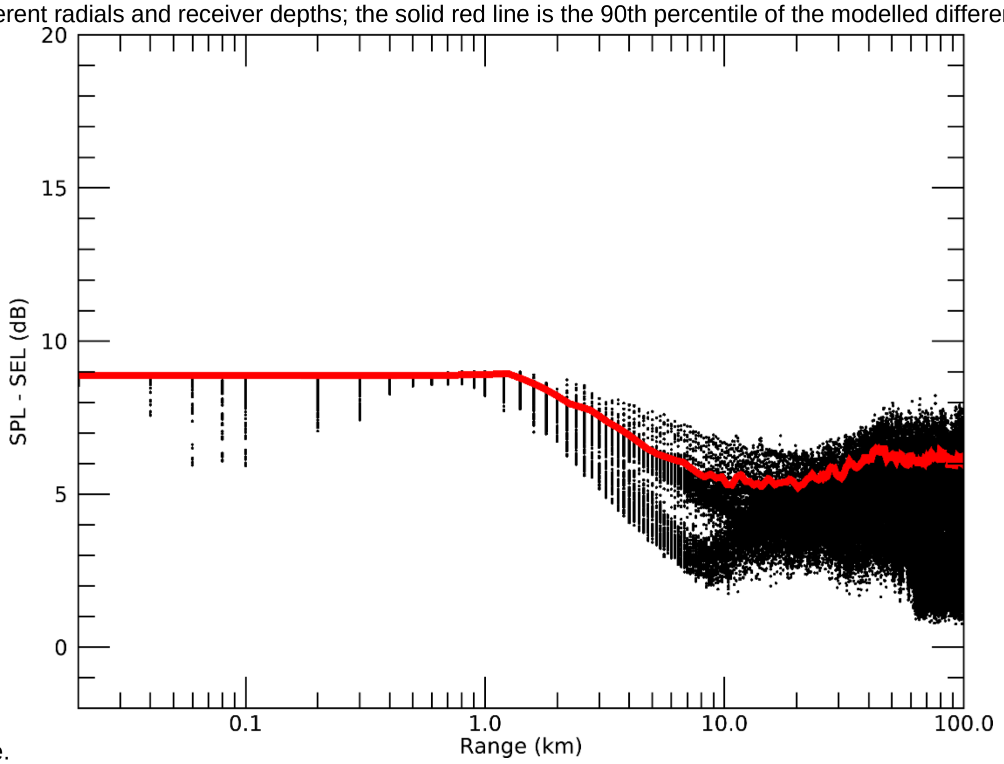


Figure D-3. *Site 4*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses for the 3480 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

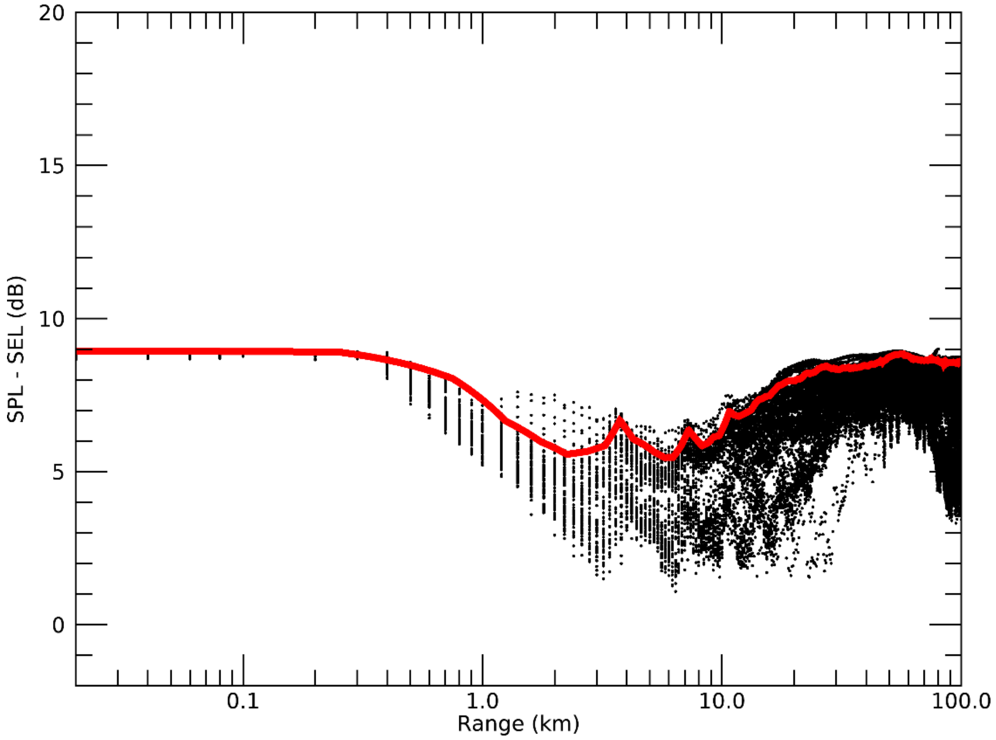


Figure D-4. *Site 6*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3480 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

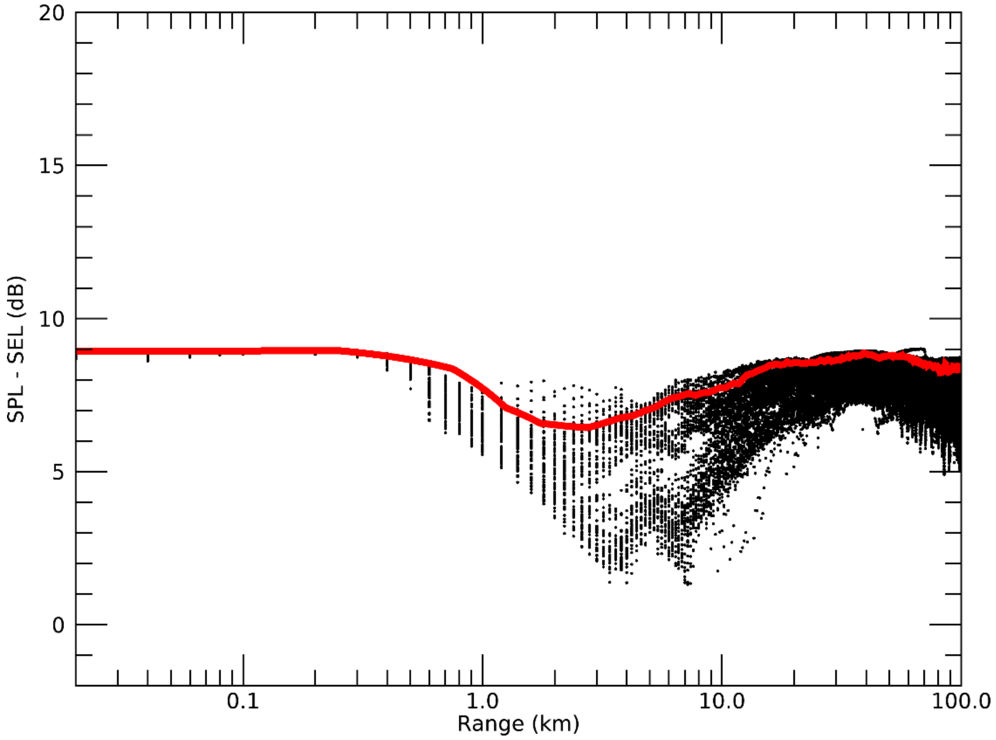


Figure D-5. *Site 9*: Range-and-depth-dependent conversion offsets for converting SEL to SPL for seismic pulses. Slices are shown for the 3480 in^3 seismic source. Black lines are the modelled differences between SEL and SPL across different radials and receiver depths; the solid red line is the 90th percentile of the modelled differences at each range.

D.3. Environmental Parameters

D.3.1. Bathymetry

Water depths throughout the modelled area were extracted from the Australian Bathymetry and Topography Grid, a 9 arc-second grid rendered for Australian waters (Whiteway 2009) for the region shown in Figure 1. Bathymetry data were extracted and re-gridded onto a Map Grid of Australia (MGA) coordinate projection (Zone 50) with a regular grid spacing of 100 × 100 m to generate the bathymetry in Figure D-6.

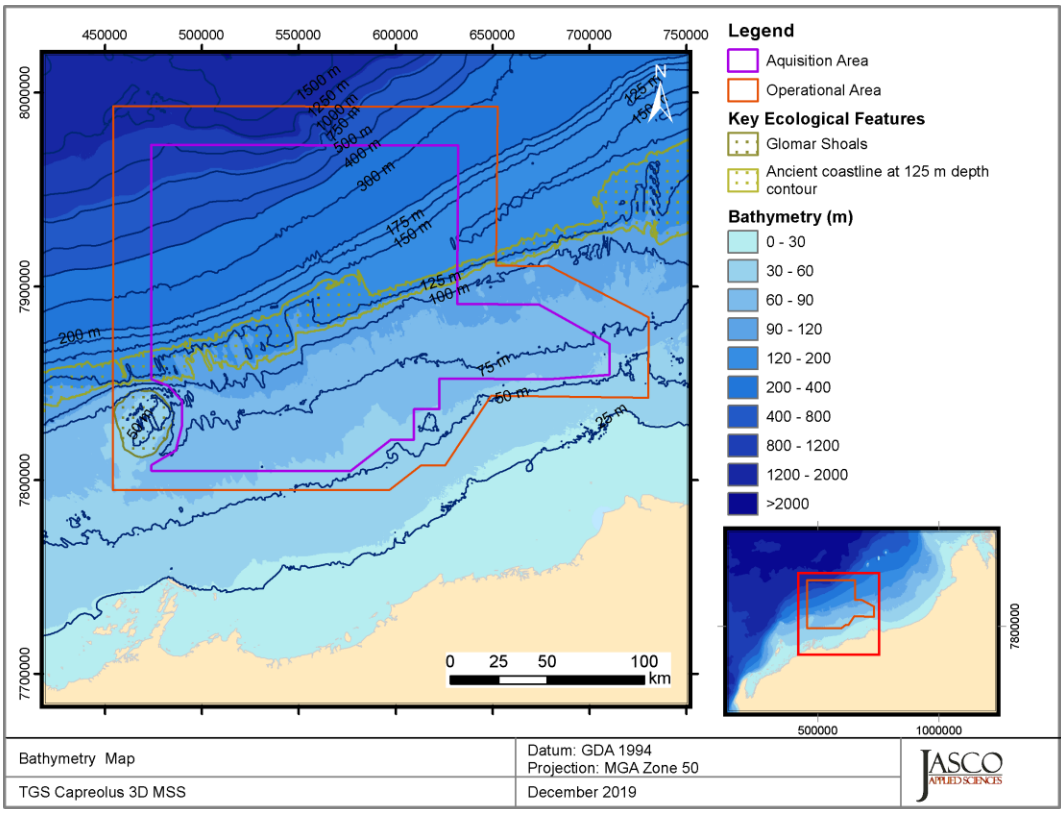


Figure D-6. Bathymetry map of the modelling area for the Capreolus-2 3D MSS.

D.3.2. Sound speed profile

The sound speed profiles for the modelled sites were derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles (all months) were derived from the GDEM profiles within a 100 km box radius encompassing all modelled sites. The June sound speed profile is expected to be most favourable to longer-range sound propagation during the proposed survey time frame. As such, June was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure D-7 shows the resulting profile used as input to the sound propagation modelling.

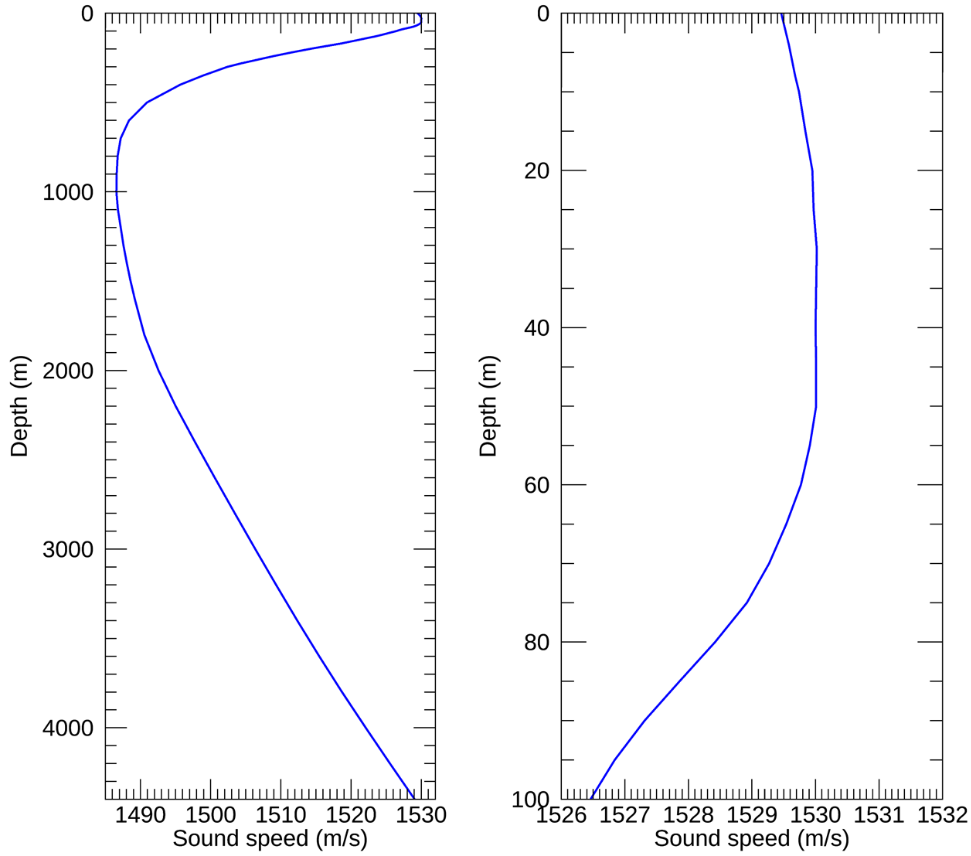


Figure D-7. The sound speed profile (June) used for the modelled sites 1–4 for scenario 1 showing the entire water column (left) and the top 100 m within the profile (right). Profiles are calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

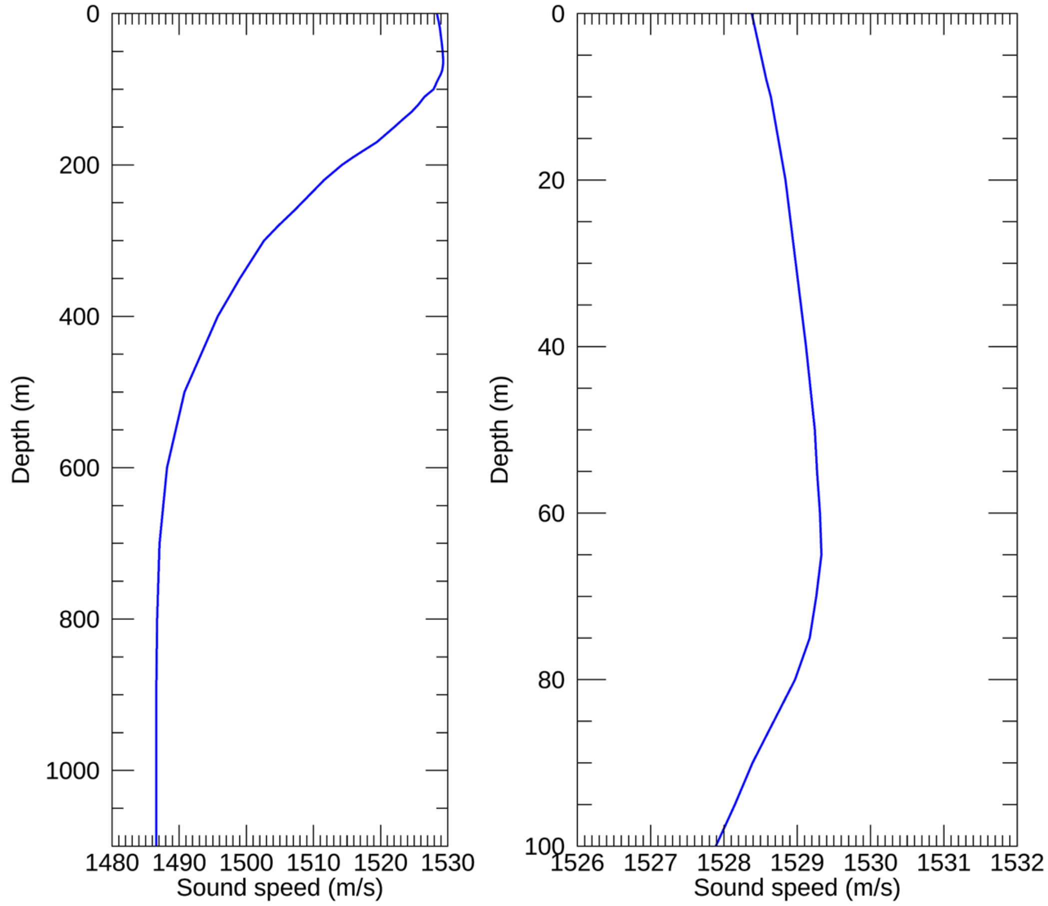


Figure D-8. The sound speed profile (June) used for the modelled sites 5–9 for scenario 2 showing the entire water column (left) and the top 100 m within the profile (right). Profiles are calculated from temperature and salinity profiles from GDEM V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

D.3.3. Geoacoustics

The geoacoustic parameters used for modelling at sites in deeper waters (Sites 1–4) were derived from sedimentary grain size measurements from the Australian Government's Marine Sediments (MARS) database (Heap 2009). On average, the surficial grain size indicates muddy fine carbonate sand throughout the modelled area. Representative grain sizes and porosity were used in the grain-shearing model proposed by Buckingham (2005) to estimate the geoacoustic parameters required by the sound propagation models. Core information from IODP Cruise 356 (Gallagher et al. 2017) was used to determine the deeper stratigraphy and to estimate the thicknes of un-lithified sediments The geoacoustic parameters from Duncan et al. (2009) were used for the cemented sediments at the bottom of the un-lithified stack. Table D-1 lists the geoacoustic parameters used for Sites 1–4.

Table D-1. Geoacoustic profile for the Sites 1–4.

Depth below seafloor (m)	Predicted lithology	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–10	Muddy carbonate sand (unconsolidated)	2.0	1639–1832	0.08–0.80	323	3.65
10–20	Increasingly consolidated carbonate Sand Silt Clay	2.0	1832–1895	0.80–0.98		
20–50	Increasingly consolidated carbonate Sand Silt Clay	2.0	1895–2011	0.98–1.30		
50–320	Increasingly consolidated carbonate Sand Silt Clay to semi-cemented calcarenite	2.0	2011–2431	1.3–2.03		
>320	Calcarenite (Cemented)	2.4	2800	0.1		

For shallow water modelled sites (water depth < 100 m) on the continental shelf, the seabed in the area has been described as a cemented substrate overlain with a layer of sand of variable thickness (Jones et al. 2007). This type of shallow water seabed stratigraphy is typical of the North West Australian Shelf (Jones 1973). This profile is very similar to seabed profiles described in association with acoustic measurement data (McCauley et al. 2016), and other modelling studies in the region (AIMS 2018). Furthermore, the propagation characteristics of a thin sand layer over top of a cemented layer have been explored by Duncan et al. (2009). Given this available regional geologic information and previous sound propagation studies, the geoacoustic parameters used for modelling at Sites 5–9 are based on Duncan et al. (2009) and the thickness of unconsolidated sand layer was estimated from Jones et al. (2007). Table D-2 lists the geoacoustic parameters used for Sites 5–9.

Table D-2. Geoacoustic profile for the Sites 5–9.

Depth below seafloor (m)	Predicted lithology	Density (g/cm³)	Compressional wave		Shear wave	
			Speed (m/s)	Attenuation (dB/λ)	Speed (m/s)	Attenuation (dB/λ)
0–5	Medium carbonate sand	1.8	1700	0.8	350	2.50
>5	Calcarenite (Cemented)	2.4	2800	0.1		

D.4. Seismic Sources

Figure D-9 shows the layout of the 3480 in^3 seismic source used for modelling in this study and considered in Appendix B.

Table D-3 provides details of the airgun parameters. The layout and airgun parameters for the 3090, 3390 and 3460 in^3 arrays considered in the preliminary array selection analysis are provided in Figures D-10 and D-12 and Tables D-4 and D-6, respectively.

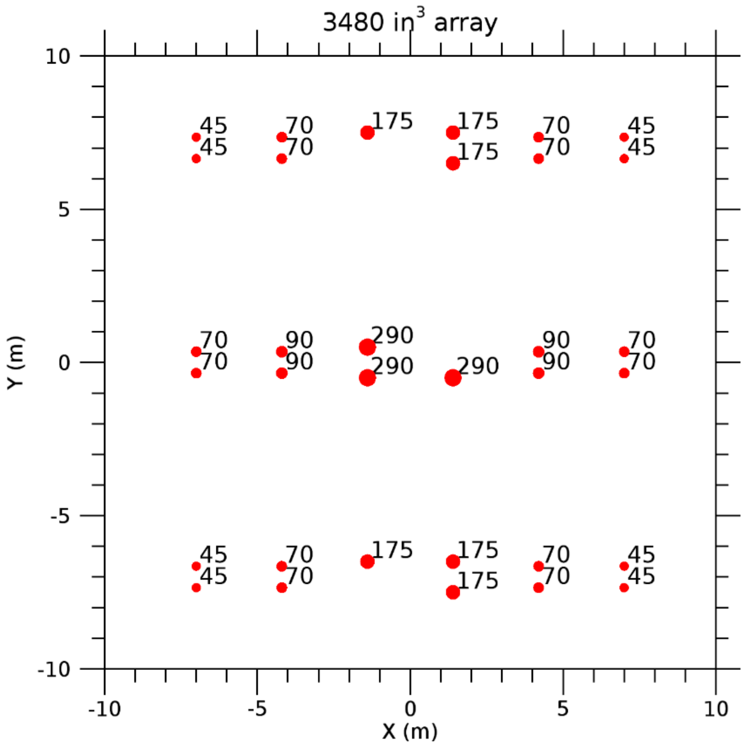


Figure D-9. Layout of the modelled 3480 in^3 seismic array. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-3.

Table D-3. Layout of the modelled 3480 in^3 seismic array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure D-9.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7	−7.35	6	45	13	7	−0.35	6	70	25	7	6.65	6	45
2	7	−6.65	6	45	14	7	0.35	6	70	26	7	7.35	6	45
3	4.2	−7.35	6	70	15	4.2	−0.35	6	90	27	4.2	6.65	6	70
4	4.2	−6.65	6	70	16	4.2	0.35	6	90	28	4.2	7.35	6	70
5	1.4	−7.5	6	175	17	1.4	−0.5	6	290	29	1.4	6.5	6	175
6	1.4	−6.5	6	175	19	−1.4	−0.5	6	290	30	1.4	7.5	6	175
8	−1.4	−6.5	6	175	20	−1.4	0.5	6	290	32	−1.4	7.5	6	175
9	−4.2	−7.35	6	70	21	−4.2	−0.35	6	90	33	−4.2	6.65	6	70
10	−4.2	−6.65	6	70	22	−4.2	0.35	6	90	34	−4.2	7.35	6	70
11	−7	−7.35	6	45	23	−7	−0.35	6	70	35	−7	6.65	6	45
12	−7	−6.65	6	45	24	−7	0.35	6	70	36	−7	7.35	6	45

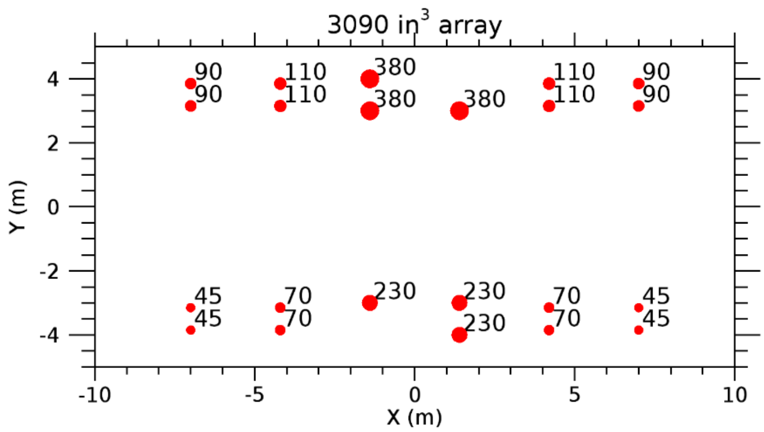


Figure D-10. Layout of the modelled 3090 in^3 seismic array. Tow depth is 6 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-4.

Table D-4. Layout of the modelled 3090 in^3 seismic array. Tow depth is 6 m. Firing pressure for all guns is 2000 psi. Also see Figure D-10.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7	-3.85	6	45	13	7	3.15	6	90
2	7	-3.15	6	45	14	7	3.85	6	90
3	4.2	-3.85	6	70	15	4.2	3.15	6	110
4	4.2	-3.15	6	70	16	4.2	3.85	6	110
5	1.4	-4	6	230	17	1.4	3	6	380
6	1.4	-3	6	230	19	-1.4	3	6	380
8	-1.4	-3	6	230	20	-1.4	4	6	380
9	-4.2	-3.85	6	70	21	-4.2	3.15	6	110
10	-4.2	-3.15	6	70	22	-4.2	3.85	6	110
11	-7	-3.85	6	45	23	-7	3.15	6	90
12	-7	-3.15	6	45	24	-7	3.85	6	90

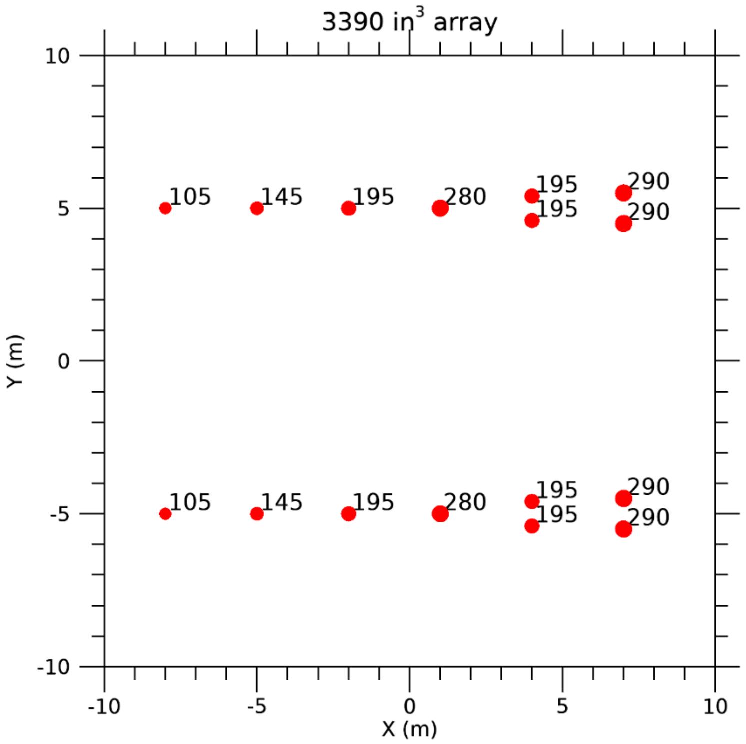


Figure D-11. Layout of the modelled 3390 in^3 seismic array. Tow depth is 7 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-5.

Table D-5. Layout of the modelled 3390 in^3 seismic array. Tow depth is 7 m. Firing pressure for all guns is 2000 psi. Also see Figure D-11.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)	Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7.5	5.5	7	290	9	7.5	-4.5	7	290
2	7.5	4.5	7	290	10	7.5	-5.5	7	290
3	4.5	5.4	7	195	11	4.5	-4.6	7	195
4	4.5	4.6	7	195	12	4.5	-5.4	7	195
5	1.5	5	7	280	13	1.5	-5	7	280
6	-1.5	5	7	195	14	-1.5	-5	7	195
7	-4.5	5	7	145	15	-4.5	-5	7	145
8	-7.5	5	7	105	16	-7.5	-5	7	105

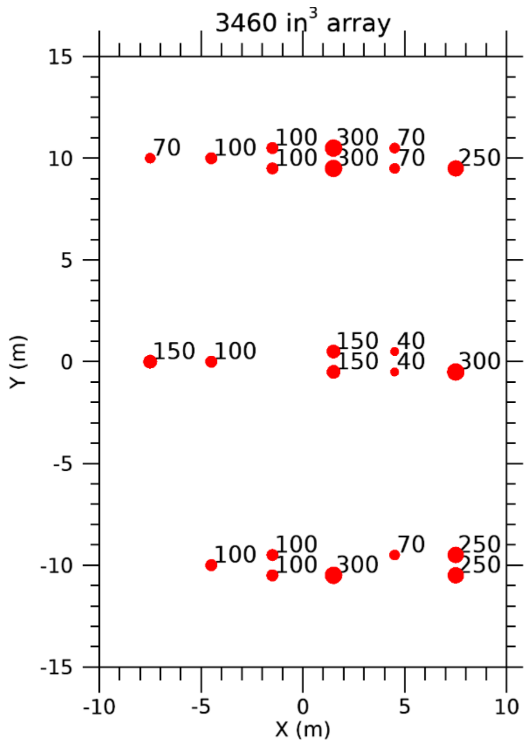


Figure D-12. Layout of the modelled 3460 in^3 seismic array. Tow depth is 7 m. The labels indicate the firing volume (in cubic inches) for each airgun. Also see Table D-6

Table D-6. Layout of the modelled 3460 in^3 seismic array. Tow depth is 7 m. Firing pressure for all guns is 2000 psi. Also see Figure D-12.

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	7.5	-9.5	7	250
2	7.5	-10.5	7	250
3	4.5	-9.5	7	70
6	1.5	-10.5	7	300
7	-1.5	-9.5	7	100
8	-1.5	-10.5	7	100
9	-4.5	-10	7	100

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
12	7.5	-0.5	7	300
13	4.5	0.5	7	40
14	4.5	-0.5	7	40
15	1.5	0.5	7	150
16	1.5	-0.5	7	150
19	-4.5	0	7	100
20	-7.5	0	7	150

Gun	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
22	7.5	9.5	7	250
23	4.5	10.5	7	70
24	4.5	9.5	7	70
25	1.5	10.5	7	300
26	1.5	9.5	7	300
27	-1.5	10.5	7	100
28	-1.5	9.5	7	100
29	-4.5	10	7	100
30	-7.5	10	7	70

D.5. Model Validation Information

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

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities which have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016).

Appendix E. Seismic Source Comparison

E.1. Acoustic Source Levels and Directivity

Four different seismic sources were considered for preliminary source analysis and selecting a worst-case seismic source, the total volumes were 3090, 3480, 3390 and 3460 in^3.The 3090 in^3 and the 3480 in^3 arrays were modelled at a tow depth of 6 m, the 3390 in^3 and 3460 in^3 arrays were modelled at a tow depth of 7 m.

The results from AASM for these sources are provided in Table E-1.

Table E-1. Far-field source level specifications for the 3090, 3480, 3390 and 3460 in^3 sources. Source levels are for a point-like acoustic source with equivalent far-field acoustic output in the specified direction. Sound level metrics are per-pulse and unweighted.

Total volume (in^3)	Direction	Peak source pressure level ($L_{S,pk}$) (dB re 1 µPa m)	Per-pulse source SEL ($L_{S,E}$) (dB 1 µPa^{2}m^{2}s)
			10–25000 Hz
3090	Broadside	249.40	225.12
3480	Broadside	248.64	225.35
3390	Broadside	248.24	224.65
3460	Broadside	247.57	223.86
3090	Endfire	245.73	223.25
3480	Endfire	247.55	225.16
3390	Endfire	246.35	224.20
3460	Endfire	247.73	225.38
3090	Vertical	255.01	228.20
3480	Vertical	258.06	230.88
3390	Vertical	254.40	227.93
3460	Vertical	256.10	229.44

E.2. Per-pulse Sound Field Comparison

FWRAM was used to model synthetic seismic pulses over a frequency range of 5–1024 Hz at Site 5 considering a tow direction of 90º. FWRAM was used to characterise the acoustic fields in terms of SEL, SPL and zero-to-peak sound pressure level (PK) metrics (as per Appendix A.1) for each source, which allows for a comparison of the two sources in a representative environment. Modelling was performed along all broadside and endfire radials for the two the seismic sources considered above.

Figure E-1–3 present the maximum-over-depth for all radials for SEL, SPL and PK metrics as a function of range. The 3480 in^3 array consistently produced the highest SELs and SPLs at the farthest distances away from the source. The difference in SEL and SPL between these arrays will result in larger isopleths for energy based assessments (i.e. the SEL_{24h} assessment) and isopleths to behavioural disturbance for the 3480 in^3 array. The 3480 in^3 array was therefore selected as the worst-case source for modelling in this study.

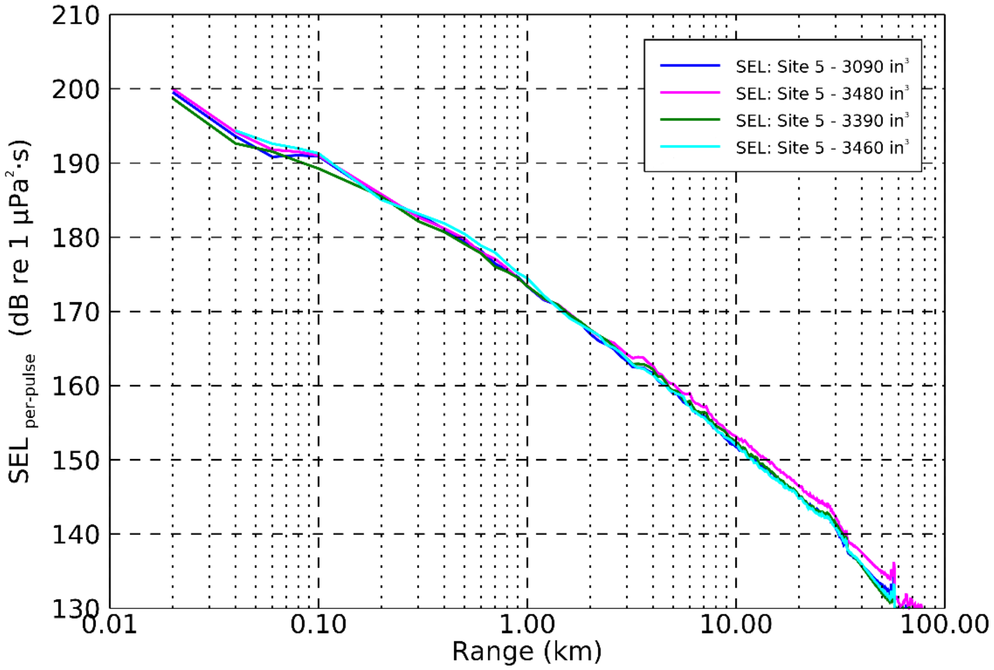


Figure E-1. Maximum-over-depth predicted SEL for the 3090, 3480, 3390 and 3460 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire and directions.

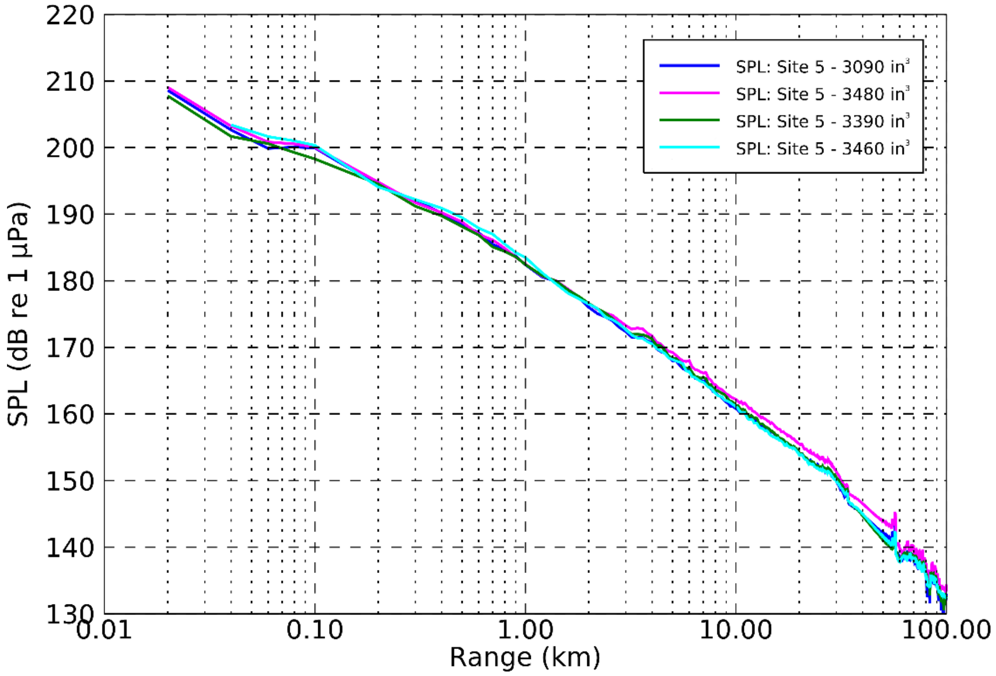


Figure E-2. Maximum-over-depth predicted SPL for the 3090, 3480, 3390 and 3460 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire and directions.

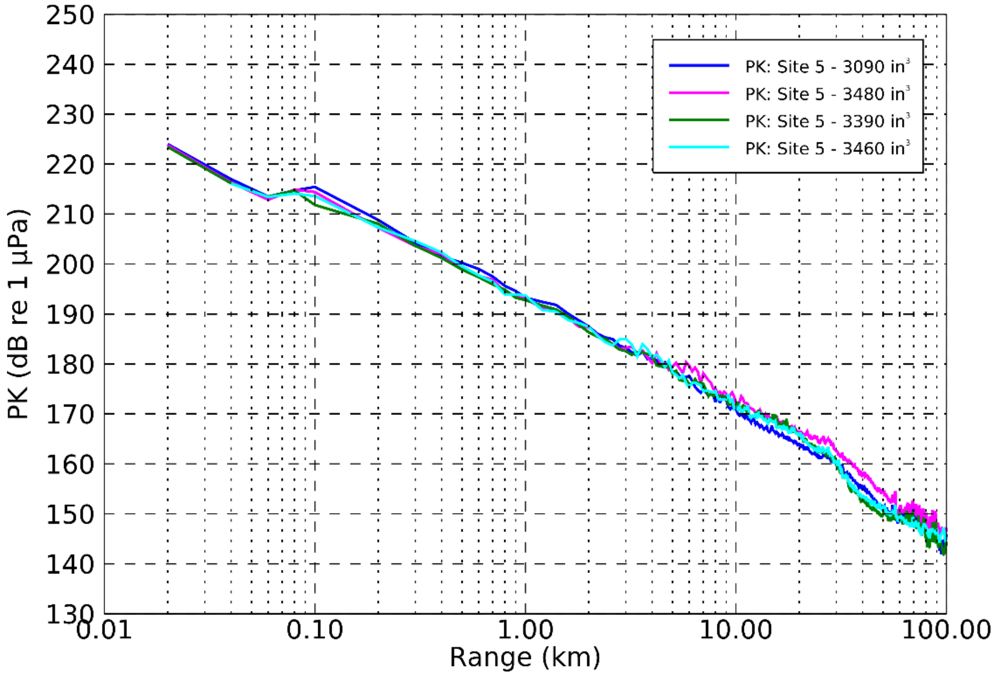


Figure E-3. Maximum-over-depth predicted PK for the 3090, 3480, 3390 and 3460 in^3 sources from FWRAM. Levels are the maximum over all the broadside and endfire and directions.

Appendix F. Additional Results

F.1. SEL Contour Maps

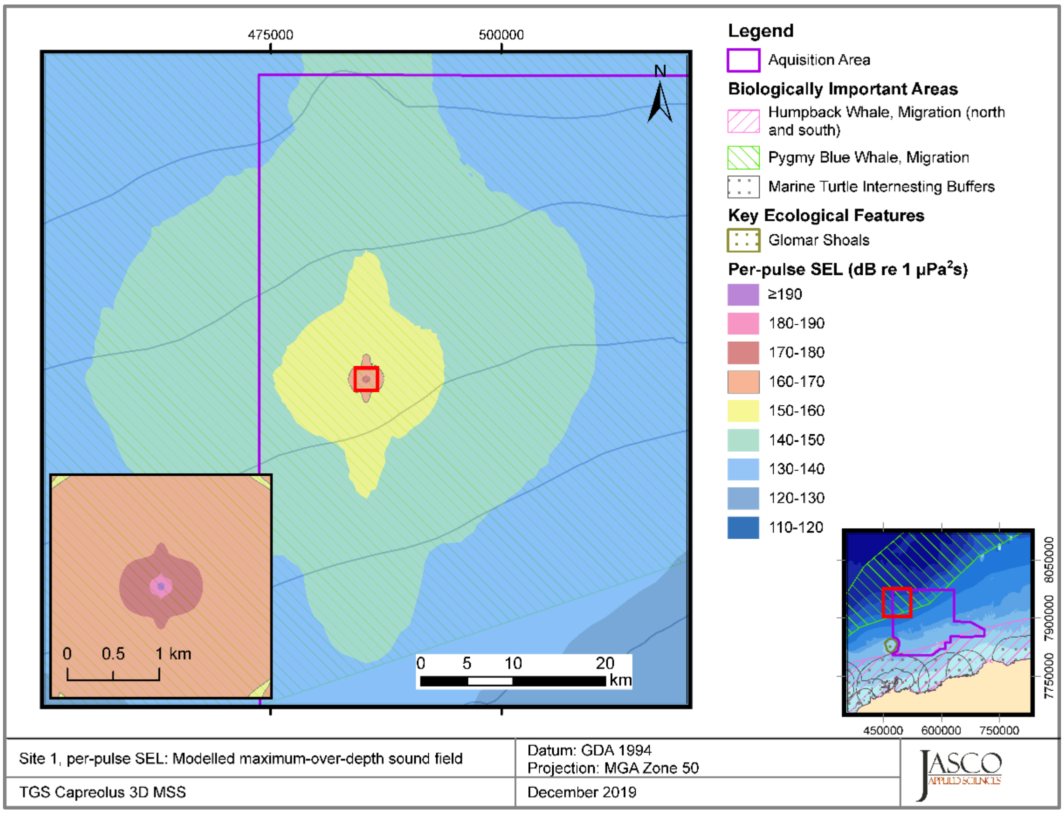


Figure F-1. *Site 1, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

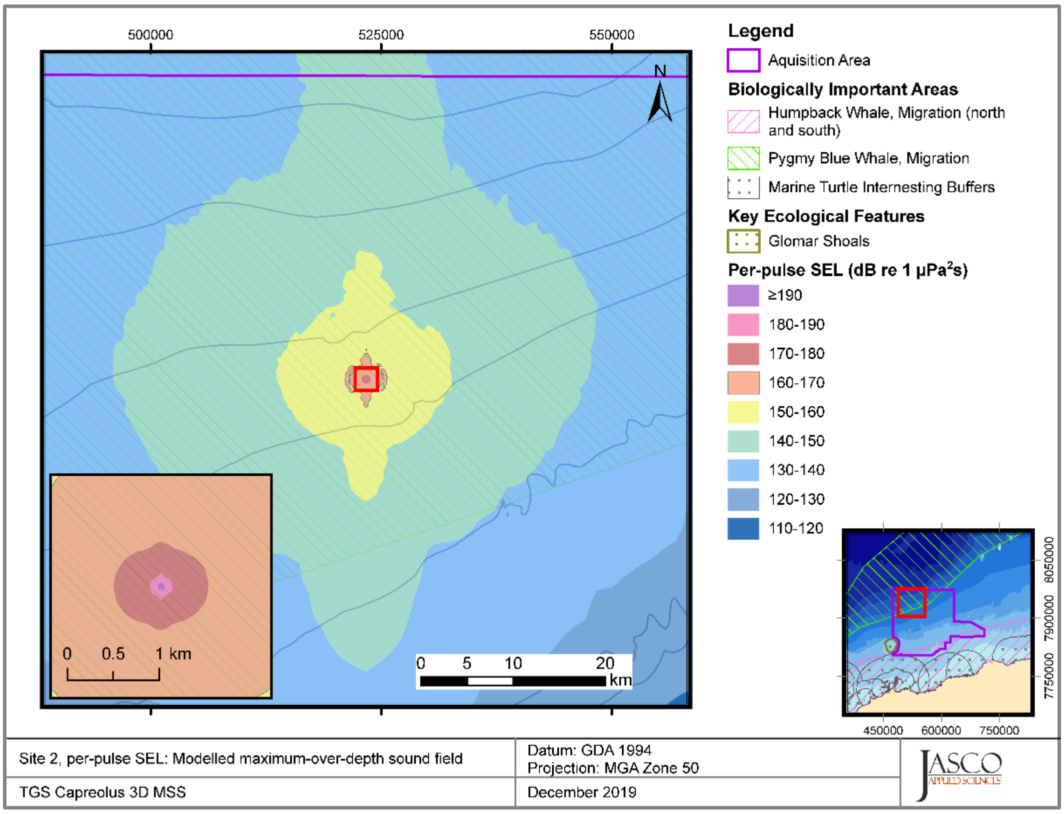


Figure F-2. *Site 2, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

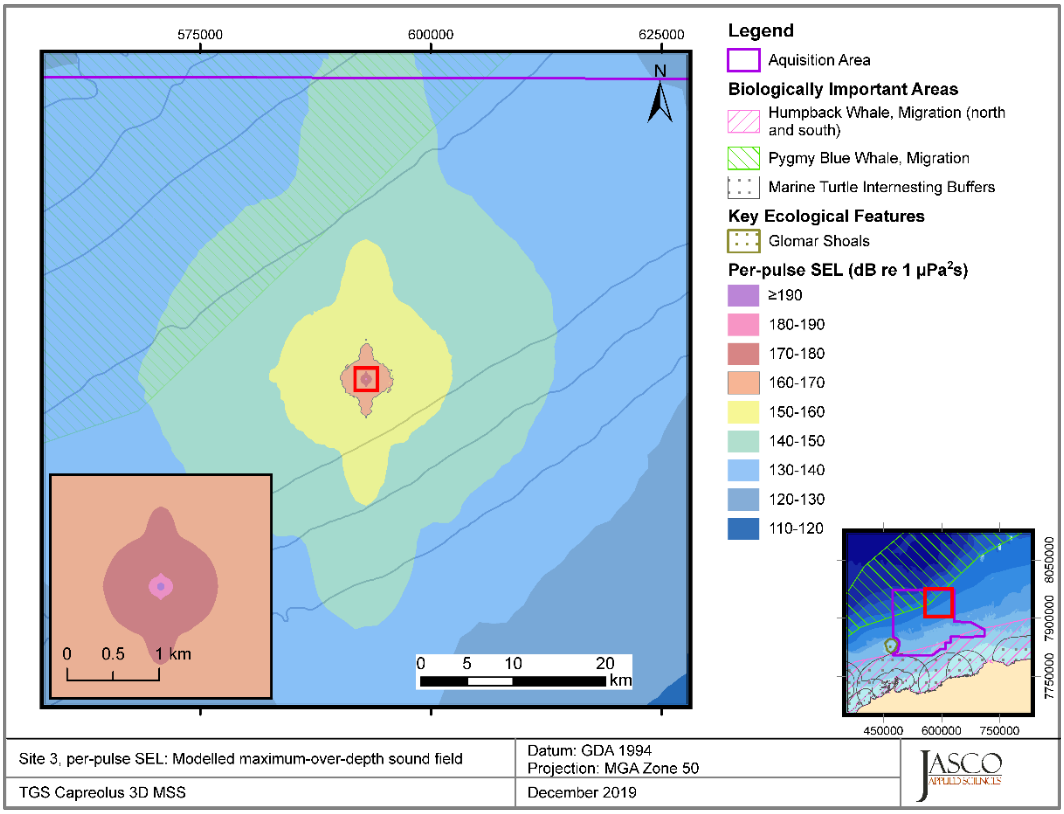


Figure F-3. *Site 3, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

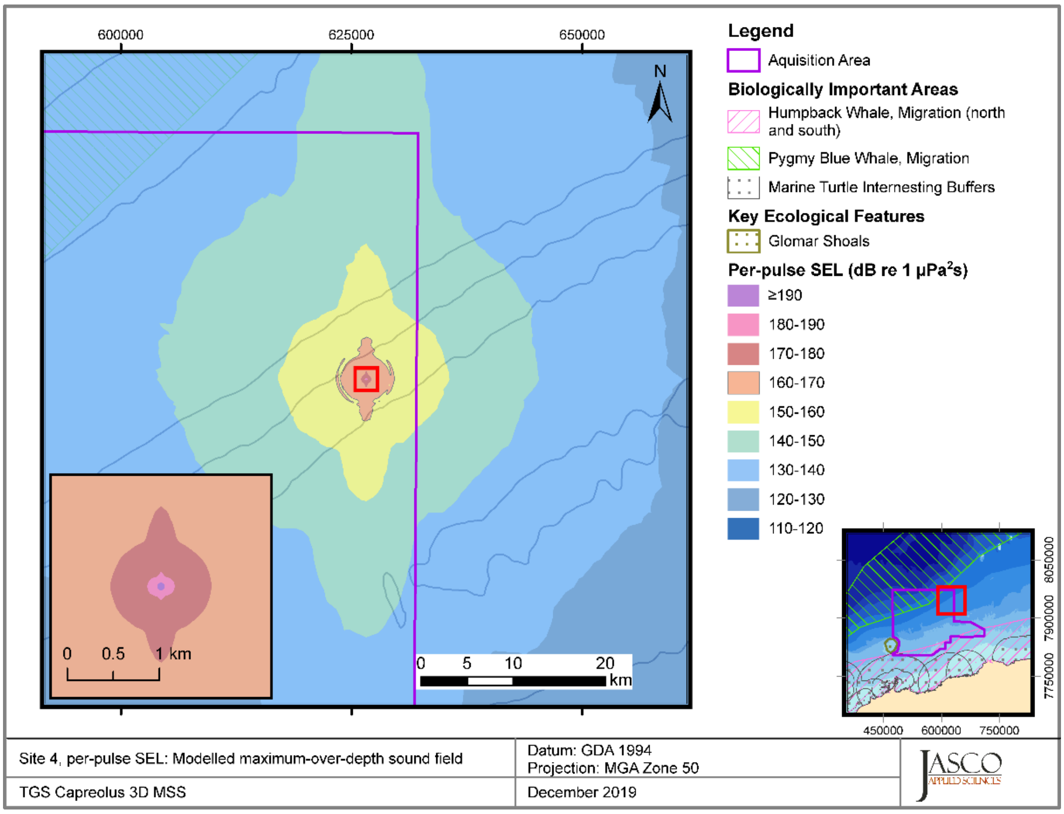


Figure F-4. *Site 4, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

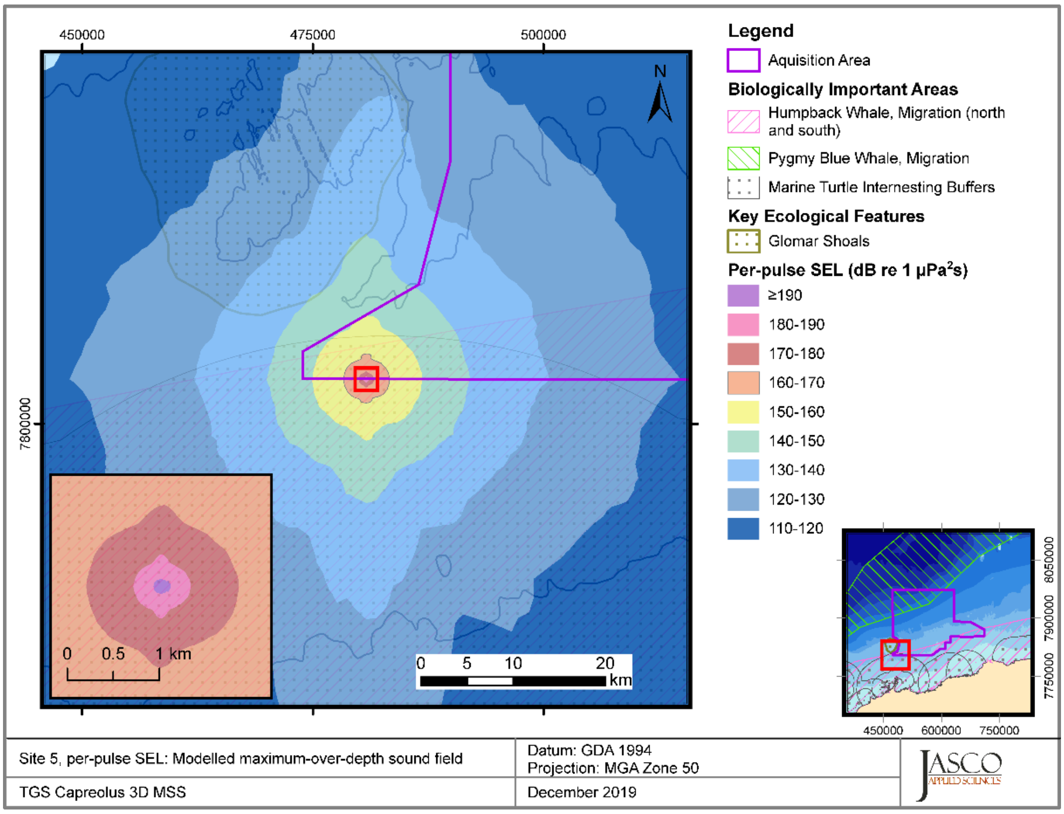


Figure F-5. *Site 5, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

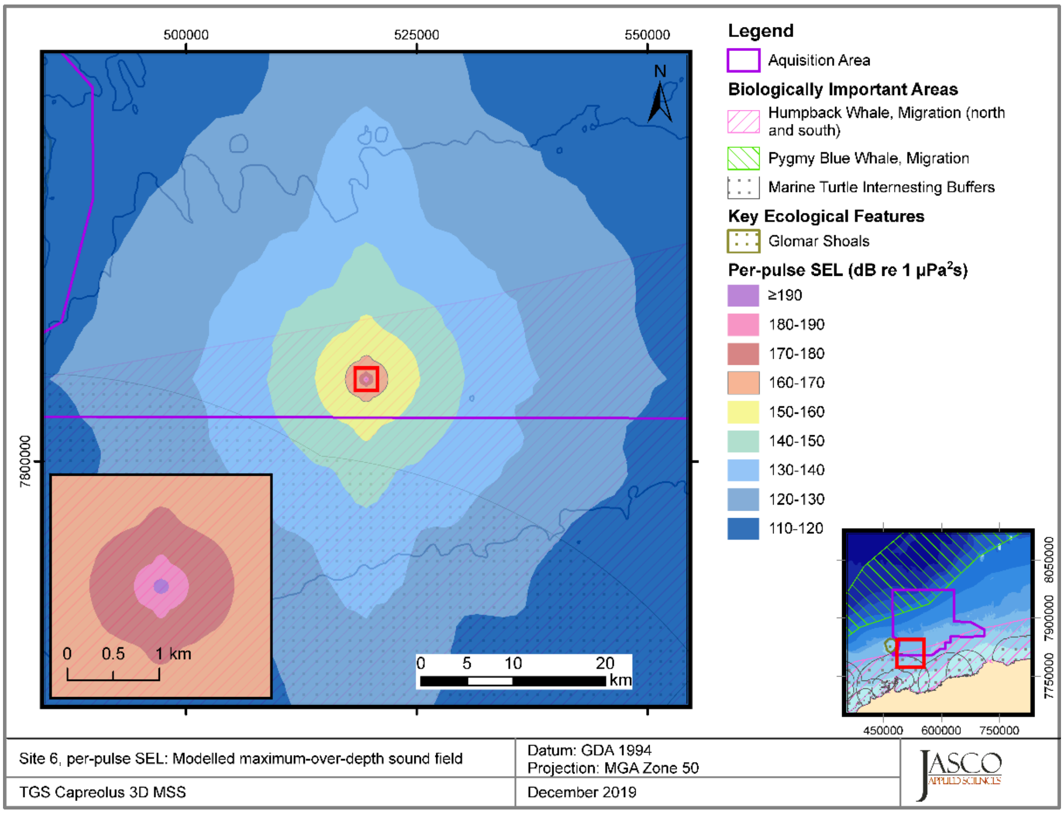


Figure F-6. *Site 6, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

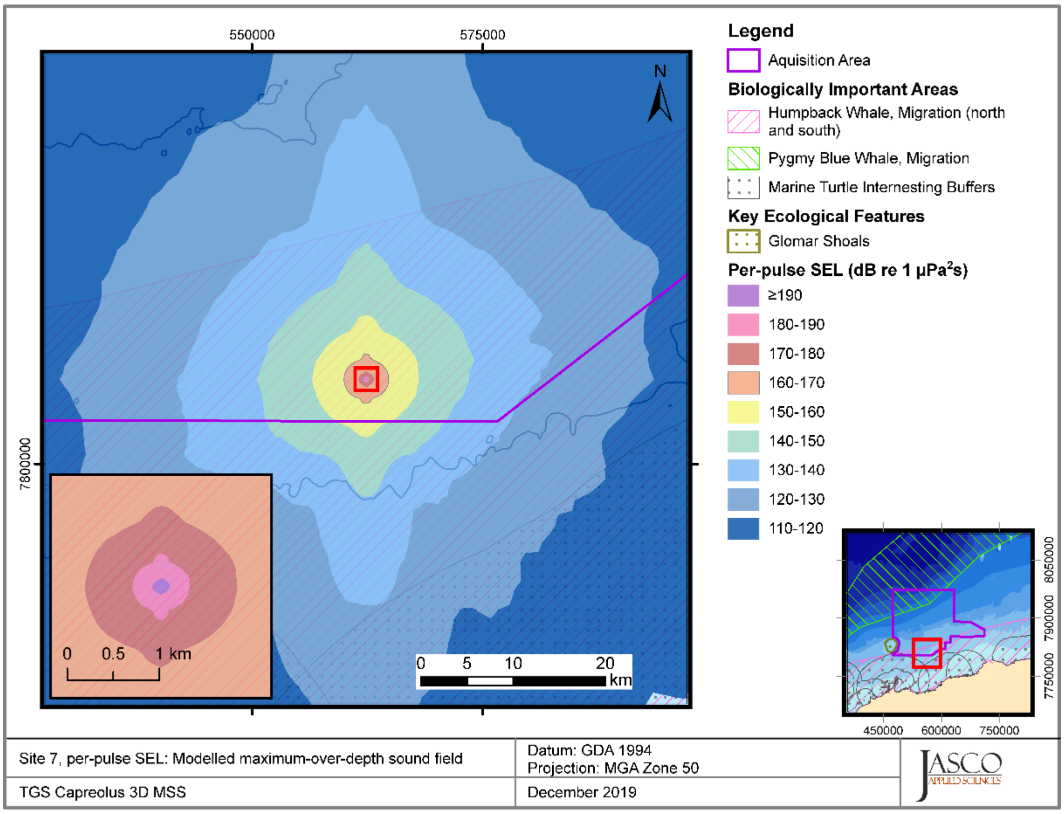


Figure F-7. *Site 7, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

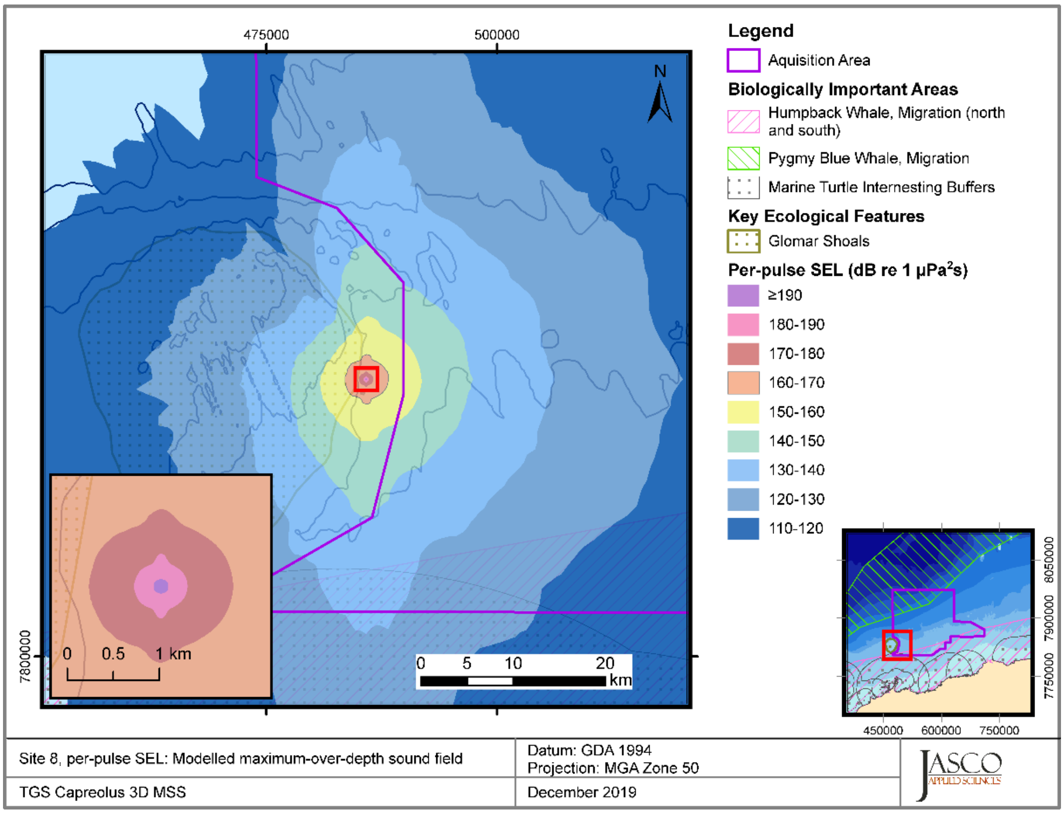


Figure F-8. *Site 8, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

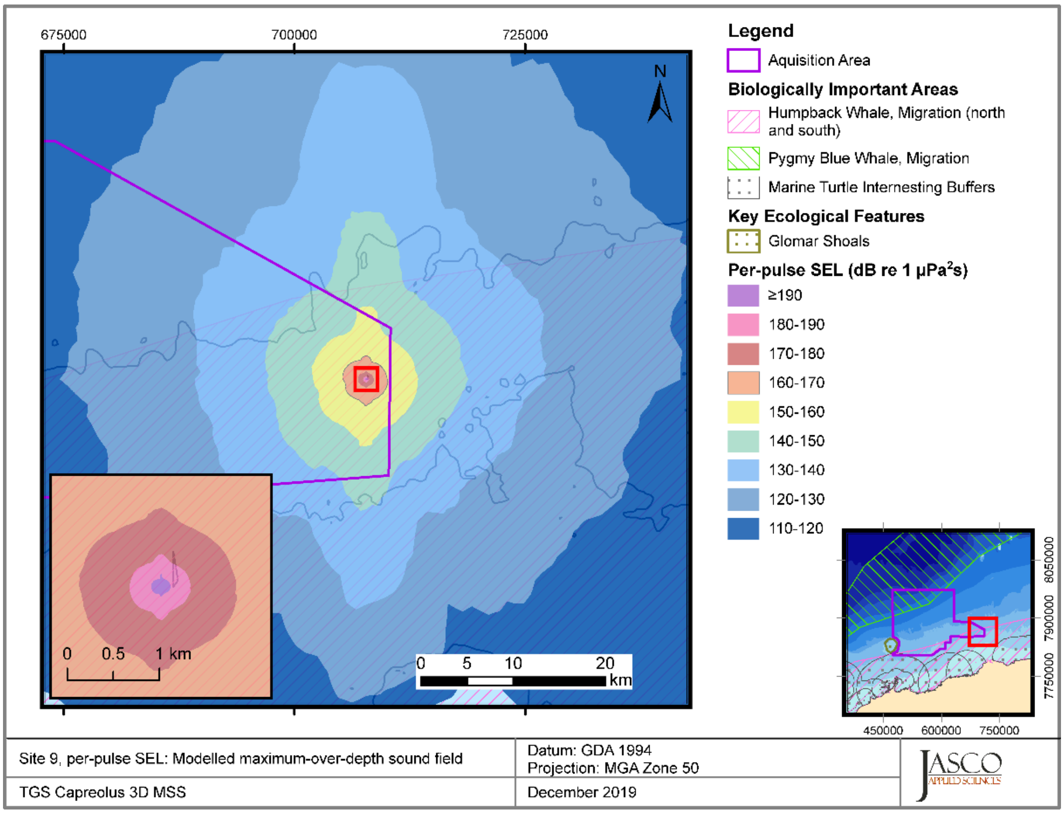


Figure F-9. *Site 9, per-pulse SEL:* Sound level contour map showing unweighted maximum-over-depth results.

APPENDIX F PYGMY BLUE WHALE EXPOSURE MODELLING

Capreolus-2 3-D Marine Seismic Survey

Pygmy Blue Whale Exposure Modelling

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27 July 2020

P001525-001
Document 02100
Version 1.0

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Suggested citation:

Weirathmueller, M.J., M.W. Koessler, and C.R. McPherson. 2020. *Capreolus-2 3-D Marine Seismic Survey: Pygmy Blue Whale Exposure Modelling*. Document 02100, Version 1.0. Technical report by JASCO Applied Sciences for Environmental Resources Management.

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Executive Summary

JASCO Applied Sciences performed an acoustic exposure analysis study of pygmy blue whales near a migratory Biologically Important Area (BIA) where it intersected the planned survey operations for the TGS Capreolus-2 3-D Marine Seismic Survey (MSS). Previously, acoustic modelling was conducted for this survey to determine ranges to acoustic exposure thresholds representing the best available science for potential injury and behavioural disruption of marine fauna including marine mammals, turtles, and fish (Koessler and McPherson 2020).

The aim of the present study was to employ animal movement (animat) modelling simulations in conjunction with these previously computed three-dimensional sound fields to predict the range at which animals are expected to be impacted above threshold criteria for injury and behavioural disturbance. To achieve this, the JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to integrate the sound fields with species-typical behaviour. JASMINE results provide an estimate of the probability of sound exposure, which can be compared to acoustic thresholds and then scaled to estimate the number of animals expected to receive sound levels that may cause injury or behavioural disruption.

Animat modelling focussed on migrating pygmy blue whales in the migration BIA. The behaviour of pygmy blue whales (*Balaenoptera musculus brevicauda*) was modelled without migration bias, i.e., the animats were resident in the animat modelling area over the entire modelling period. The two migratory behaviours (migratory dives and exploratory dives) were modelled at an even probability of occurrence. Both of these approaches were chosen to present conservative results due to the limited data available.

Simulations were run for a period of 6 days. On each day, a limited subset of seismic track lines were simulated. The line subsets were selected to provide representative results near the BIA. Using the distribution of ranges of animats predicted to be exposed to sound levels above threshold, the exposure range ($ER_{95\%}$) was computed for comparing with previous range to threshold estimates.

The results of the animat analysis predicted that the $ER_{95\%}$ of migrating pygmy blue whales potentially exposed to sound levels above the NMFS (2018) permanent and temporary threshold shift (PTS and TTS) criteria were 0.12 km and 23.80 km, respectively. $ER_{95\%}$ for exposures above the NMFS (2014) behavioural threshold was 6.60 km.

The estimated 95th percentile ranges for all scenarios were lower than comparable ranges to threshold reported in Koessler and McPherson (2020). This was expected because previous modelling efforts did not incorporate both moving sources and moving receivers, but rather assumed that, as per the NMFS (2018) criteria, SEL_{24h} 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.

1. Introduction

JASCO Applied Sciences (JASCO) performed an acoustic exposure analysis study for pygmy blue whales (*Balaenoptera musculus brevicauda*) for the planned TGS Capreolus-2 3-D Marine Seismic Survey (MSS). Only the northwest portion of the seismic acquisition area described in Koessler and McPherson (2020) overlaps with the pygmy blue whale migratory Biologically Important Area (BIA).

This report describes the modelled predictions of sound levels that individual migrating pygmy blue whales may receive during survey operations. Sound exposure distribution estimates are determined by moving large numbers of simulated animals (animats) through a modelled time-evolving sound field, computed using specialised sound source and sound propagation models. This approach provides the most realistic prediction of the maximum expected root-mean-square sound pressure level (SPL, L_p), peak pressure level (PK, L_{pk}), and the temporal accumulation of sound exposure level (SEL, L_E) that are now considered the most relevant sound metrics for impact assessment. The most recent science in the peer-reviewed literature regarding sound propagation and animal movement modelling was used.

Koessler and McPherson (2020) conducted a detailed sound modelling study, and the resulting sound fields were used to predict animat sound exposures. The initial study reported on acoustic modelling results at nine locations (Site numbers 1–9). For the current study, two additional sites were modelled to better represent the area covered by the exposure analysis (Sites 10 and 11). The locations and depths of the two new sites are summarized in Table 1 and the modelled locations that are within the animat simulation area are shown on the map in Figure 1.

Table 1. Location details for the additional single impulse modelled sites.

Site	Latitude (S)	Longitude (E)	MGA* Zone 50		Water depth (m)	Tow direction (°)
			x (m)	*y* (m)		
10	19° 16' 23.5050"	117° 09' 37.8844"	51686	7868936	113	90/270
11	19° 10' 45.0200"	117° 22' 34.2053"	539549	7879304	128	90/270

* Map Grid of Australia

2. Exposure Modelling Scenario

For the planned TGS Capreolus-2 3-D MSS, source and propagation modelling were conducted to generate 3-D sound fields which are used in conjunction with animal movement modelling. The exposure modelling scenario considered a total of 6 days of survey tracks. Each 24-h segment of track lines were independent and non-sequential. The pairs were selected to sample the impact of the seismic survey as a function of location relative to the pygmy blue whale migratory BIA. Each line pair included the western halves of two consecutive track lines, where the planned survey follows a racetrack pattern with 10 km spacing. Line pairs were oriented at 90°/270°. The animal movement modelling simulation area was designed to extend to approximately 80km beyond the area of overlap between the pygmy blue whale migratory BIA and the survey area in order to encompass the largest possible ranges to sound exposure thresholds. Simulated animats are seeded only with the BIA to best represent the true spatial distribution of this species. Exposure modelling simulation extents and animat seeding area are shown in Figure 1.

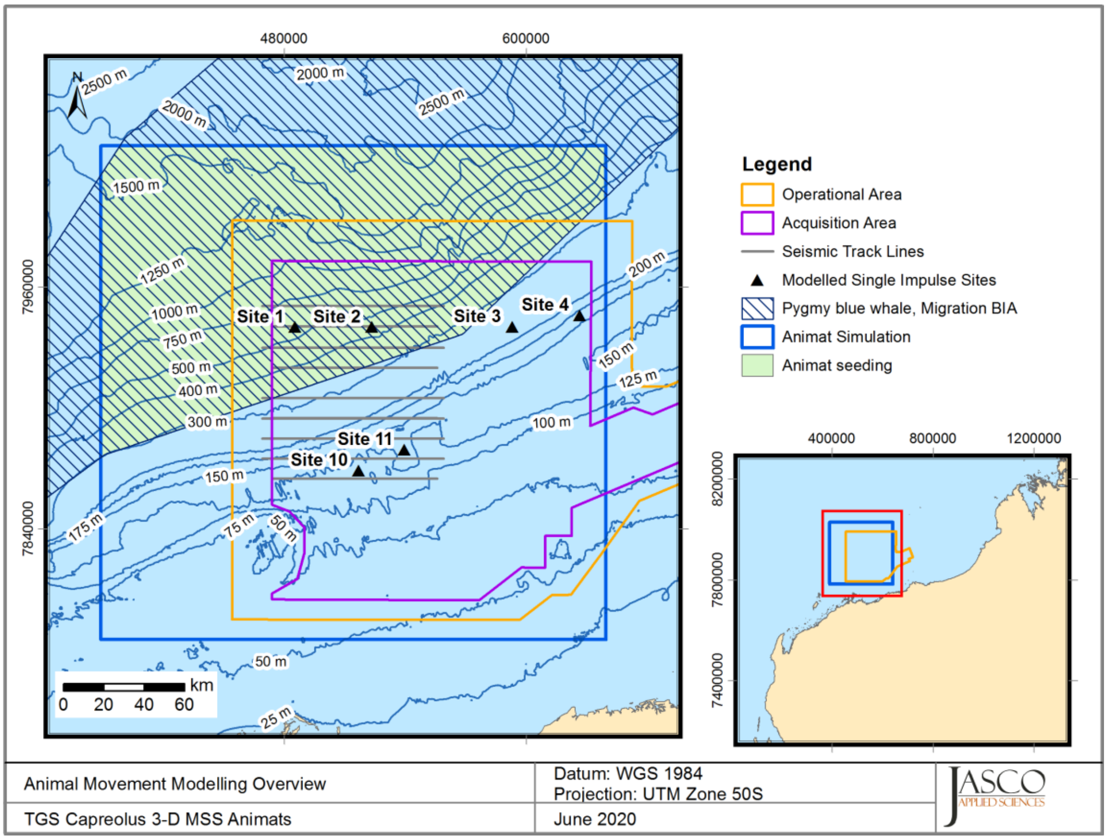

Figure 1. Animat modelling extent, seeded area, single impulse modelled sites, and modelled source tracks. Sites 1–4 are from the previous modelling study (Koessler and McPherson 2020), while Sites 10 and 11 were modelled as part of the current study.

3. Noise Effect Criteria

The noise effect criteria which were considered for pygmy blue whales in the acoustic modelling (Koessler and McPherson 2020) are summarised in this section to contextualize these exposure modelling results.

The sound level metrics of PK, SPL and SEL, were considered, and the acoustic metrics in this report reflect the updated ISO standard for acoustic terminology, ISO/DIS 18405.2:2017 (2017). More detail is provided in Appendix A.

The noise criteria considered are those suggested by the best available science:

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from the US 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 (Table 2).
2. Marine mammal behavioural threshold based on the US National Oceanic and Atmospheric Administration (NOAA 2019) criterion of 160 dB re 1 µPa SPL (L_p) for impulsive sound sources (Table 2).

Table 2. Unweighted sound pressure level (SPL), 24 h sound exposure level (SEL_{24h}), and peak pressure (PK) thresholds for acoustic effects on marine mammals.

Hearing group	**NOAA (2019)**	**NMFS (2018)**			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 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}, denotes flat–peak sound pressure that is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24-hour period and has a reference value of 1 µPa²s.
Subscripts indicate the designated marine mammal auditory weighting.

4. Methods

4.1. Acoustic Modelling

A summary of the acoustic modelling presented in Koessler and McPherson (2020) is included to provide context for the acoustic exposure assessment.

4.1.1. 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 selected seismic source was 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 seismic source considered was modelled over AASM's full frequency range, up to 25 kHz.

4.1.2. Sound Propagation Models

Two sound propagation models were used to predict the acoustic field around the seismic source:

- Combined range-dependent parabolic equation and Gaussian beam acoustic ray-trace model (MONM-BELLHOP, 5 Hz to 25 kHz).
- Full Waveform Range-dependent Acoustic Model (FWRAM, 5 Hz to 1024 Hz).

The models were used in combination to characterise the acoustic fields in terms of SEL, SPL, PK, and PK-PK. MONM-BELLHOP was used to calculate 3-D SEL fields as a function of range and depth relative to the source. The 3-D SPL fields were computed by applying an SEL to SPL conversion factor to the SEL sound fields. The conversion factor was obtained using FWRAM, which is substantially more computationally expensive than MONM-BELLHOP, but retains the full phase and amplitude information needed to estimate SPL or PK. Because ranges to relevant PTS and TTS PK thresholds were found to be ≤ 60 m and therefore well within the acoustic near-field of the seismic arrays, acoustic sound fields were not generated for the full azimuthal resolution and the associated animal movement modelling was not conducted for the PK threshold.

4.1.3. Parameter Overview

The specifications of the seismic source and the environmental parameters used in the propagation models are described in detail in Koessler and McPherson (2020). The seismic source considered was a 3480 in^3 seismic source array consisting of 3 strings towed at a 6 m depth, with a nominal firing pressure of 2000 psi

For modelling, the considered sound speed profile was based on the seasonal period that would result in the longest acoustic propagation ranges. The month of June was identified as the seasonal period that would most likely provide the farthest propagation due to the presence of a slightly upward refracting sound speed profile. A geological profile consistent with associated water depths were also used. Further details on the environmental parameters are provided in Koessler and McPherson (2020).

4.2. Animal Movement and Exposure Modelling

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was used to predict the exposure of animats (virtual marine mammals) to sound arising from the seismic surveys. Sound exposure models like JASMINE integrate the predicted sound field with biologically meaningful movement rules for each marine mammal species (here: pygmy blue whales) that result in an exposure history for each animat in the model. Inside JASMINE, the sound source, which can be stationary or moving (Figure 2), mimics the proposed seismic survey patterns. As shown in Figure 2, animats are programmed to behave like the marine animals that may be present in the area. The parameters used for forecasting realistic behaviours (e.g., diving, foraging, aversion, surface times) are determined and interpreted from marine mammal studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's sound exposure levels are summed over a specified duration, such as 24 hours or the entire simulation, to determine its total received energy, and then compared to the threshold criteria (for detailed information on JASMINE see Appendix A).

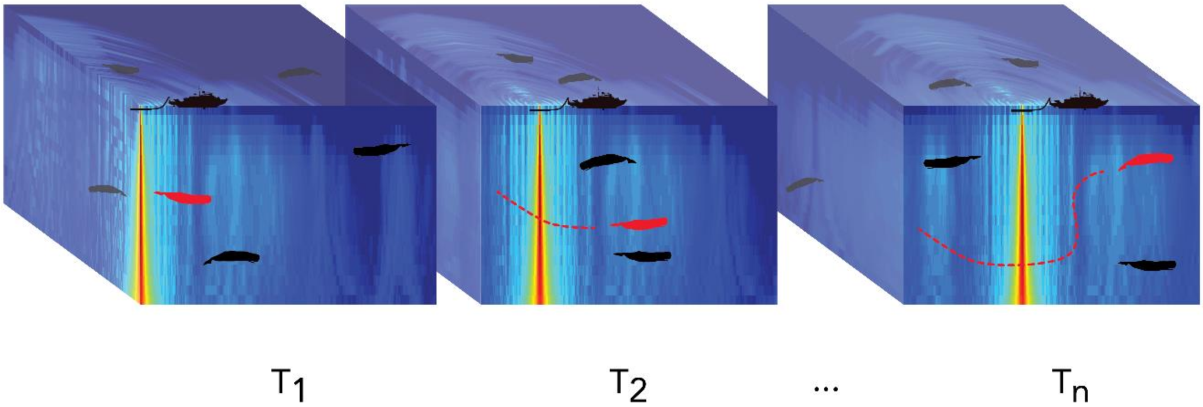

Figure 2. Cartoon of animats in a moving sound field. Example animat (red) shown moving with each time step (T_n). The acoustic exposure of each animat is determined by where it is in the sound field, and its exposure history is accumulated as the simulation steps through time.

4.2.1. Methodology

The exposure criteria for impulsive sounds (described in Section 3) were used to determine the number of animats exceeding thresholds. Model simulations were run with animat densities of 2.0 animats/km^2. To evaluate potential injury (PTS and TTS) and behavioural disturbance, exposure results were obtained using detailed behavioural information for pygmy blue whales (described in Section 4.2.2 and summarised in Appendix B). The simulation was run for a representative period of 6 days. Each of the track pairs was treated as an independent simulation and summary exposure range results conservatively provide the maximum range over all days for each metric.

Pygmy blue whales are found primarily within specific BIAs depending on behavioural mode (e.g., migrating or foraging). This was implemented in the animal movement simulation by restricting the spatial distribution of animats to the BIA.

The results from the animal movement and exposure modelling provided a way to estimate ranges to impact thresholds. The range to the closest point of approach (CPA) for each of the animats was recorded. The $ER_{95\%}$ (95% Exposure Range) is the horizontal range that includes 95% of the animat CPAs that exceeded a given impact threshold (Figure 3). Within the $ER_{95\%}$ range, there are generally some proportion of animats that do not exceed threshold criteria.

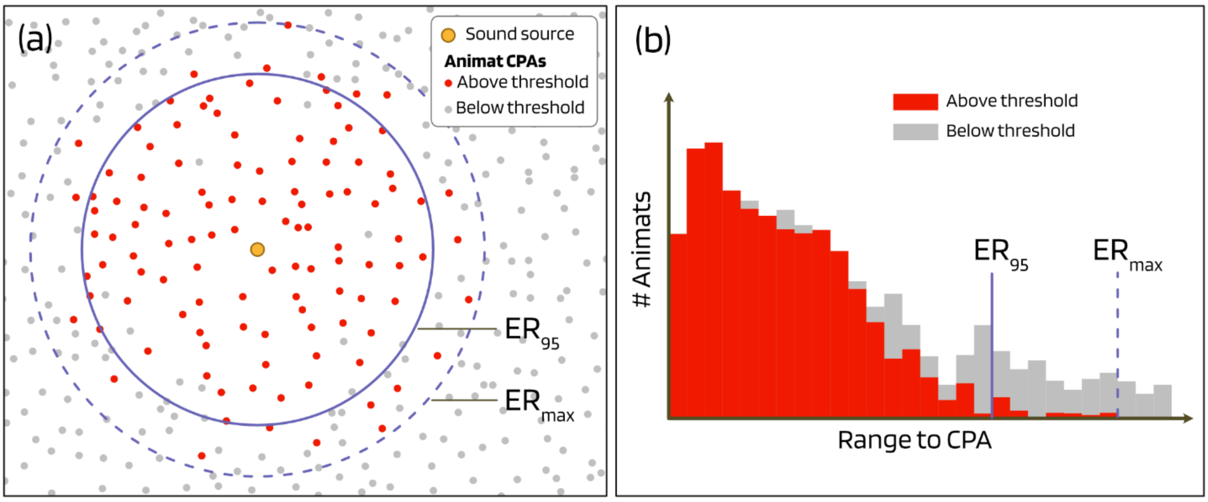

Figure 3. Example distribution of animat closest points of approach (CPAs). Panel (a) shows the horizontal distribution of animats near a sound source. Panel (b) shows the distribution of ranges to animat CPAs. The 95% and maximum exposure ranges ($ER_{95\%}$ and ER_{max}) are indicated in both panels.

4.2.2. Animal Behaviour

One behavioural profile was considered for pygmy blue whales, that of migration. The research summarised in this section was used to inform the species behavioural definition (see Appendix B.2). Detailed, fine-scale diving behaviour of a migrating pygmy blue whale was derived from Owen et al. (2016) who equipped a sub-adult with a multi-sensor tag off the west coast of Australia. The study identified areas of high residence using the horizontal movement data; the analysis of the dive data showed that the depth of migratory dives was highly consistent over time and unrelated to local bathymetry. Blue whales (*Balaenoptera musculus*) are known to primarily migrate and feed in the first few hundred metres of the water column (Croll et al. 2001, Goldbogen et al. 2011), with the deepest dive being reported from a pygmy blue whale (*Balaenoptera musculus brevicauda*) being 506 m (Owen et al. 2016).

Owen et al. (2016) identified dives for their tagged animal as migratory, feeding, or exploratory behaviour. The mean depth of migratory dives (82% of all dives) was 14 ± 4 m, and the whale spent 94% of observed time and completed 99% of observed migratory dives at water depths of less than 24 m. A total of 21 feeding dives were identified during the duration of the tag deployment (one week) with a mean maximum depth of 129 ± 183 m (13–505 m range). The mean maximum depth of exploratory dives (107 ± 81 m, 23–320 m range) was similar to the mean maximum depth of feeding dives (129 m) and did not appear to be related to seafloor depth.

Croll et al. (2001) explicitly reports on non-foraging dives for an adult blue whale, while other research, such as Calambokidis et al. (2007) and Oleson et al. (2007), do not. A digitisation of the data presented in Croll et al. (2001) therefore defines shallow, or migratory dives, to have a mean depth of 26.9 ± 1.2 m. This migratory dive depth has been used instead of the sub-adult dive depth presented in Owen et al. (2016); however, the exploratory dive depth data in Owen et al. (2016) was still applied.

The behaviour of pygmy blue whales was modelled without migration bias, i.e., the animats were resident in the animat modelling area over the entire modelling period. In reality, pygmy blue whales can be expected to transit through the area in less than half a day (based on McCauley and Jenner 2010). Accordingly, the approach used is conservative as it results in higher exposure levels and a higher number of animals exposed to levels exceeding the criteria thresholds.

The two migratory behaviours (migratory dives and exploratory dives) were modelled at an even probability of occurrence (i.e., probability for transitioning from one behaviour to another was 0.5 for both), while dive data published by Owen et al. (2016) suggest a higher likelihood for migratory dives to occur. This approach was chosen in the absence of quantitative information on the true proportion between the two dive behaviours.

5. Results

A summary of exposure ranges for migrating pygmy blue whales is included in Table 3. Maximum exposure ranges over all six 24 h segments are provided. Exposure ranges to peak thresholds were not computed for this analysis, but acoustic ranges are provided for reference.

Table 3. Summary of animat simulation results for migratory pygmy blue whales. The 95th percentile exposure ranges are provided. For comparison, maximum distances to threshold from previously completed acoustic modelling are provided.

Threshold		**Maximum distance (km) to threshold from acoustic modelling**	**Migrating pygmy blue whale range, $ER_{95\%}$ (km)**
Description	Sound level (dB)		
TTS, PK	213*	0.06	-
TTS, SEL_{24h}	168†	65.4	23.80
PTS, PK	219*	0.03	-
PTS, SEL_{24h}	183†	2.34	0.12
Behavioural response	160‡	9.6	6.60

* PK (L_{pk}; dB re 1 µPa)
† LF-weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
‡ SPL (L_p; dB re 1 µPa)
A dash indicates where ranges were not relevant for PK exposures (see Section 4.1.2)

The exposure ranges are strongly dependent on the location of the source relative to the BIA. To demonstrate the impact of this effect, exposure ranges to SEL PTS and TTS thresholds were analysed in 24 h segments. Figure 4 shows the entire track coloured by day of the simulated survey, where the start of the survey is at the northwest corner of the survey area. All daily tracks are 24 h in length. Table 4 summarises the exposure ranges computed for each day.

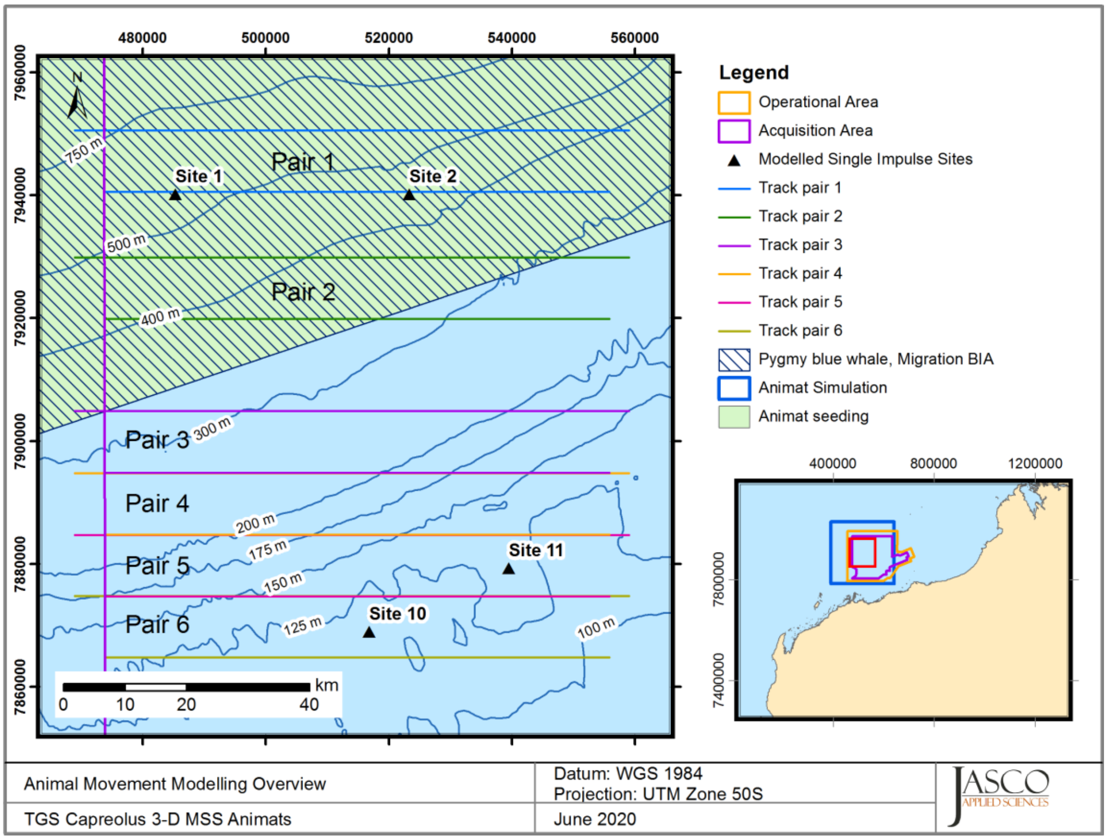

Figure 4. Seismic source tracks used in animal movement modelling, coloured by day of survey.

Table 4. Exposure ranges ($ER_{95\%}$) for both permanent threshold shift (PTS) and temporary threshold shift (TTS) 24 h sound exposure level (SEL_{24h}) thresholds for each day of the simulated survey.

Track line pair	Range, $ER_{95\%}$, km	
	PTS, SEL_{24h}	TTS, SEL_{24h}
1	0.10	22.92
2	0.12	20.47
3	0.11	23.80
4	-	23.29
5	-	23.79
6	-	-

6. Discussion

The estimated sound fields produced by source and propagation models for the seismic survey were incorporated into a sound exposure model to estimate the range within which 95% of the exposure exceedances occur ($ER_{95\%}$).

Exposure ranges ($ER_{95\%}$) to SEL thresholds were 0.12 km for PTS and 23.80 km for TTS. All predicted $ER_{95\%}$ exposure ranges to SEL thresholds were lower than the corresponding ranges to threshold estimated from propagation modelling or accumulated SEL_{24h} results presented in Koessler and McPherson (2020) Previous modelling efforts were inherently more conservative because they did not incorporate the complex interactions of both a moving sound field and moving receivers, but rather assumed a static receiver.

There is potential for behavioural impact, with $ER_{95\%}$ of 6.60 km predicted based on exposure modelling. This is only slightly shorter than the range predicted by acoustic modelling, but this expected because it is based on the single loudest exposures experienced by each of the animats in the simulation.

The 24 h analysis of $ER_{95\%}$ underscored the fact that most impact to pygmy blue whales is predicted to occur when the seismic vessel is within, or adjacent to, the BIA boundary. No PTS SEL_{24h} exposures were predicted for the final three line pairs assessed, and no TTS SEL_{24h} exposures were predicted for the final day of the scenario, the last line pair. Any day where the minimum range from the seismic source to the BIA was longer than the $ER_{95\%}$ will have no modelled exposures.

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Appendix A. Acoustic Metrics

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially 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}; $L_{p,\text{pk}}$; dB re 1 µPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max\left(|p(t)|\right)}{p_0}\right] \tag{A-1}$$

PK is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a noise event, it is generally a poor indicator of perceived loudness.

The peak-to-peak sound pressure level (PK-PK; $L_{\text{pk-pk}}$; $L_{p,\text{pk-pk}}$; 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, $p(t)$:

$$L_{p,pk-pk} = 10\log_{10}\left\{\frac{\left[\max\left(p(t)\right)-\min\left(p(t)\right)\right]^2}{p_0^2}\right\} \tag{A-2}$$

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:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \tag{A-3}$$

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; $L_{E,\text{p}}$; 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):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \tag{A-4}$$

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:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right). \qquad \text{(A-5)}$$

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 $\mu Pa^2 \cdot s$. 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 $\mu Pa^2 \cdot s$.

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 PTS (and TTS) 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:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a \left[1+(f/f_{hi})^2\right]^b}\right)\right] \tag{A-6}$$

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

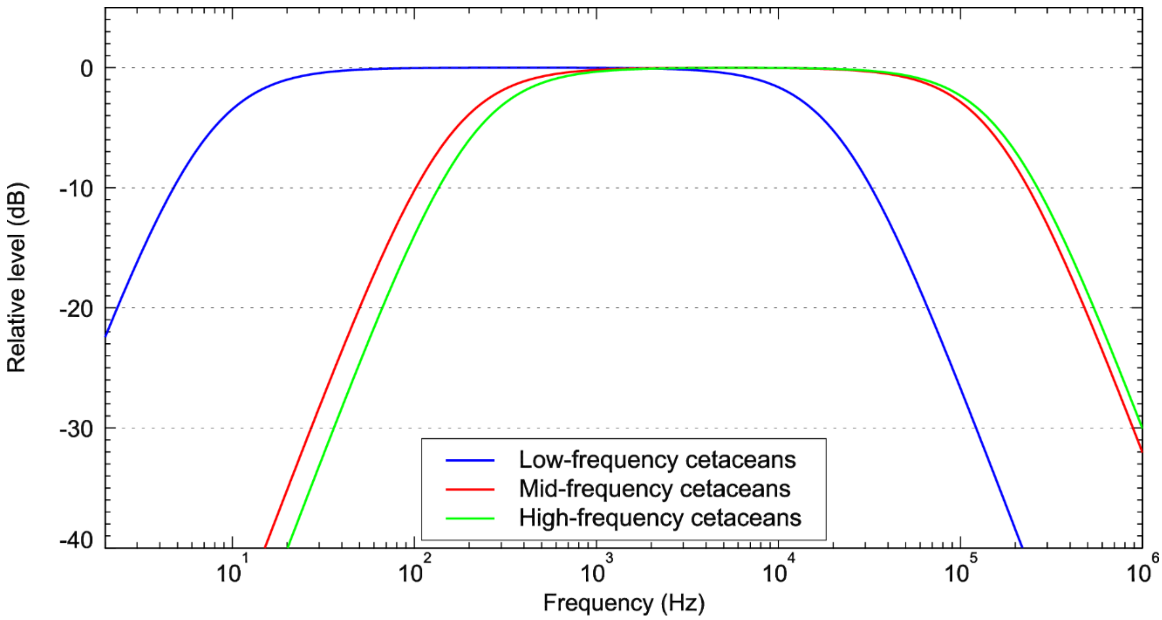

Figure A-1. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by NMFS (2018).

Appendix B. Animal Movement and Exposure Modelling

Animal movement and exposure modelling takes into account the movement of both sound sources and animals over time. Acoustic source and propagation modelling are used to generate 3-D sound fields that vary as a function of range, depth, and azimuth. Sound sources are modelled at several representative sites and the resulting sound fields are assigned to seismic shot locations using the minimum Euclidean distance. The sound received by an animal at any given time depends on its location relative to the source. Because the true locations of the animals within the sound fields are unknown, realistic animal movements are simulated using repeated random sampling of various behavioural parameters. The Monte Carlo method of simulating many animals within the operations area is used to estimate the sound exposure history of the population of simulated animals (animats).

Monte Carlo methods provide a heuristic approach for determining the probability distribution function (PDF) of complex situations, such as animals moving in a sound field. The probability of an event's occurrence is determined by the frequency with which it occurs in the simulation. The greater the number of random samples, in this case the more simulated animats, the better the approximation of the PDF. Animats are randomly placed, or seeded, within the simulation boundary at a specified density (animats/km^2). Higher densities provide a finer PDF estimate resolution but require more computational resources. To ensure good representation of the PDF, the animat density is set as high as practical allowing for computation time. The animat density is much higher than the real-world density to ensure good representation of the PDF. The resulting PDF is scaled using the real-world density.

Several models for marine mammal movement have been developed (Ellison et al. 1987, Frankel et al. 2002, Houser 2006). These models use an underlying Markov chain to transition from one state to another based on probabilities determined from measured swimming behaviour. The parameters may represent simple states, such as the speed or heading of the animal, or complex states, such as likelihood of participating in foraging, play, rest, or travel. Attractions and aversions to variables like anthropogenic sounds and different depth ranges can be included in the models.

The JASCO Animal Simulation Model Including Noise Exposure (JASMINE) was based on the open-source marine mammal movement and behaviour model (3MB, Houser 2006) and used to predict the exposure of animats (virtual pygmy blue whales) to sound arising from the seismic activities. Animats are programmed to behave like the pygmy blue whales likely to be present in the survey area. The parameters used for forecasting realistic behaviours (e.g., diving, foraging, aversion, surface times, etc.) are determined and interpreted from marine species studies (e.g., tagging studies) where available, or reasonably extrapolated from related species. An individual animat's modelled sound exposure levels are summed over the total simulation duration to determine its total received energy, and then compared to the assumed threshold criteria.

JASMINE uses the same animal movement algorithms as 3MB (Houser, 2006), but has been extended to be directly compatible with MONM and FWRAM acoustic field predictions, for inclusion of source tracks, and importantly for animats to change behavioural states based on time and space dependent modelled variables such as received levels for aversion behaviour, although aversion was not considered in this study.

B.1. Animal Movement Parameters

JASMINE uses previously measured behaviour to forecast behaviour in new situations and locations. The parameters used for forecasting realistic behaviour are determined (and interpreted) from marine species studies (e.g., tagging studies). Each parameter in the model is described as a probability distribution. When limited or no information is available for a species parameter, a Gaussian or uniform distribution may be chosen for that parameter. For the Gaussian distribution, the user determines the mean and standard deviation of the distribution from which parameter values are drawn. For the uniform distribution, the user determines the maximum and minimum distribution from which parameter values are drawn. When detailed information about the movement and behaviour of a species are available, a user-created distribution vector, including cumulative transition probabilities, may be used (referred to here as a vector model; Houser 2006). Different sets of parameters can be defined for different behaviour states. The probability of an animat starting out in or transitioning into a given behaviour state can in turn be defined in terms of the animat's current behavioural state, depth, and the time of day. In addition, each travel parameter and behavioural state has a termination function that governs how long the parameter value or overall behavioural state persists in simulation.

The parameters used in JASMINE describe animal movement in both the vertical and horizontal planes. The parameters relating to travel in these two planes are briefly described below.

Travel sub-models

- **Direction**– determines an animat's choice of direction in the horizontal plane. Sub-models are available for determining the heading of animats, allowing for movement to range from strongly biased to undirected. A random walk model can be used for behaviours with no directional preference, such as feeding and playing. In a random walk, all bearings are equally likely at each parameter transition time step. A correlated random walk can be used to smooth the changes in bearing by using the current heading as the mean of the distribution from which to draw the next heading. An additional variant of the correlated random walk is available that includes a directional bias for use in situations where animals have a preferred absolute direction, such as migration. A user-defined vector of directional probabilities can also be input to control animat heading. For more detailed discussion of these parameters, see Houser (2006) and Houser and Cross (1999).
- **Travel rate**–defines an animat's rate of travel in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models

- **Ascent rate**–defines an animat's rate of travel in the vertical plane during the ascent portion of a dive.
- **Descent rate**–defines an animat's rate of travel in the vertical plane during the descent portion of a dive.
- **Depth**–defines an animat's maximum dive depth.
- **Reversals**–determines whether multiple vertical excursions occur once an animat reaches the maximum dive depth. This behaviour is used to emulate the foraging behaviour of some marine mammal species at depth. Reversal-specific ascent and descent rates may be specified.
- **Surface interval**–determines the duration an animat spends at, or near, the surface before diving again.

B.1.1. Exposure Integration Time

The interval over which acoustic exposure (L_E) should be integrated and maximal exposure (L_p) determined is not well defined. Both Southall et al. (2007) and the NMFS (2018) recommend a 24 h baseline accumulation period, but state that there may be situations where this is not appropriate (e.g., a high-level source and confined population). Resetting the integration after 24 h can lead to overestimating the number of individual animals exposed because individuals can be counted multiple times during an operation. The type of animal movement engine used in this study simulates realistic movement using swimming behaviour collected over relatively short periods (hours to days) and does not include large-scale movement such as migratory circulation patterns. For this study, 5.2 days were modelled, but then scaled down to 24 h.

Ideally, a simulation area is large enough to encompass the entire range of a population so that any animal that could approach the seismic survey area during an operation is included. However, there are limits to the simulation area, and computational overhead increases with area. For practical reasons, the simulation area is limited in this analysis to a maximum distance from the seismic survey operations. In the simulation, every animat that reaches a border is replaced by another animat entering at the opposing border—e.g., an animat crossing the northern border of the simulation is replaced by one entering the southern border at the same longitude. When this action places the animat in an inappropriate water depth, the animat is randomly placed on the map at a depth suited to its species definition. The exposures of all animats (including those leaving the simulation and those entering) are kept for analysis. This approach maintains a consistent animat density and allows for longer integration periods with finite simulation areas.

B.1.2. Seeding Density and Scaling

The exposure criteria for impulsive sounds were used to determine the number of animats exceeding exposure thresholds. To generate statistically reliable probability density functions, all simulations were seeded with an animat density of 2 animats/km^2 over the entire simulation area. To evaluate potential injury or behavioural disruptions, threshold exceedance was determined in a 24 h time window.

B.2. Pygmy Blue Whale Species Details

Table B-1. *Migrating pygmy blue whales*: Data values and references input in JASMINE to create diving behaviour (number values represent means [standard deviations] unless otherwise indicated).

Behaviour	Variable	Value	Reference
Migratory dive	Travel direction	Correlated random walk	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 0.78 (0.61)	Sears and Perrin (2009), Owen et al. (2016)
	Ascent rate (m/s)	Gaussian 0.7 (0.2)	Goldbogen et al. (2011)
	Descent rate (m/s)	Gaussian 1.5 (0.1)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 26.8 (1.5)	Croll et al. (2001)
	Reversals	No	Owen et al. (2016)
	Surface interval (s)	Gaussian 78.0 (30.2)	Acevedo-Gutiérrez et al. (2002)
	Bout duration (s)	Gaussian 12060 (1800)	Owen et al. (2016)
Exploratory dive	Travel direction	Correlated random walk	Houser (2006), D. Houser, pers.comm.
	Perturbation value	10	Houser (2006), D. Houser, pers.comm.
	Termination coefficient	0.2	Houser (2006), D. Houser, pers.comm.
	Travel rate (m/s)	Gaussian 1.25 (0.42)	Sears and Perrin (2009)
	Ascent rate (m/s)	Gaussian 1.6 (0.5)	Goldbogen et al. (2011)
	Descent rate (m/s)	Gaussian 2.6 (0.5)	Goldbogen et al. (2011)
	Dive depth (m)	Gaussian 107.0 (81.0)	Owen et al. (2016)
	Reversals	No	Owen et al. (2016)
	Surface interval (s)	Gaussian 162.0 (66.0)	Goldbogen et al. (2011)
	Bout duration (s)	Gaussian 516 (120)	Owen et al. (2016)
General	Shore following (m)	30	Approximated
	Depth limit on seeding (m)	100.0 (minimum), 110000.0 (maximum)	Approximated

APPENDIX G OIL SPILL MODELLING REPORT

TGS CAPREOLUS-2 3D MSS OIL SPILL MODELLING

Oil Spill Modelling

MAQ0892J
TGS Capreolus-2 3D MSS Oil Spill Modelling
Rev1
15 January 2020

rpsgroup.com

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
Rev0	Draft issued for client review	Jordan Glen	Jeremie Bernard	Dr Sasha Zigic	27 November 2019
Rev1	Final report		Jeremie Bernard	Dr Sasha Zigic	15 January 2020

Approval for issue

Dr Sasha Zigic	S. Zigic	15 January 2020

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EXECUTIVE SUMMARY

Background

TGS-NOPEC Geophysical Company Pty Ltd (TGS) proposes to undertake the Capreolus-2 3D Marine Seismic Survey (MSS) in the Roebuck Basin, off the north-west coast of Western Australia. As part of the operation, an oil spill modelling study was conducted to assist in the development of the Oil Pollution Emergency Plan (OPEP) and Environmental Plan (EP).

The study assessed the risk and potential exposure to the surrounding waters and contact to the shorelines from a hypothetical hydrocarbon spill scenario due to a survey vessel tank rupture and in turn releasing 1,062 m^3 of marine diesel oil (MDO) over 6 hours on the sea surface. Due to the size of the Operational Area, stochastic modelling was conducted at 3 release sites, which were carefully selected based on proximity to shorelines and sensitive receptors. Results are based on an annual assessment (combined seasons).

Methodology

The modelling study was carried out in several stages. Firstly, a five-year current dataset (2013–2017) that includes the combined influence of large-scale ocean and nearshore tidal currents was developed. Secondly, the currents, local winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or probabilistic) approach, which involved running 100 randomly selected single trajectory simulations per release location for an annual period, with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but varying start time. This ensured that each spill trajectory was subjected to varying wind and current conditions.

Oil Properties

The marine diesel oil (MDO) used for the this assessment has a density of 829.1 kg/m^3 (API gravity of 37.6) and a dynamic viscosity of 4.0 cP at 25ºC, classifying it as a Group II light persistent oil according to the International Tankers Owners Pollution Federation (ITOPF, 2014) and USEPA/USCG classifications. MDO is characterised by a high percentage of volatile components (95%), which will evaporate when on the sea surface. It also contains 5% persistent hydrocarbons, which will not evaporate and will breakdown over time. It is important to note that some heavy components contained in MDO have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but can re-float to the surface if these energies abate.

Results

- Shoreline contact was only predicted for Release Site 2 at Bedout Island, which has a 7% probability at the low threshold.

- The maximum distance from a release site to low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥50 g/m^2) exposure levels on the sea surface were 115.0 km west-northwest (Release Site 3), 66.4 km south-southwest (Release Site 3) and 19 km west-northwest (Release Site 1), respectively.

- In the surface layer (0-10 m), the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 1% for Montebello Australian Marine Park (AMP), Ancient coastline at 125 m depth contour, Continental Slope Demersal Fish Communities and Glomar Shoals KEFs to 27% for the Pilbara (offshore) IMCRA at Release Site 1. At Release Site 2, the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 5% for Roebourne Interim Biogeographic Regionalisation for Australia (IBRA) and Northwest Shelf IMCRA to 66% for Eighty Mile Beach AMP. At Release Site 3, the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 1% for the Ancient coastline at 125 m depth contour KEF to 3% for the Northwest Shelf IMCRA. No receptors were predicted to be exposed at the moderate or high dissolved hydrocarbon exposure thresholds for Release Site 3, while no receptors were predicted to be exposed at the high hydrocarbon exposure threshold for Release Site 1 and 2.

- In the surface layer (0-10 m), the Argo-Rowley Terrace, Eighty Mile Beach, Gascoyne and Montebello AMPs were all predicted to be exposed to entrained hydrocarbons at the low threshold concentration at each Release Site with probabilities ranging from 1% (multiple receptors) to 100% (Eighty Mile Beach, Release Site 2). Additionally, the Ancient coastline at 125 m depth contour, Continental Slope Demersal Fish Communities, Exmouth Plateau and Glomar Shoals KEFs as well as Glomar Shoal, Rankin Bank RSBs and Western Australia State Waters all were predicted to be exposed to entrained hydrocarbons at the low threshold concentration at each Release Site with probabilities ranging from 2% (Glomar Shoal and Rankin Bank RSBs, Release Site 3) to 84% (Western Australia State Waters, Release Site 2). Additionally, a number of receptors were predicted to be exposed at the high entrained hydrocarbon threshold concentration with probabilities ranging from 1% (multiple receptors) to 97% (Eighty Mile Beach, Release Site 2).

1 INTRODUCTION

1.1 Background

TGS-NOPEC Geophysical Company Pty Ltd (TGS) proposes to undertake the Capreolus-2 3D Marine Seismic Survey (MSS) in the Roebuck Basin, off the north-west coast of Western Australia. Figure 1.1 shows the proposed Operational Area.

In order to support the development of the Environment Plan (EP) and Oil pollution Emergency Plan (OPEP), Environmental Resources Management Australia Pty Ltd (ERM), on behalf of TGS, has commissioned RPS to undertake a comprehensive oil spill modelling study for the proposed Capreolus-2 3D MSS.

The study assessed the risk and potential exposure to the surrounding waters and contact to shorelines from a hypothetical spill originating from the survey vessel tank rupture, releasing 1,062 m^3 of marine diesel oil over 6 hours on the sea surface.

Due to the size of the Operational Area, stochastic modelling was conducted at 3 release sites, which were carefully selected based on proximity to shorelines and sensitive receptors. The coordinates of the release sites are shown in Table 1.1 and graphically in Figure 1.1. The results are presented on an annual basis (combined seasons).

The purpose of the modelling is to provide an understanding of a conservative 'outer envelope' of the potential area that may be affected in the unlikely event of a hydrocarbon release. The modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill. Therefore, the modelling results represent the maximum extent that the released hydrocarbon may influence.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping Analysis Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

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*" (ASTM, 2013).

Table 1.1 Coordinates of the release sites used in the oil spill modelling.

Release Site	Latitude	Longitude	Water Depth (mLAT)
1	19° 56' 29.8998" S	116° 57' 26.517" E	~63
2	19° 29' 56.241" S	119° 5' 46.3194" E	~38
3	18° 8' 55.1328" S	118° 26' 31.095" E	~264

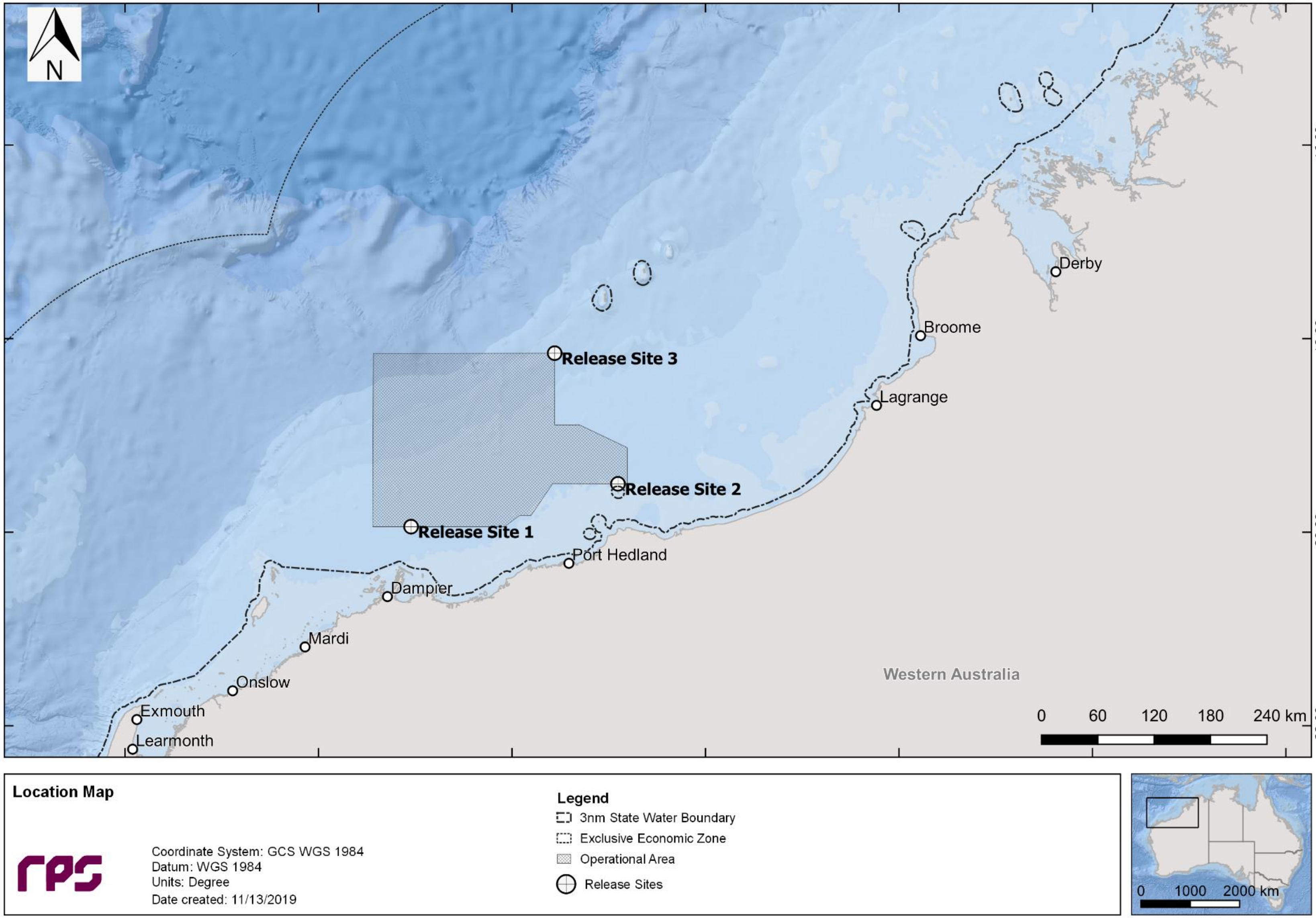


Figure 1.1 Location of the Capreolus-2 3D MSS Operational Area and the release sites used in the oil spill modelling study.

1.2 Scope of Work

The scope of work included the following components:

1. Generate five years of winds and three-dimensional currents from 2013 to 2017 (inclusive). The currents include the combined influence of ocean and tidal currents.

2. Use wind data, current data and MDO characteristics were input into the three-dimensional oil spill model SIMAP, to predict the movement, spreading, entrainment, weathering and potential oil contact to the shoreline over time;

3. Stochastic modelling was carried out to determine the potential exposure to the sea surface, water column and shoreline contact. This involved running 100 randomly selected single simulations per release site (or a total of 300 simulations), with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but the start times were randomly selected to occur at any point throughout the year. This ensured that each simulation was subjected to unique wind and current conditions;

4. Combine the 100 simulations completed for each release site into a single stochastic output to map the zone of potential exposure, calculate the probability and minimum time to contact to receptors by hydrocarbons on the sea-surface, shoreline and water column (entrained and dissolved) for defined thresholds, as well as the predicted shoreline loading (if any); and

5. From the stochastic modelling results, identify the “worst case” deterministic run with the largest oil swept area on the sea surface above 1 g/m^2 (low surface oil exposure threshold).

2 REGIONAL CURRENTS

Literature suggests that waters within the Operational Area would be influenced by the dual effect of the Indonesian Throughflow (ITF) and the Leeuwin Current (LC). The ITF is a large scale current system characterised as a series of migrating gyres that flow through the region bringing warmer waters from the Arafura Sea and Gulf of Carpentaria (DEWHA 2008). As these gyres migrate through the area via the South Equatorial Current (SEC) and Eastern Gyral Current (EGC) large spatial variations in the speed and direction of currents occurs. The LC, which is linked to the ITF, SEC and EGC, flows strongly southwards along the Western Australian coastline (Godfrey & Ridgeway 1985; Holloway 1993; Holloway & Nye 1985) (Figure 2.1).

The Northwest Shelf is subject to strong seasonal variability, which affects the strength of Indonesian Throughflow and Leeuwin Current. The weakest southwards flow occurs from November to April (Sampey et al. 2004). Maximum flow velocities are experienced during autumn and winter. A comprehensive description of the circulation patterns of the Northwest Shelf is provided in a review by Condie & Andrewartha (2008). A schematic of the ocean currents along the Northwest Australian continental shelf is shown in Figure 2.1.

While, the tidal currents are generally weaker in the deeper waters (beyond the Gulf), its influence is greatest along the near shore, within the Gulf, coastal passage regions and, in and around the 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.

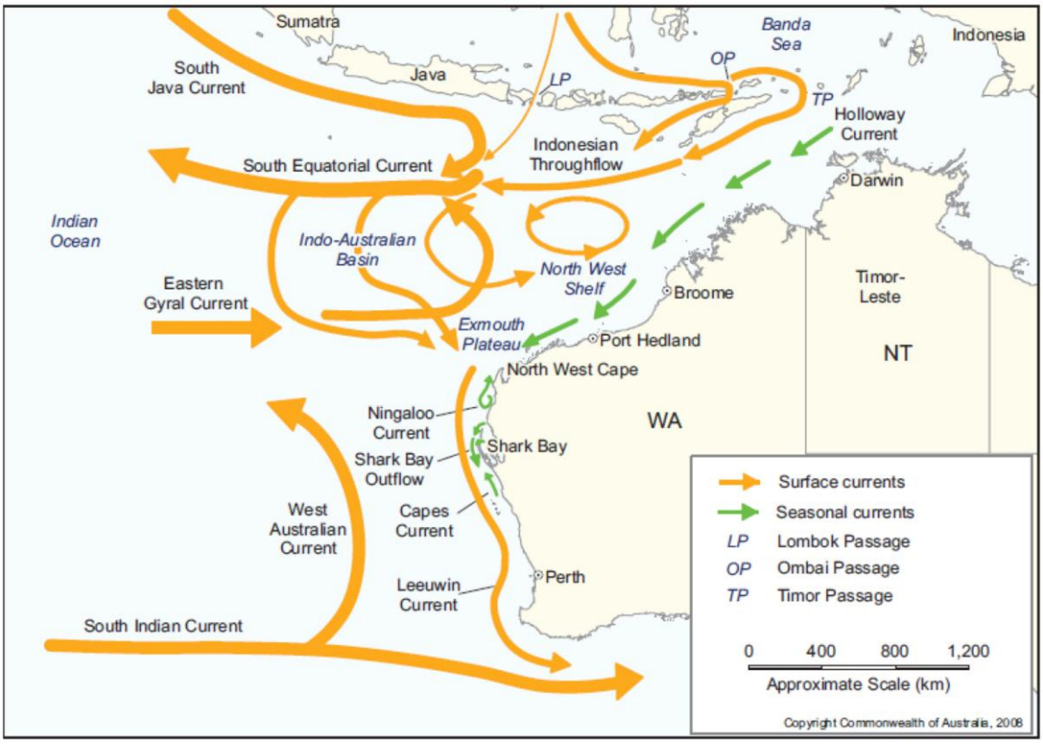


Figure 2.1 Schematic of ocean currents along the Northwest Australian continental shelf. Image adapted from DEWHA (2008).

2.1 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 for more than 30 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 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).

2.1.1 Grid Setup

The tidal model domain has been 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 2.2 shows the tidal model grid covering the study domain.

A combination of datasets was used and merged to describe the shape of the seabed within the grid domain (Figure 2.3). 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).

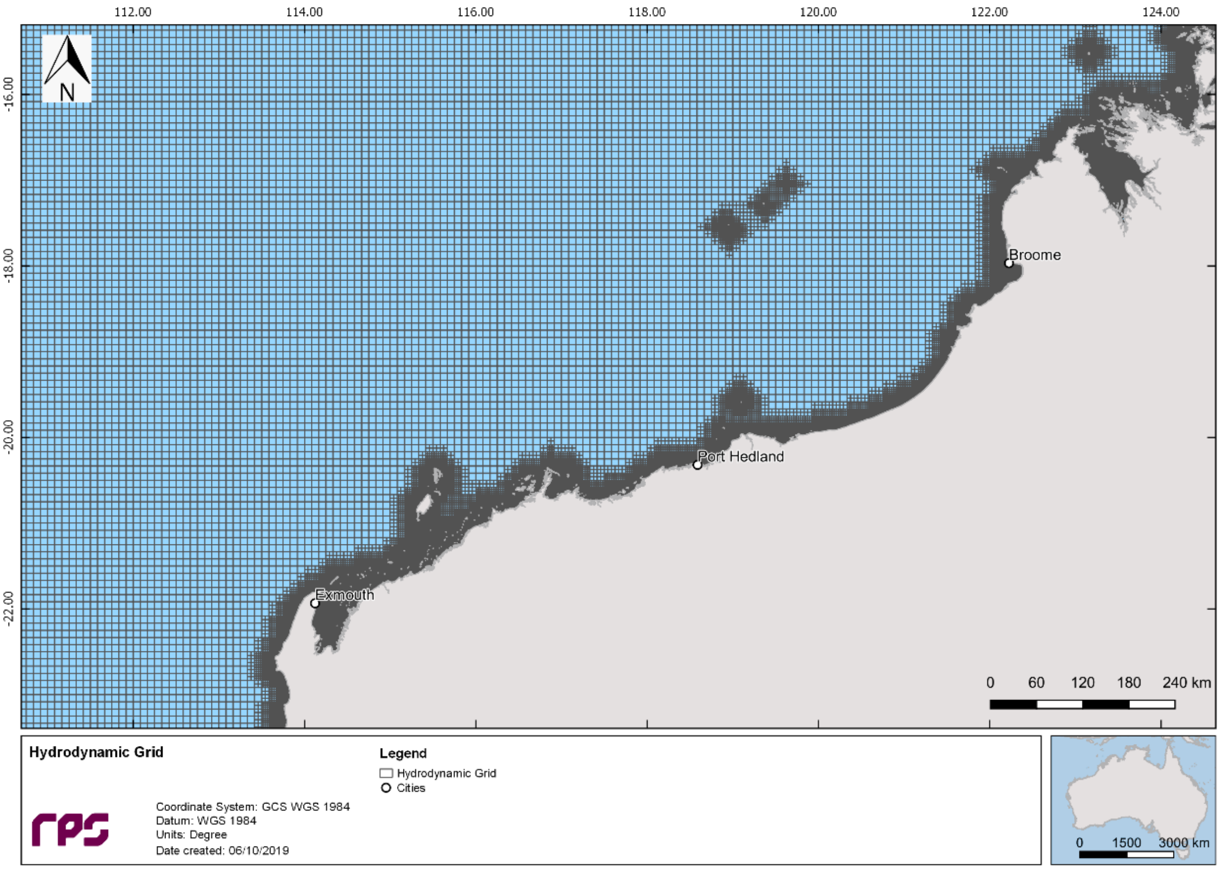


Figure 2.2 Sample of the model grid used to generate the tidal currents for the study region. Higher resolution areas are shown by the denser mesh.

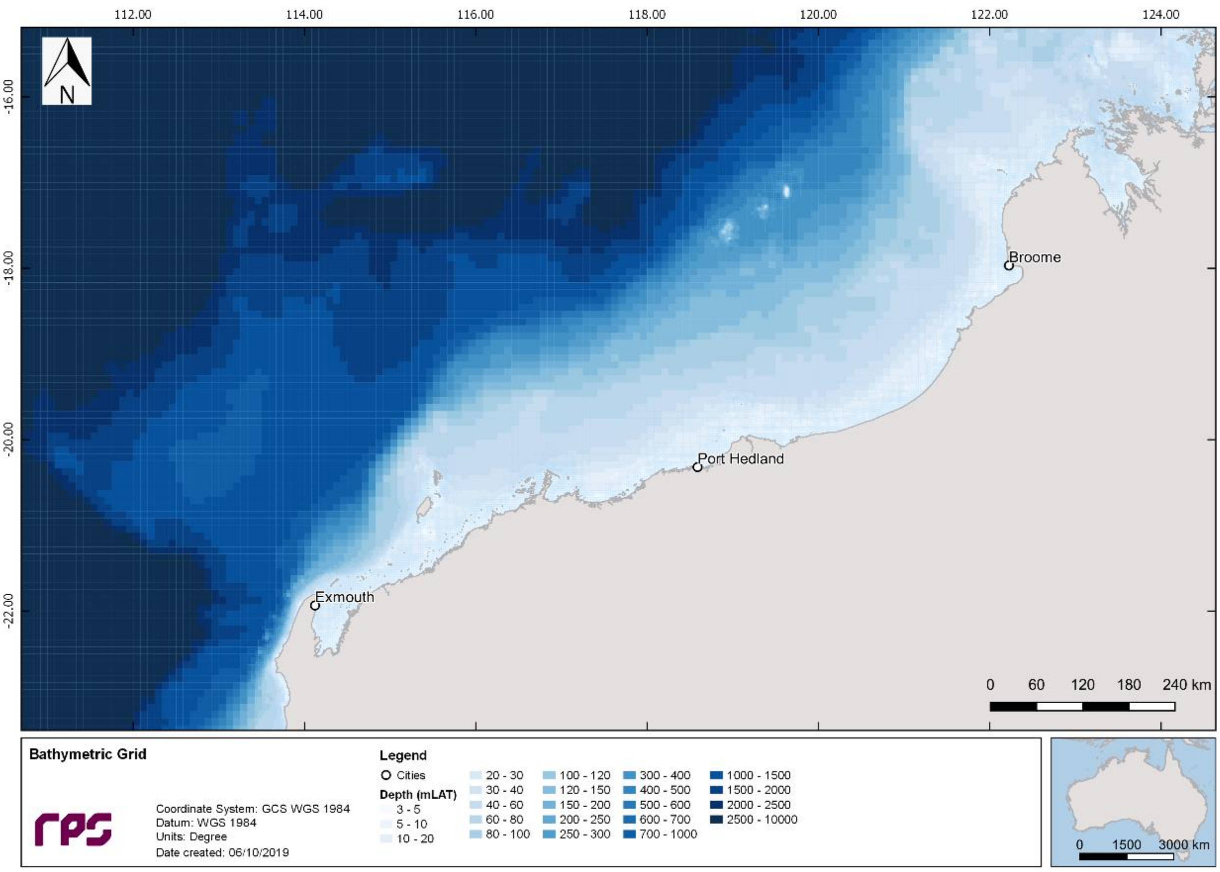


Figure 2.3 Bathymetry defined throughout the tidal model domain.

2.1.2 Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provides estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model. 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 is produced and quality controlled by the National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters that were capable of taking sea level measurements to an accuracy of less than 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005; see Fu et al., 1994; NASA/Jet Propulsion Laboratory 2013a; 2013b). 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 the subject of 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 accurate for this study.

2.1.3 Surface Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at seven locations (see Figure 2.4).

To provide a statistical measure of the models performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982 and Willmott & 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:

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i| \quad \text{Eq.1}$$

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:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2} \quad \text{Eq.2}$$

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 2.5 and Figure 2.6 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 2.1 shows the IOA and MAE values for the selected locations.

Table 2.1 Statistical comparison between the observed and HYDROMAP predicted surface elevations.

Tide Station	IOA	MAE (m)
Learmonth	0.98	0.14
Onslow	0.96	0.17
Barrow Island - Tkr Mrg	0.98	0.21
Cape Legendre	0.98	0.27
Port Walcott	0.98	0.30
Port Hedland	0.98	0.34
Red Bluff	0.99	0.30

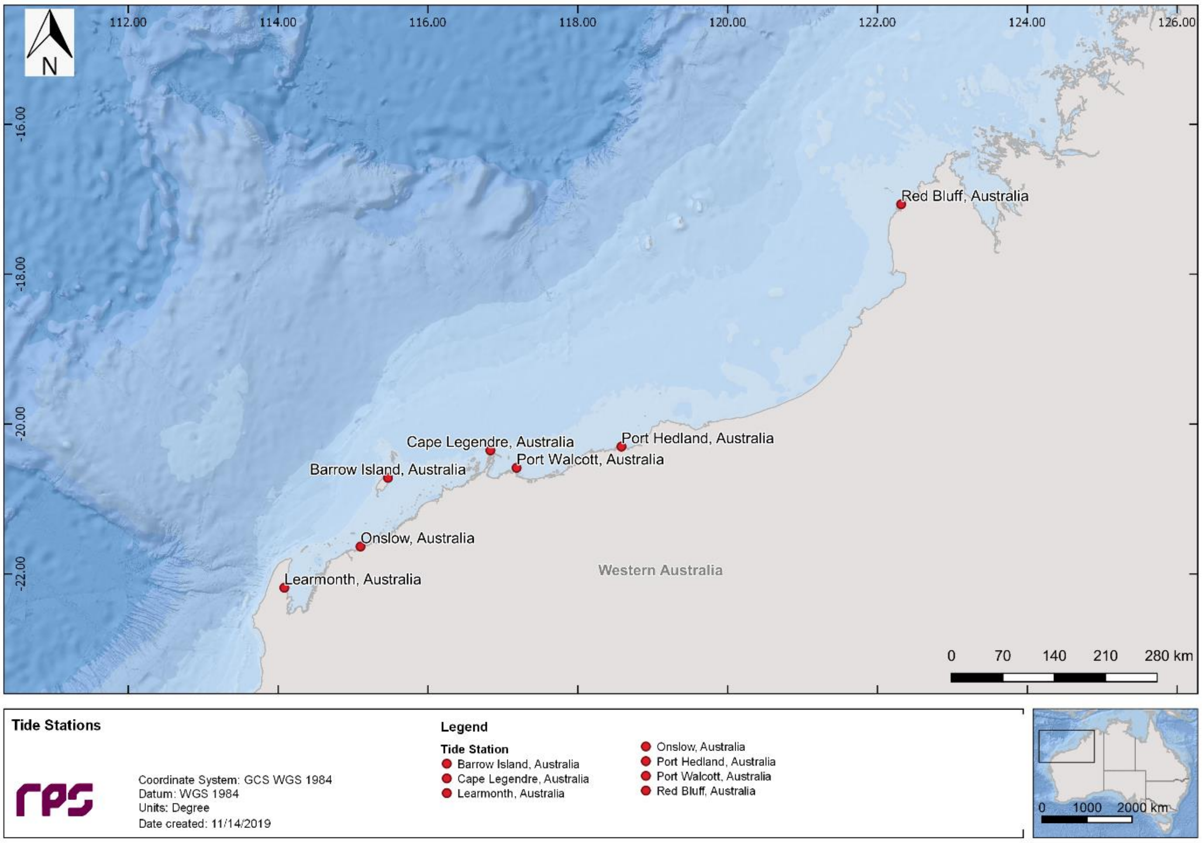


Figure 2.4 Location of the tide stations used for the HYDROMAP surface elevation validation.

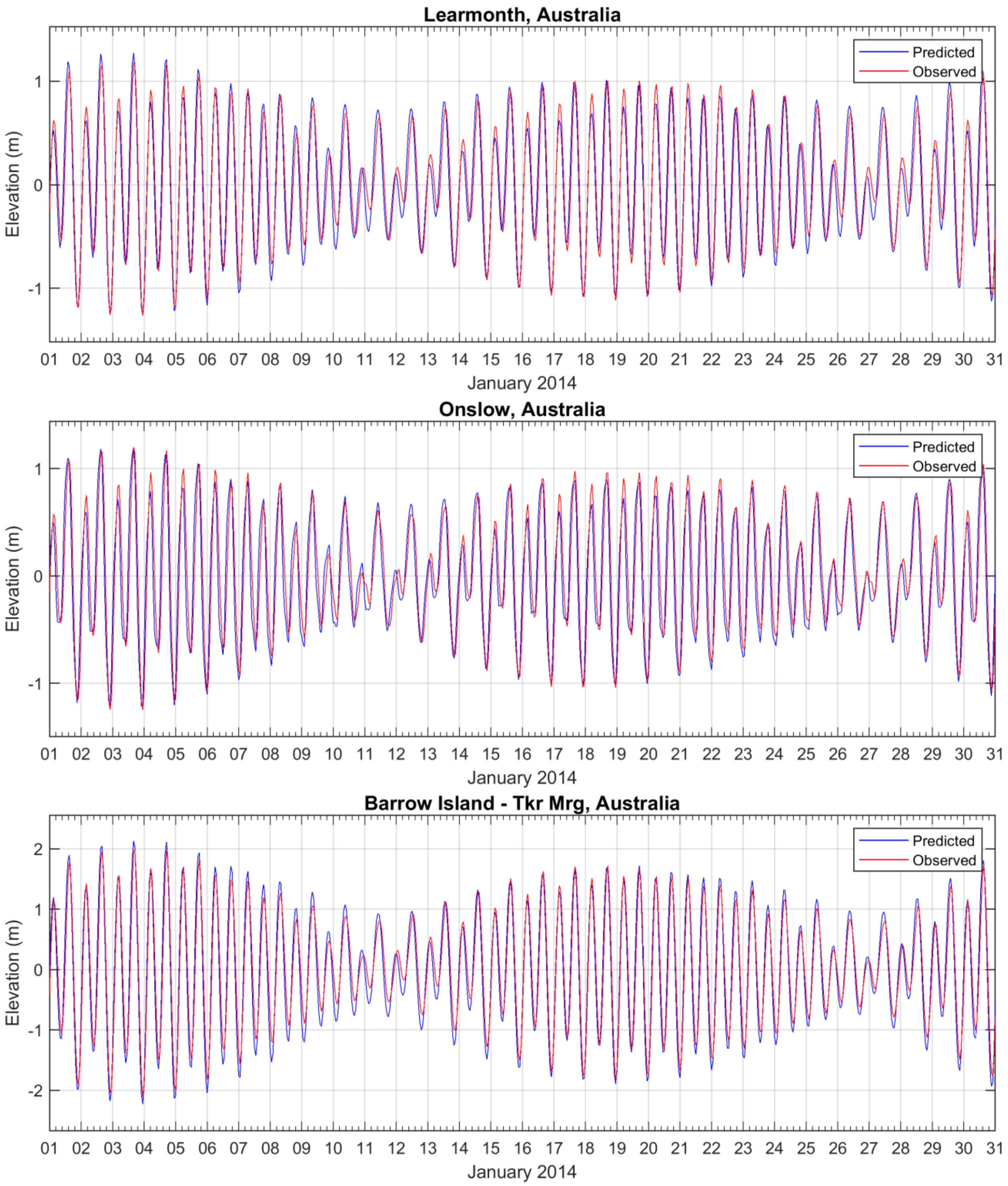


Figure 2.5 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation at tidal stations Learmonth (upper image), Onslow (middle image) and Barrow Island – Tkr Mrg (lower image).

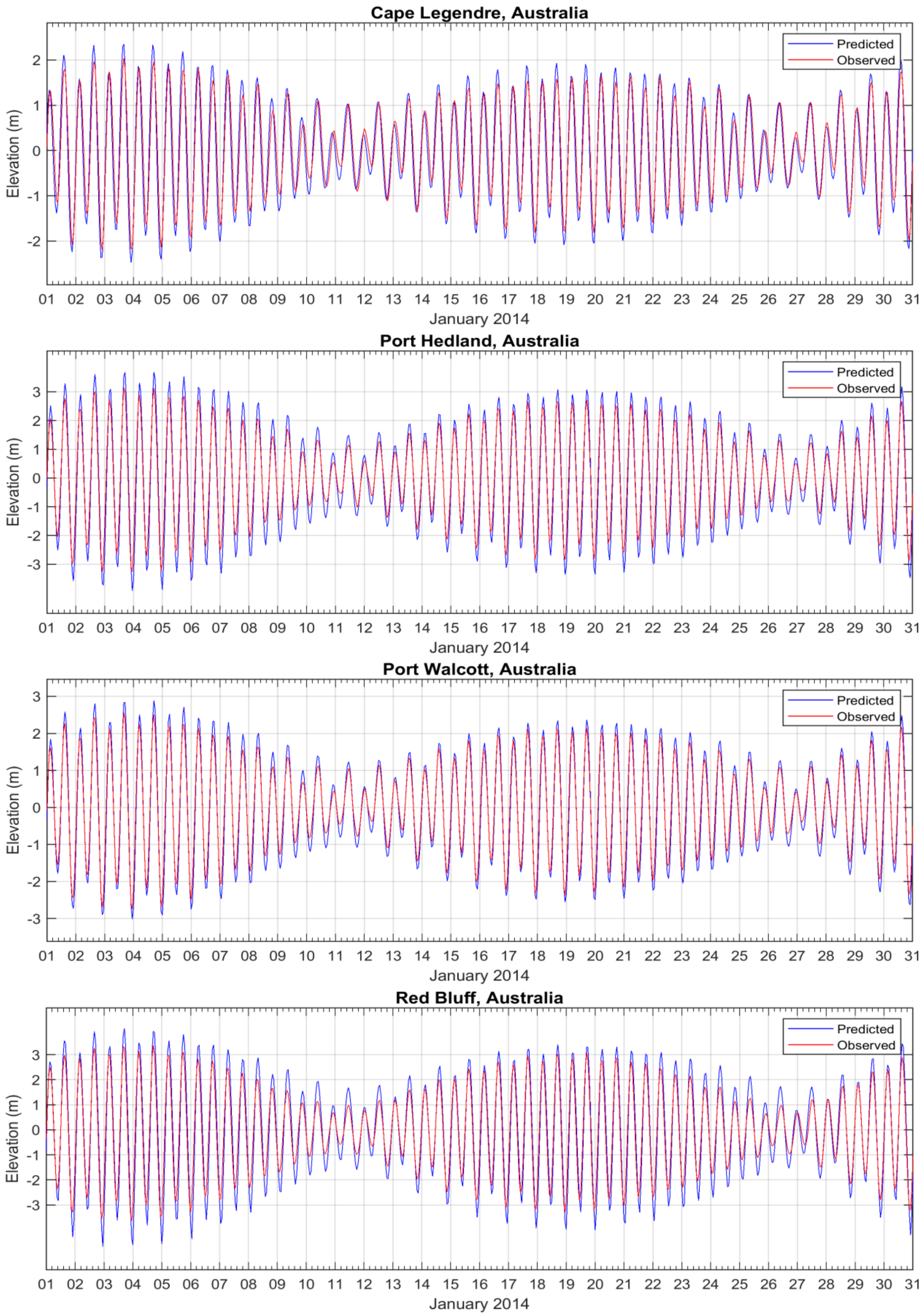


Figure 2.6 Comparison between HYDROMAP predicted (blue line) and observed (red line) surface elevation at tidal stations Cape Legendre (upper image), Port Hedland (upper middle image) Port Walcott (lower middle image) and Red Bluff (lower image).

2.2 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, 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 hindcast current dataset was obtained for the years 2013 to 2017 (inclusive). Figure 2.7 shows an example of the mean modelled surface ocean currents (HYCOM) during winter conditions.

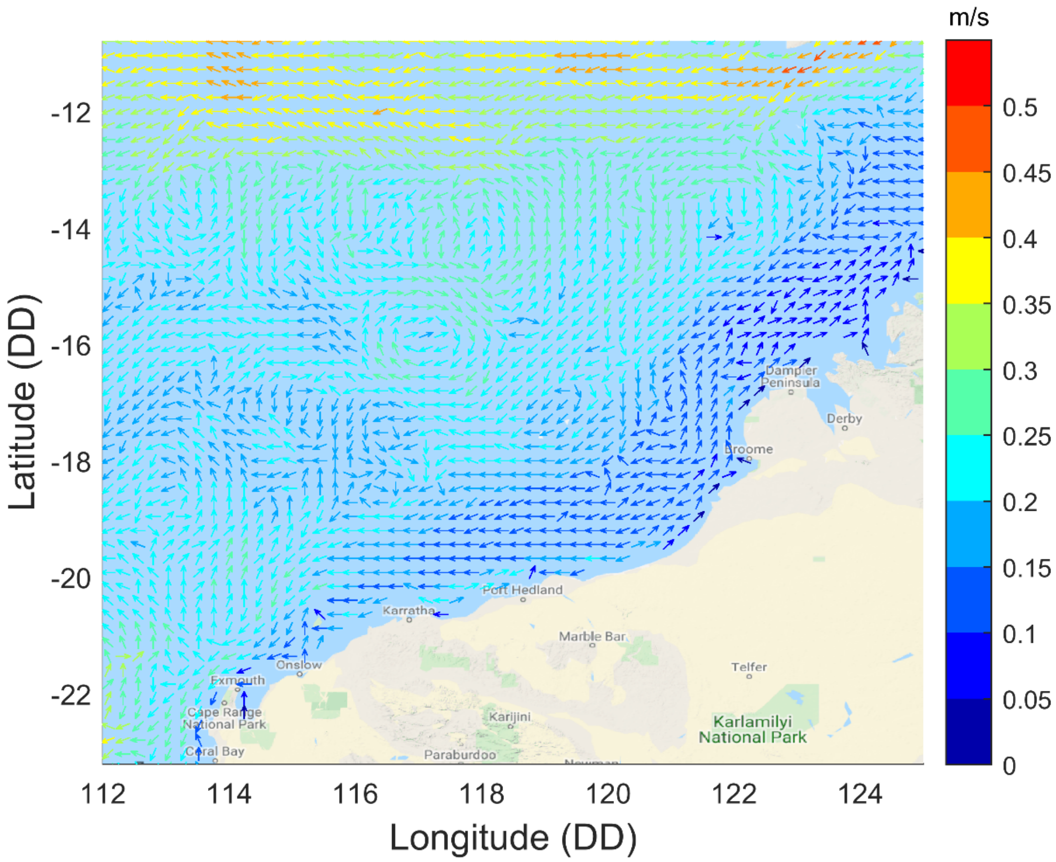


Figure 2.7 Example mean surface ocean currents during winter conditions.

2.3 Surface Currents

Surface currents presented herein resulted from the combination of HYCOM large-scale ocean currents and HYDROMAP nearshore tidal currents to account for the total drift throughout the model domain.

Table 2.2 displays the average and maximum combined current speeds at the centre of the Operational Area. Figure 2.8 and Figure 2.9 show the monthly and total (all months and years combined) current rose distributions from 2013 – 2017 (inclusive).

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 directions are used. 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 modelled combined current data (ocean plus tides) showed that waters nearby the Operational Area are predominantly influenced by the tides, respectively flooding and ebbing along the southeast and northwest axis. Surface currents were characterised by a monthly average speed of approximately 0.36 m/s throughout the year and a maximum speed of 1.28 m/s.

Table 2.2 Predicted monthly average and maximum surface current speeds at the centre of the Operational Area. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data from 2013-2017 (inclusive).

Month	Average current speed (m/s)	Maximum current speed (m/s)	General Direction (Towards)
January	0.35	1.03	North-northwest and Southeast
February	0.37	1.28	Northwest and Southeast
March	0.39	1.05	Northwest and Southeast
April	0.38	1.23	Northwest and South-southeast
May	0.34	0.99	Northwest and South-southeast
June	0.36	1.01	West-northwest
July	0.36	0.98	Northwest and South-southeast
August	0.37	1.07	Northwest and Southeast
September	0.38	1.07	Northwest and Southeast
October	0.35	1.11	Northwest and Southeast
November	0.33	0.92	Northwest and Southeast
December	0.32	0.84	North-northwest and Southeast
Minimum	**0.32**	**0.84**	
Maximum	**0.39**	**1.28**	

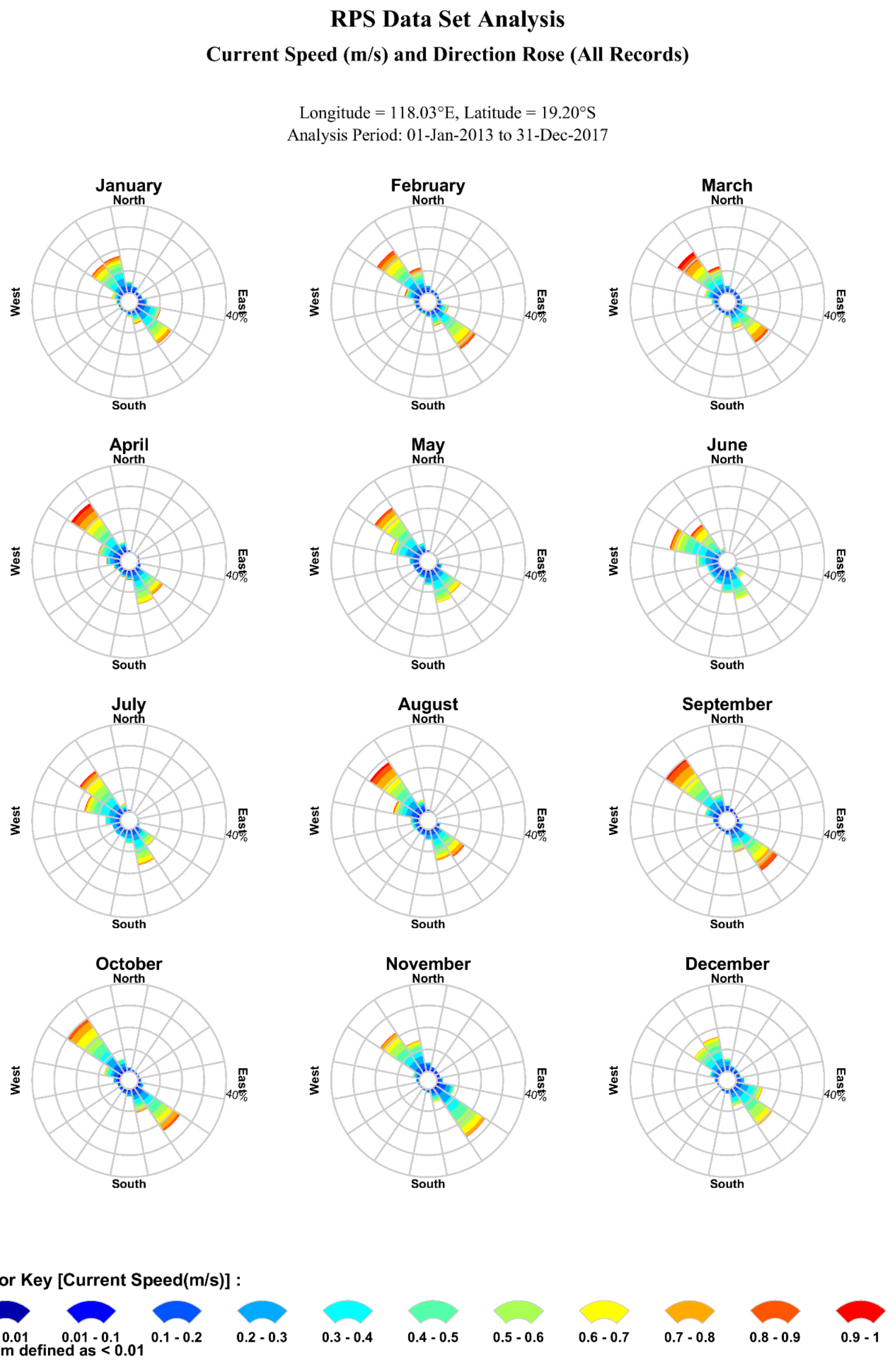


Figure 2.8 Predicted monthly surface current rose plots at the centre of the Operational Area. Data was derived by combining the HYCOM large-scale ocean currents and HYDROMAP nearshore tidal currents for 2013-2017 inclusive.

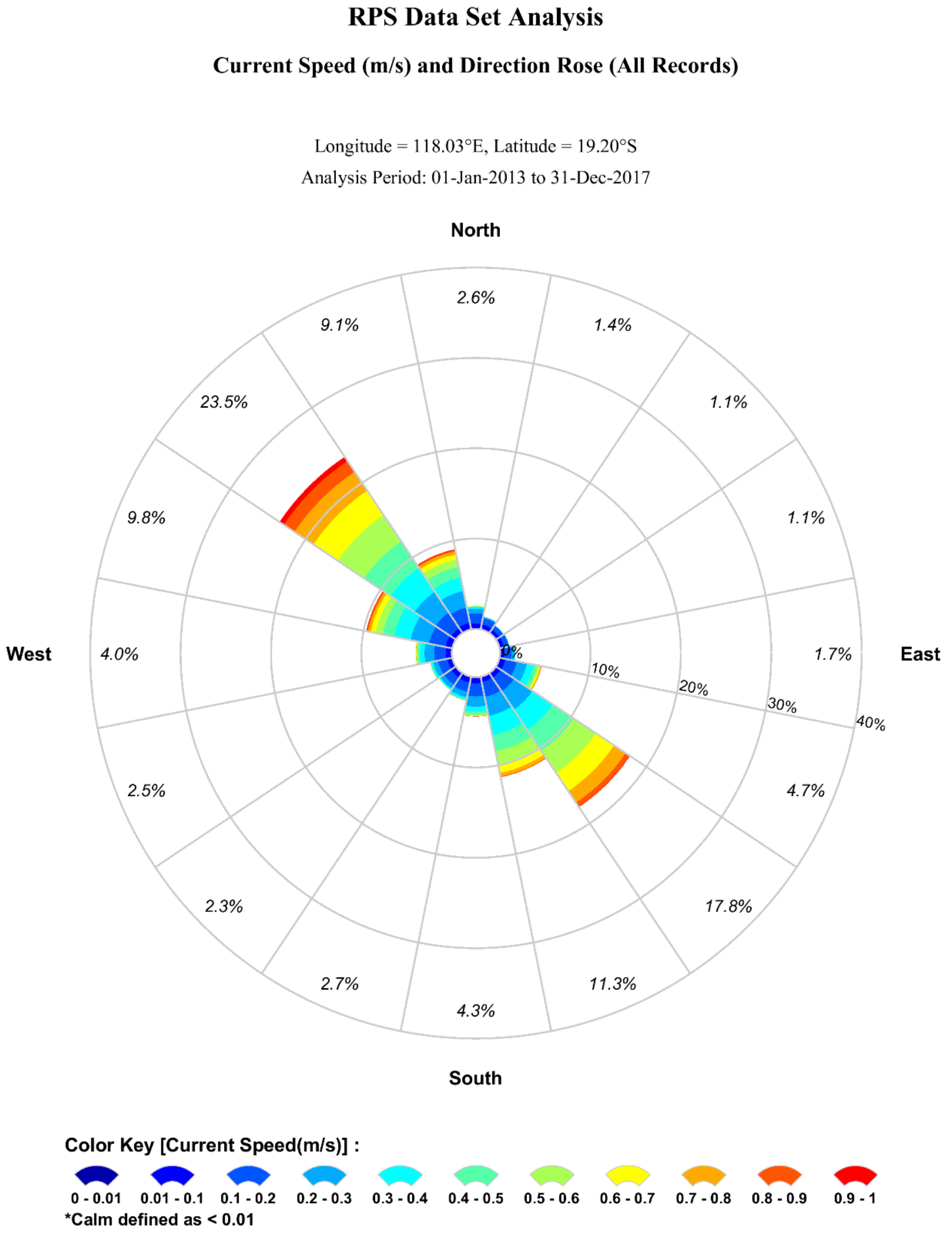


Figure 2.9 Total surface current rose plots at the centre of the Operational Area. Data was derived by combining the HYCOM large-scale ocean currents and HYDROMAP nearshore tidal currents for 2013-2017 inclusive.

3 WIND DATA

The wind data from 2013 to 2017 (inclusive) was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010). The CFSR wind model includes observations from many data sources; surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model 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 3.1 shows the spatial resolution of the wind field used as input into the oil spill model.

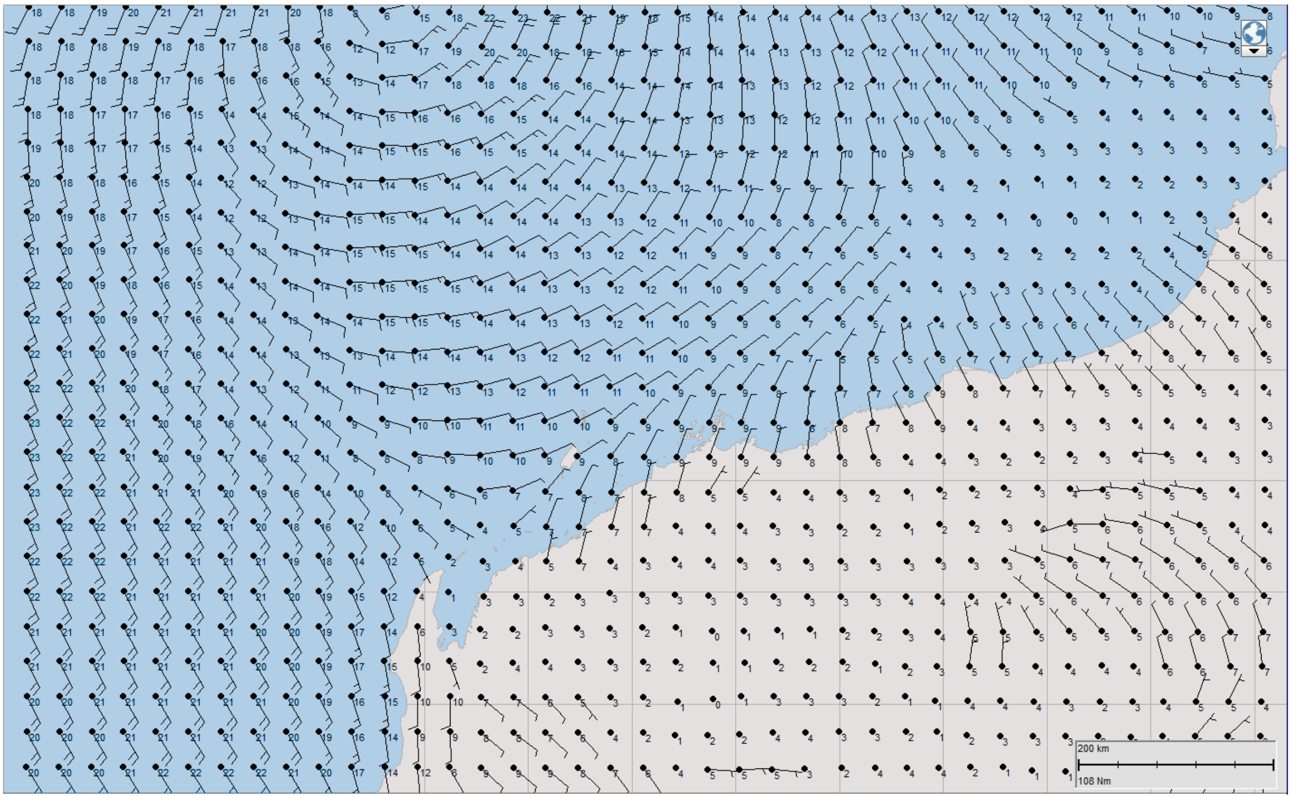


Figure 3.1 Spatial resolution of the CFSR modelled wind data used as input into the oil spill model.

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 directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 2 knots are predominantly 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 3.1 shows the monthly average and maximum winds derived from a CFSR node closest to the Operational Area.

Figure 3.2 and Figure 3.3 respectively show the monthly and total (all months and years combined) wind rose distributions from 2013 to 2017 (inclusive) derived from the CFSR data for the wind node closest to the Operational Area. The wind data demonstrated wind speeds averaging between approximately 5 knots (March) to 8 knots (June) while maximum wind speeds reached 25.6 knots in December. The wind direction was most commonly from the west-southwest during summer and east-southeast during winter.

Table 3.1 Predicted average and maximum wind speeds for the closest CFSR node to the Operational Area.

Month	Average wind (knots)	Maximum wind (knots)	General direction (from)
January	6.2	18.3	West
February	5.5	24.7	West-southwest
March	4.9	16.8	West-southwest
April	5.3	18.2	East-southeast
May	5.6	15.9	East-southeast
June	7.8	17.2	East-southeast
July	6.6	14.3	East-southeast
August	5.7	15.1	East-southeast
September	5.1	13.5	Southwest
October	5.7	12.7	West-southwest
November	5.9	13.3	West-southwest
December	6.0	25.6	West
Minimum	**4.9**	**12.7**	
Maximum	**7.8**	**25.6**	

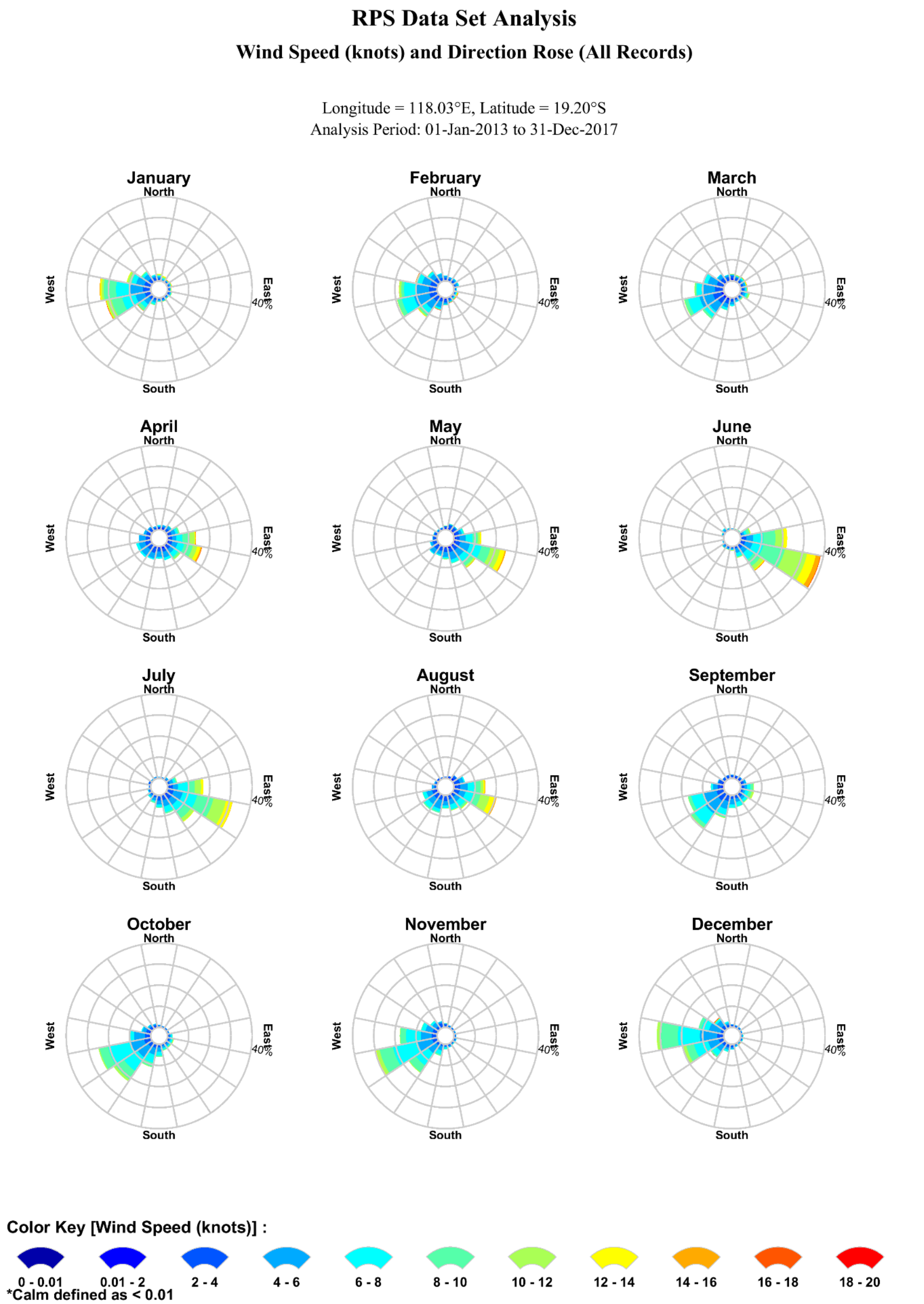


Figure 3.2 Monthly wind rose plots derived from the CFSR data from 2013-2017 (inclusive), for an adjacent wind node to the Operational Area.

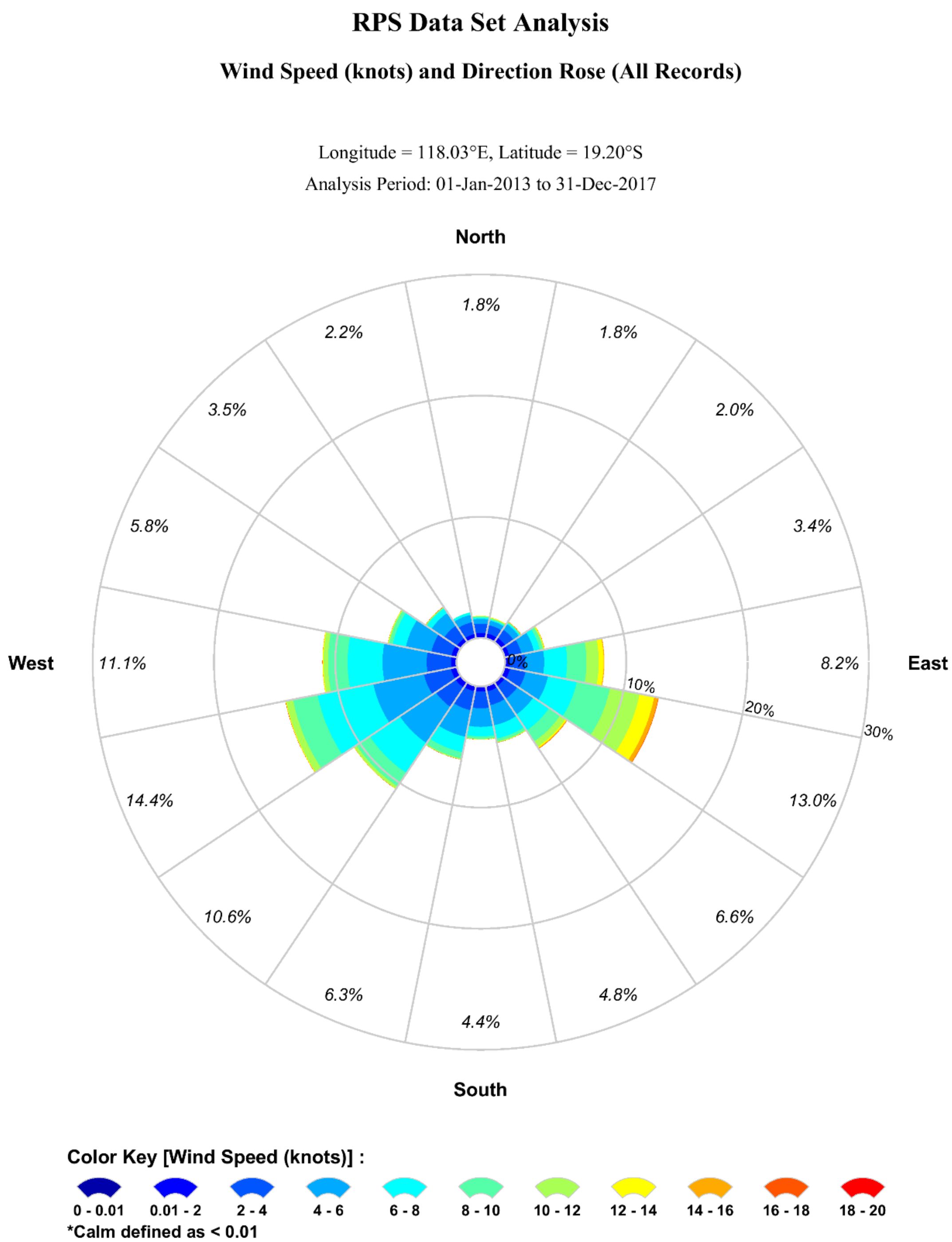


Figure 3.3 Total wind rose plots derived from the CFSR data from 2013-2017 (inclusive), for an adjacent wind node to the Operational Area.

4 SURFACE WATER TEMPERATURE AND SALINITY

The monthly sea temperature and salinity profiles of the water column near the Operational Area was obtained from the World Ocean Atlas 2013 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Center for Oceanography (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 depth intervals from 0 m to 85 m. Table 4.1 presents the sea temperature and salinity of the surface layer (0-5 m).

The monthly average sea surface temperatures ranged between 25.0°C (August) and 30.4°C (March) (see Table 4.1). The monthly average salinity values remained relatively stable ranging between 34.5 psu (May) and 35.2 psu (December).

These parameters were used as factors to inform the weathering, movement and evaporative loss of hydrocarbon spills in the surface and sub-surface layers.

Table 4.1 Monthly average sea surface temperature and salinity adjacent to the Operational Area.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	28.3	29.2	30.4	29.1	26.6	25.5	25.8	25.0	25.5	26.0	27.7	27.9
Salinity (psu)	34.9	34.7	34.7	34.9	34.5	35.0	34.7	34.8	34.8	34.8	34.9	35.2

5 OIL SPILL MODEL - SIMAP

Modelling of the trajectory and fate of oil was performed using the Spill Impact Mapping Analysis Program (SIMAP). SIMAP is designed to simulate the transport and weathering processes that affect the outcomes of spilled hydrocarbons for both the surface and subsurface releases, accounting for specific oil type, spill scenario, and prevailing wind and current patterns (Spaulding et al. 1994; French et al. 1999; French-McCay, 2003, 2004; French-McCay et al. 2004).

SIMAP has been used to predict the weathering and fate of oil spills during and after major incidents including: Montara (Australia) well blowout August 2009 in the Timor Sea (Asia-Pacific ASA, 2010); Macondo (USA) well blowout April 2010 in the Gulf of Mexico; Bohai Bay (China) oil spill August 2011; and the pipeline oil spill July 2013 in the Gulf of Thailand.

The SIMAP model calculates the transport, spreading, entrainment, evaporation and decay of surface hydrocarbon slicks as well as the entrained and dissolved oil components in the water column, either from surface slicks or from oil discharged subsea. The movement and weathering of the spilled oil is calculated for specific oil types. Input specifications for oil mixtures include the density, viscosity, pour point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges.

SIMAP is a three-dimensional model that allows for various response actions to be modelled including oil removal from skimming, burning, or collection booms, and surface and subsurface dispersant application.

The SIMAP oil spill model includes advanced weathering algorithms, specifically focussed on unique oils that tend to form emulsions and/or tar balls. The weathering algorithms are based on 5 years of extensive research conducted in response to the Deepwater Horizon oil spill in the Gulf of Mexico (French et al., 2015).

Biodegradation is included in the oil spill model. In the model, SIMAP, degradation is calculated for the surface slick, deposited oil on the shore, the entrained and dissolved hydrocarbon constituents in the water column, and oil in the sediments. For surface oil, water column oil, and sedimented oil a first order degradation rate is specified. Biodegradation rates are relatively high for hydrocarbons in dissolved state or in dispersed small droplets.

5.1 Stochastic Modelling

As spills can occur during any set of wind and current conditions, SIMAP's stochastic model was used to quantify the probability of exposure to the sea surface, in-water and shoreline contacts for the hypothetical MDO spill scenario over a 5-year period.

For this assessment, 100 single spills were simulated from each release site (i.e. 300 in total). Each simulation had the same spill information (i.e. spill volume, duration and oil type) but with varying start times, and in turn, the prevailing wind and current conditions. This approach ensures that the predicted transport and weathering of an oil slick is subject to a 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 of the spill trajectories have been run, the results were overlaid (NOPSEMA, 2018, Figure 5.1) to determine:

- 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.

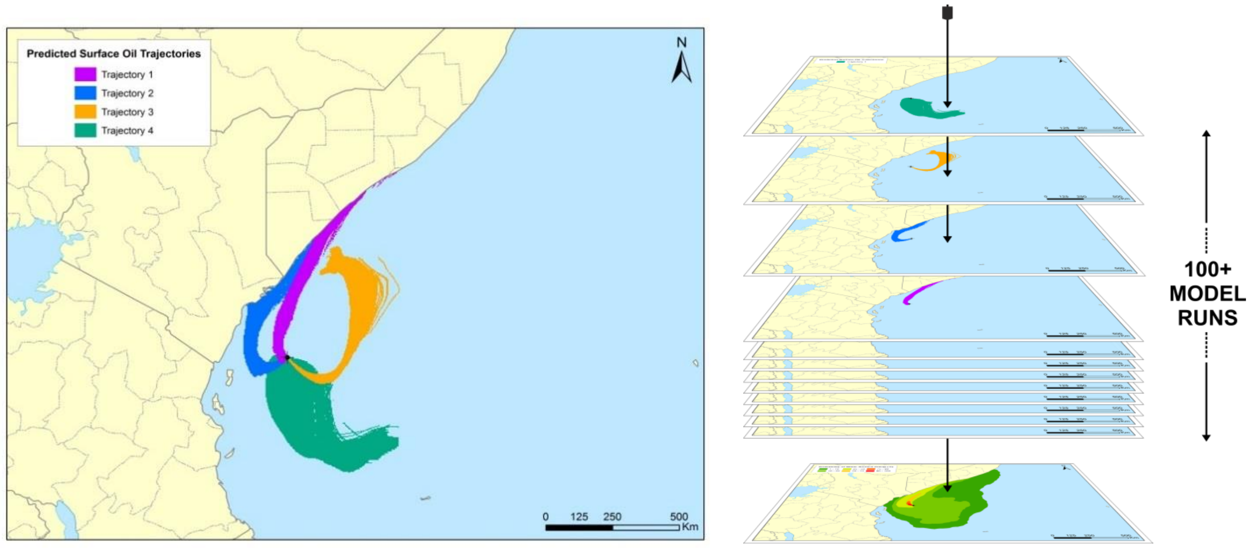


Figure 5.1 Predicted movement of four single oil spill simulations by SIMAP for the same scenario (left image). All model runs are overlain (right image) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability (Source: NOPSEMA, 2018).

5.2 Sea Surface, Shoreline and In-Water Thresholds

The thresholds and their relationship to exposure for the sea surface, shoreline and water column (entrained and dissolved hydrocarbons) are presented in Sections 5.2.1 to 5.2.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the survey area are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

5.2.1 Sea-Surface Thresholds

The lowest sea surface exposure threshold used was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement 2009) (see Table 5.1). Figure 5.2 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. Table 5.1 provides a description of the appearance in relation to exposure thresholds.

Ecological impact has been estimated to occur at or above 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) according to French et al. (1996) and French-McCay (2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 are also considered the lower actionable threshold, whereby oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015a; 2015b).

Scholten et al. (1996) and Koops et al. (2004) indicated that at oil concentrations on the sea surface of 25 g/m^2 (or greater), would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening. The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 5.2 summarises the sea surface exposure thresholds reported herein.

Table 5.1 The Bonn Agreement Oil Appearance Code

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	*Sheen (silvery/grey)*	0.04 – 0.30	40 – 300
2	*Rainbow*	0.30 – 5.0	300 – 5,000
3	*Metallic*	5.0 – 50	5,000 – 50,000
4	*Discontinuous True Oil Colour*	50 – 200	50,000 – 200,000
5	*Continuous True Oil Colour*	200 –>	200,000 –>

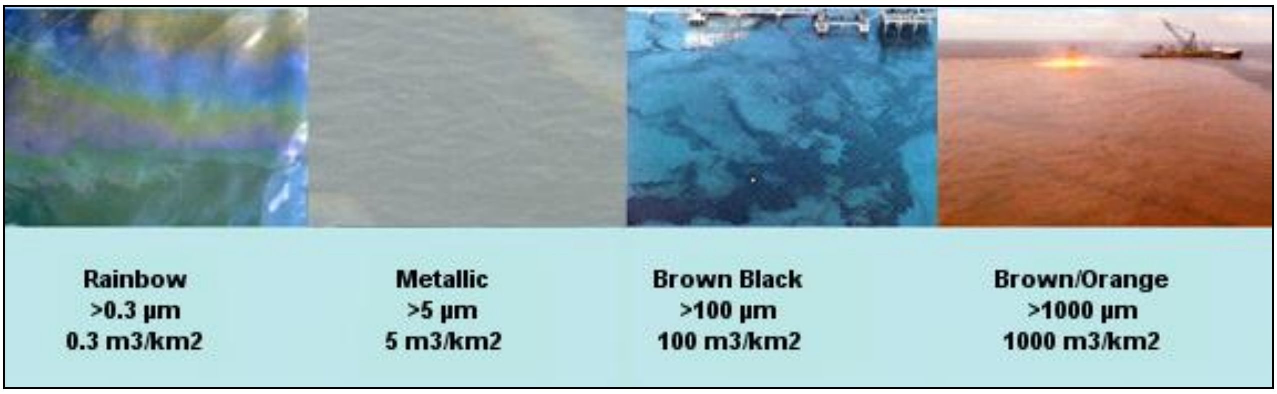


Figure 5.2 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil SpillSolutions.org, 2015)

Table 5.2 Oil exposure thresholds on the sea surface used in this report (in alignment with NOPSEMA 2019).

Threshold level	Floating oil g/m^2	Description
Low	1	Approximates range of socioeconomic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50	Approximates surface oil slick and informs response planning

5.2.2 Shoreline Contact Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influence the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling herein, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence, the results contained herein would be indicative of a worst-case scenario, where the highest volume of oil may be stranded on the shoreline (when compared to other shoreline types, such as exposed rocky shores).

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline contact. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline contacted. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline contact threshold has been selected to define the zone of potential “low shoreline contact”.

French et al. (1996) and French-McCay (2009) have defined a hydrocarbon exposure threshold for shorebirds and wildlife (furbearing aquatic mammals and marine reptiles) on or along the shore at 100 g/m^2, which is based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay 2003; French-McCay et al. 2004, French-McCay et al. 2011; 2012; NOAA 2013). The 100 g/m^2 shoreline contact threshold is also recommended in the Australian Maritime Safety Authority’s (AMSA) foreshore assessment guide[1] as the acceptable minimum thickness that does not inhibit the potential for recovery and is best remediated by natural coastal processes alone (AMSA 2007). It equates to approximately ½ a cup of hydrocarbon per square meter of shoreline contacted. The appearance is described as a hydrocarbon coat. Therefore, 100 g/m^2 has been selected to define the zone of potential “moderate shoreline contact”.

Observations by Lin & Mendelssohn (1996), demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant, Clarke & Allaway 1993; Suprayogi & Murray 1999). Hence, 1,000 g/m^2 has been selected to define the zone of potential “high shoreline contact”. It equates to approximately 1 litre of hydrocarbon per square meter of shoreline contacted. The appearance is described as a hydrocarbon cover.

It is noted that the shoreline contact thresholds derived from extensive literature review (outlined in Table 5.3) are aligned with the commonly used threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 5.3 Shoreline oil contact thresholds used in this report (in alignment with NOPSEMA 2019).

Zone Description	Shoreline Concentration (g/m^2)	Description
Low (socioeconomic/sublethal)	10 – 100	Predicts potential for some socio-economic impact
Moderate	100* - 1,000	Loading predicts area likely to require clean-up effort
High	> 1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

[1] Recommended for shoreline types including sandy beach, boulder shorelines, pebble shorelines, rock platforms and industry facility structures.

5.2.3 In-Water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrates varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

5.2.3.1 Dissolved hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls et al., 2008; Nordtug et al., 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed “bioavailable”.

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty et al., 1992a, 1992b; Mackay et al., 1992; McCarty & Mackay, 1993; Verhaar et al., 1992, 1999; Swartz et al., 1995; French-McCay, 2002; McGrath et al., 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water. Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2-3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson et al., 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb total PAH concentration after 96 hrs exposure, with an average of 50 ppb. Hence, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1 hour timestep (see Table 5.4) were applied to indicate increasing potential for sub-lethal to lethal toxic effects (or low to high), in alignment with the commonly used exposure values for oil spill modelling presented in NOPSEMA (2019).

5.2.3.2 Entrained hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. As such, insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, hence are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

The 10-ppb threshold represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC (2000) water quality guidelines. Due to the requirement for relatively long exposure times (> 24 hours) for these concentrations to be significant, they are likely to be more meaningful for juvenile fish, larvae and planktonic organisms that might be entrained (or otherwise moving) within the entrained plumes, or when entrained hydrocarbons adhere to organisms or trapped against a shoreline for periods of several days or more.

Exposure to entrained oil at 10 ppb is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill. This area does not define the area of influence as it is considered that the environment will not be affected by the entrained hydrocarbon at this level.

Thresholds of 10 ppb and 100 ppb were applied over a 1 hour time exposure (Table 5.4), to cover the range of thresholds outlined in the ANZECC/ARMCANZ (2000) water quality guidelines, the incremental change for greater potential effect and is per NOPSEMA (2019).

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

Table 5.4 Dissolved and entrained hydrocarbon instantaneous exposure thresholds used in this report (in alignment with NOPSEMA 2019).

Level	Dissolved Hydrocarbon Concentration (ppb)	Entrained Hydrocarbon Concentrations (ppb)
Low	10	10
Moderate	50	N/A
High	400	100

6 OIL PROPERTIES

This oil spill modelling study used a marine diesel oil (MDO) to represent a rupture from the survey vessel tank rupture as input into the model.

MDO has a density of 829.1 kg/m^3 (API gravity of 37.6) and a dynamic viscosity of 4.0 cP at 25ºC, classifying it as a Group II oil according to the International Tankers Owners Pollution Federation (ITOPF, 2014) and USEPA/USCG classifications. MDO is characterised by a large mixture (95%) of low and semi- to low-volatiles and contains 5% persistent hydrocarbons. It is important to note that some heavy components contained in MDO have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but can re-float to the surface if these energies abate.

Table 6.1 and Table 6.2 show the physical characteristics and boiling point ranges for the MDO.

Figure 6.1 illustrates the weathering graph of a 1,062 m^3 of MDO spill over 6 hours under 3 static wind conditions. The graphs illustrate greater persistence of MDO on the sea surface with decreasing wind speeds, which coincided with increasing volumes of MDO forced into the water column with increasing wind speeds. Additionally, the loss to evaporation was greatest during the 5-knot static wind speed, allowing for the MDO to remain on the sea surface.

Table 6.1 Physical characteristics for the MDO.

Characteristic	MDO
Density (kg/m^3)	829.1 @ 15˚C
API	37.6
Dynamic viscosity (cP)	4.0 @ 25°C
Pour Point (ºC)	-14
Oil Property Category	Group II
Oil Persistence Classification	Light-persistent oil

Table 6.2 Boiling point ranges for the MDO.

Characteristic	Volatiles (%)	Semi-volatiles (%)	Low volatiles (%)	Residual (%)
Boiling point (˚C)	<180	180 – 265	265 – 380	>380
MDO	6.0	34.6	54.4	5
		Non-persistent		*Persistent*

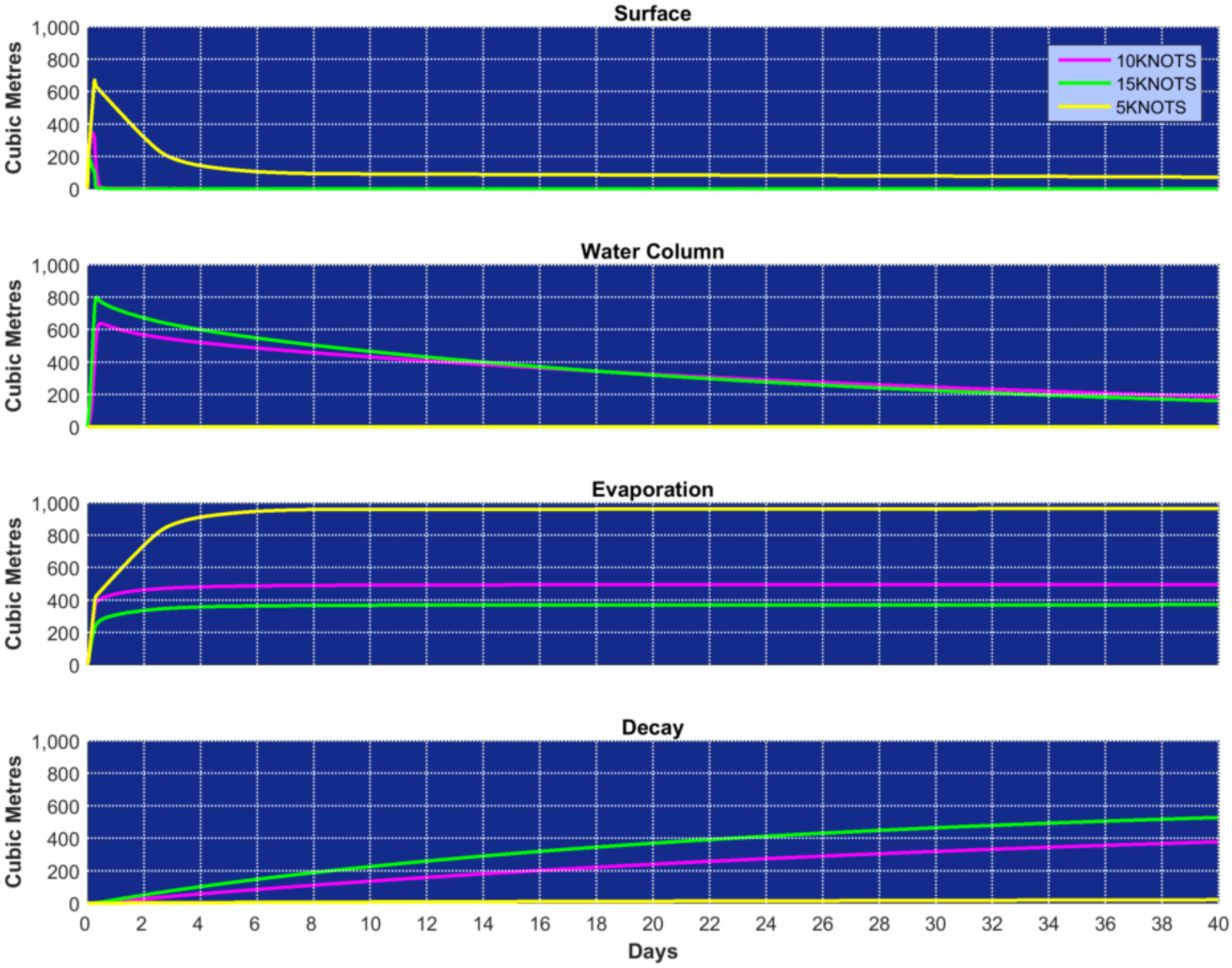


Figure 6.1 Weathering and fate graphs, as a function of volume, under 5, 10 and 15 knot static wind conditions. Results are based on a 1,062 m^3 surface release of MDO over 6 hours (tracked over 40 days).

7 MODEL SETTINGS

This oil spill modelling study quantified the annual risk and potential exposure to the surrounding waters and shorelines from 1,062 m^3 surface release of MDO over 6 hours. The scenario represents the loss from the largest external fuel tank from a survey vessel at either of the three release sites (refer to Figure 1.1).

Table 7.1 provides a summary of the oil spill model settings.

Table 7.1 Summary of the oil spill model settings used in this assessment.

Parameter	Vessel Collision Incident
Release Sites	3 x release sites (Release Site 1, Release Site 2 & Release Site 3) along the perimeter of the Operational Area
Number of randomly selected spill start times at each release site	100
Total number of spill trajectories completed for the study	300
Model period	Annual
Oil Type	MDO
Spill Volume (m^3)	1,062
Release Type	Surface
Release duration (hrs)	6
Simulation length (days)	40
Surface oil concentration thresholds (g/m^2)	1, 10 and 50
Shoreline load threshold (g/m^2)	10, 100 and 1,000
Dissolved hydrocarbon instantaneous exposure (ppb)	10 ppb, potential low exposure 50 ppb, potential moderate exposure 400 ppb, potential high exposure
Entrained hydrocarbon instantaneous exposure (ppb)	10 ppb potential low exposure 100 ppb, potential high exposure

8 INTERPRETING MODEL RESULTS

The modelling results are presented as several tables and figures, which aim to provide an understanding of the exposure to surrounding waters and shoreline contact.

8.1 Deterministic Trajectory Analysis

The stochastic results from all three release sites were reviewed and the "worst case" deterministic run that resulted in the largest swept area of oil on the sea surface above 1 g/m^2 (low and visible surface oil threshold) and is presented in detail in Section 9.2.

This detail analysis included the presentation of time series plots and maps of sea surface oil exposure above 1 g/m^2 and 10 g/m^2 (actionable surface oil) along with the corresponding weathering and fates graphs and accompanying commentary.

8.2 Stochastic Analysis

The results are based on the following principles:

- The ***greatest distance of sea surface exposure*** **–** is defined as the maximum distance from the release location to a specified exposure threshold (i.e. low, moderate or high) along with the corresponding direction of travel from the release location. The greatest distance from the release location to a specified exposure threshold (i.e. low, moderate or high) based on the ***99th percentile analysis*** is also reported.

- The ***potential zones of exposure (surface oil, entrained and dissolved hydrocarbons)*** – is determined by identifying the maximum loading (surface) or exposure (in-water) within a grid cell and is then classified according to identified surface or subsea thresholds.

- 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.

- 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.

8.3 Receptors Assessed

A range of environmental receptors and shorelines were assessed for sea surface exposure, shoreline contact and water column exposure as part of the study (see Table 8.1). The receptors are presented graphically in Figure 8.1 to Figure 8.9.

Note, Table 8.2 describes the receptors that were excluded from tabulated results due to the release sites residing within each respective receptor boundary.

Table 8.1 Summary of receptors assessed for surface and in-water exposure and shoreline contact to hydrocarbons.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water column	Sea Surface	Shoreline
Australian Marine Park	AMP	✓	✓	✗
State Marine Park	MP	✓	✓	✗
National Park	NP	✓	✓	✗
National Nature Reserve	NR	✓	✓	✗
Marine Management Area	MMA	✓	✓	✗
Integrated Marine and Coastal Regionalisation of Australia	IMCRA	✓	✓	✗
Interim Biogeographic Regionalisation for Australia	IBRA	✓	✓	✓
Key Ecological Feature	KEF	✓	✓	✗
Ramsar wetlands	RAMSAR	✓	✓	✗
Reefs, Shoals and Banks	RSB	✓	✓	✗
State Waters	State Waters	✓	✓	✗
Shoreline	Shoreline	✗	✗	✓

Table 8.2 Summary of receptors excluded from tabulated results for each release site.

Receptor		Release Site 1	Release Site 2	Release Site 3
IMCRA	Northwest Shelf	✗	✓	✓
	Pilbara (offshore)	✓	✗	✓
EEZ	Australian Exclusive Economic Zone	✗	✗	✗

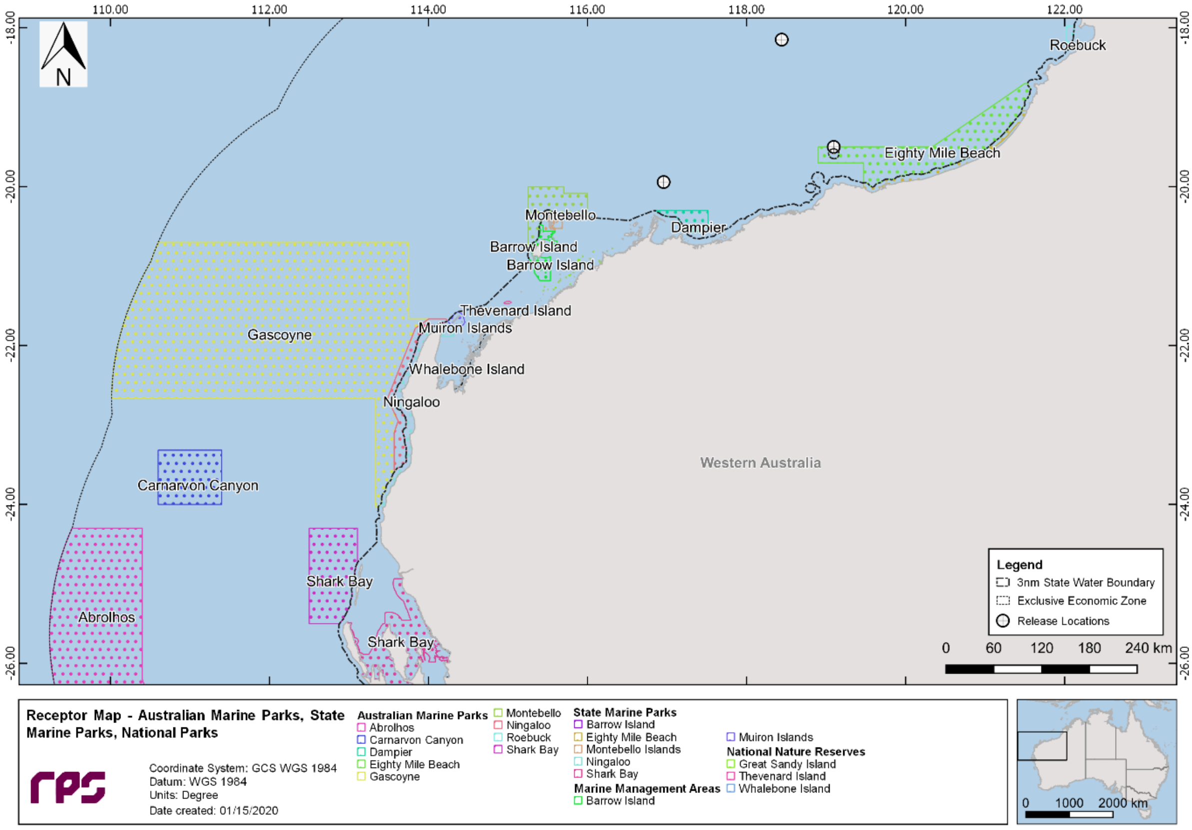


Figure 8.1 Receptor map for Australian Marine Parks, State Marine Parks, Marine Management Areas and National Nature Reserves (1 of 2).

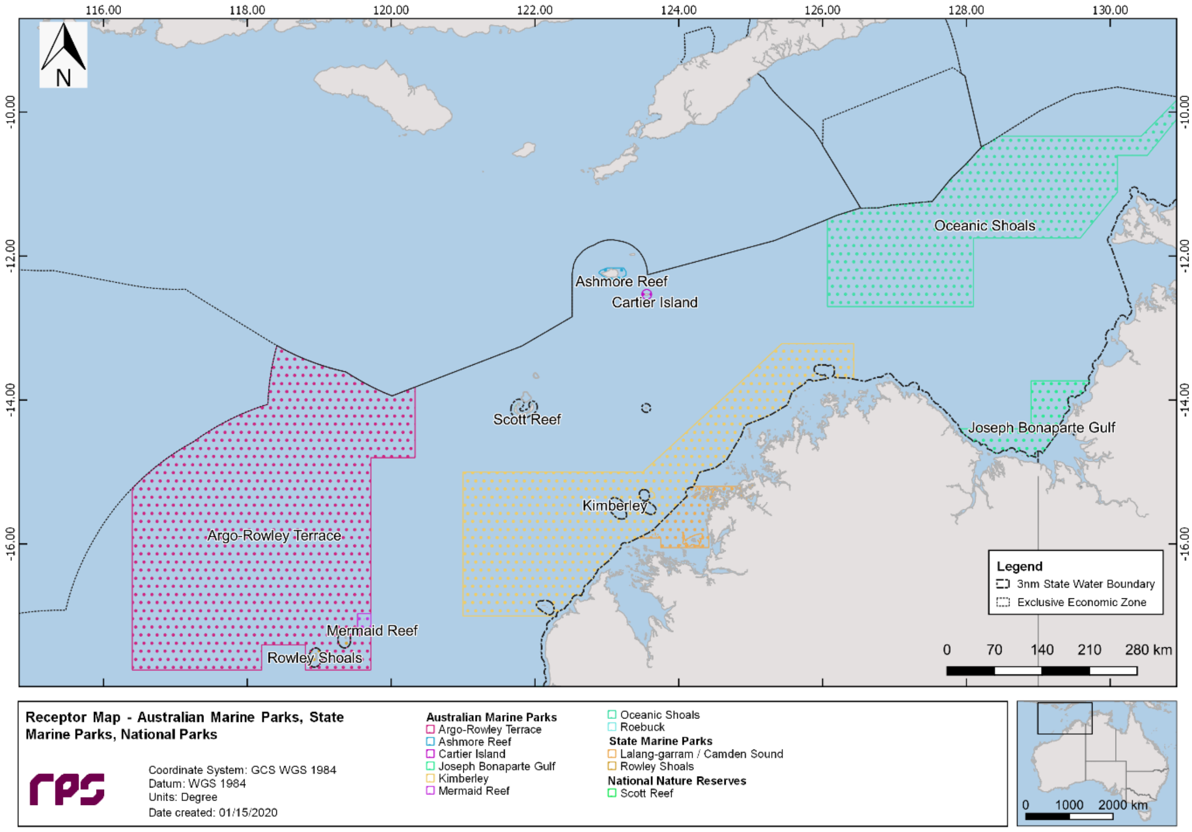


Figure 8.2 Receptor map for Australian Marine Parks, State Marine Parks and National Nature Reserves (2 of 2).

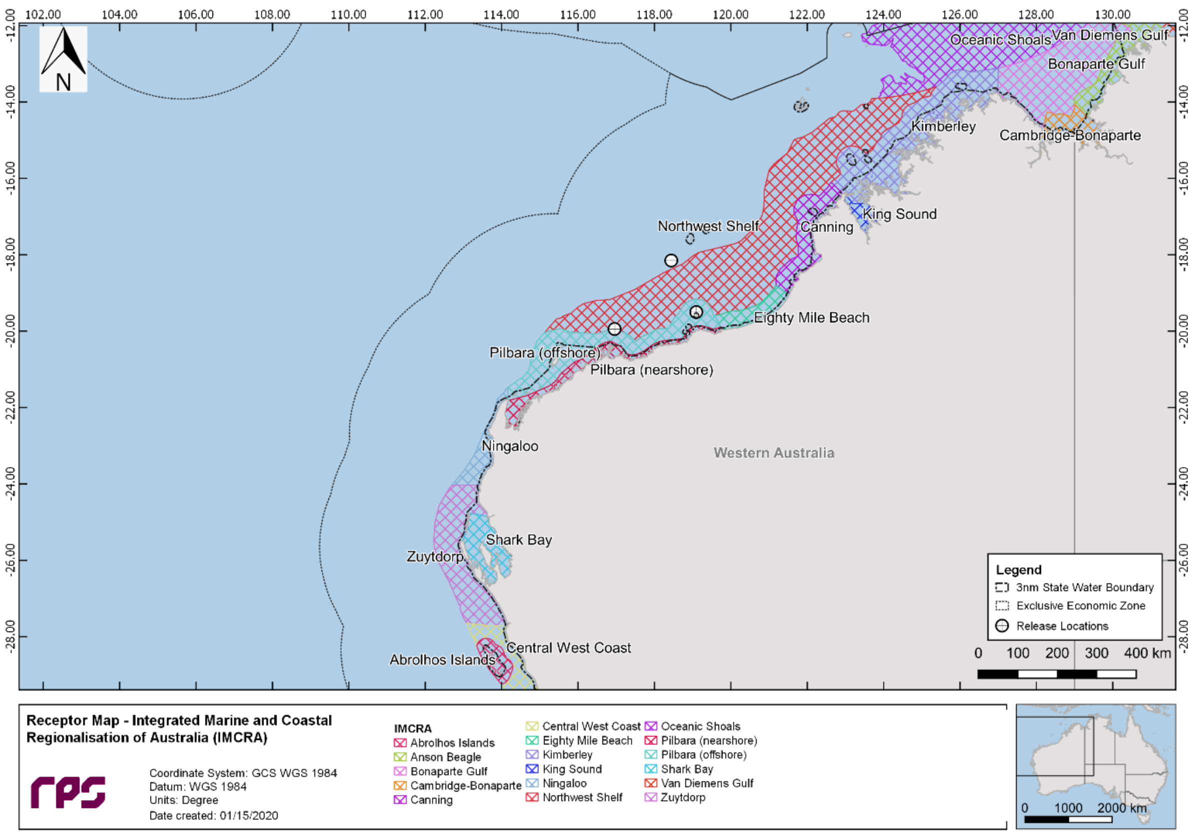


Figure 8.3 Receptor map for Integrated Marine and Coastal Regionalisation of Australia (IMCRA).

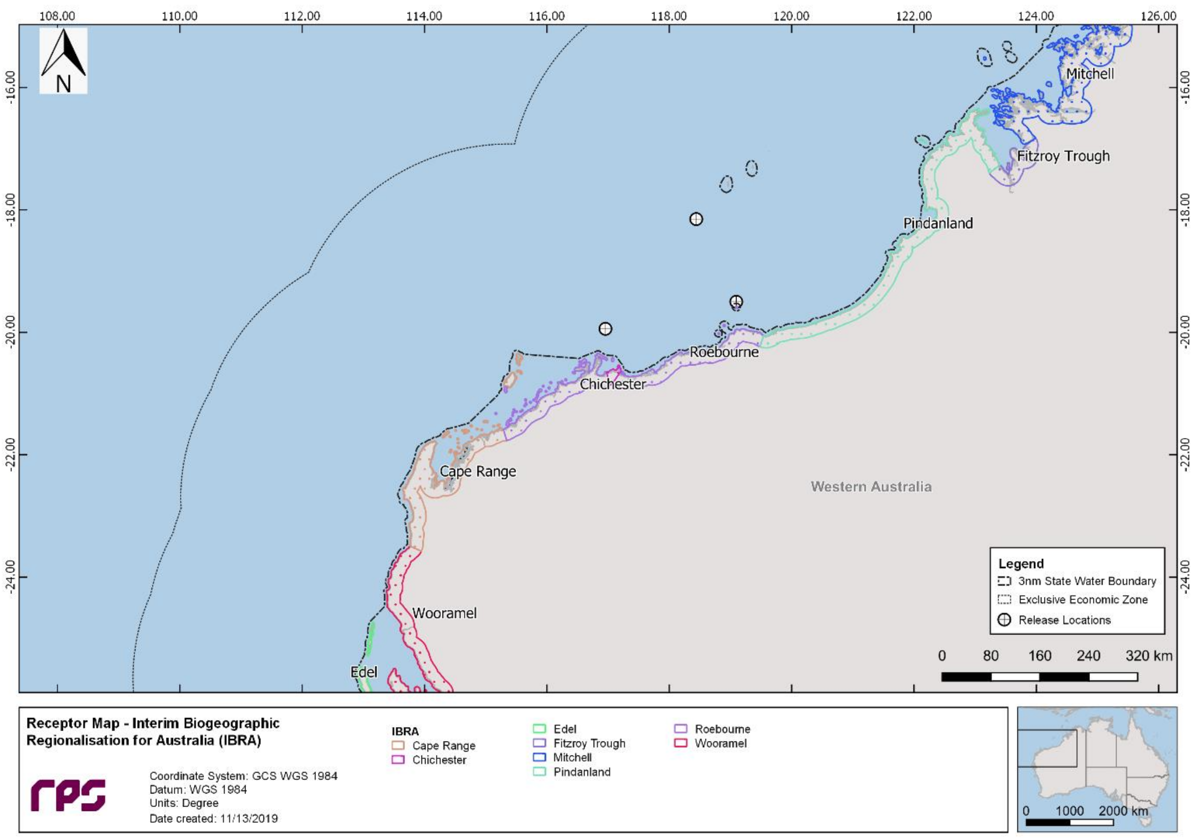


Figure 8.4 Receptor map for Interim Biogeographic Regionalisation for Australia (IBRA).

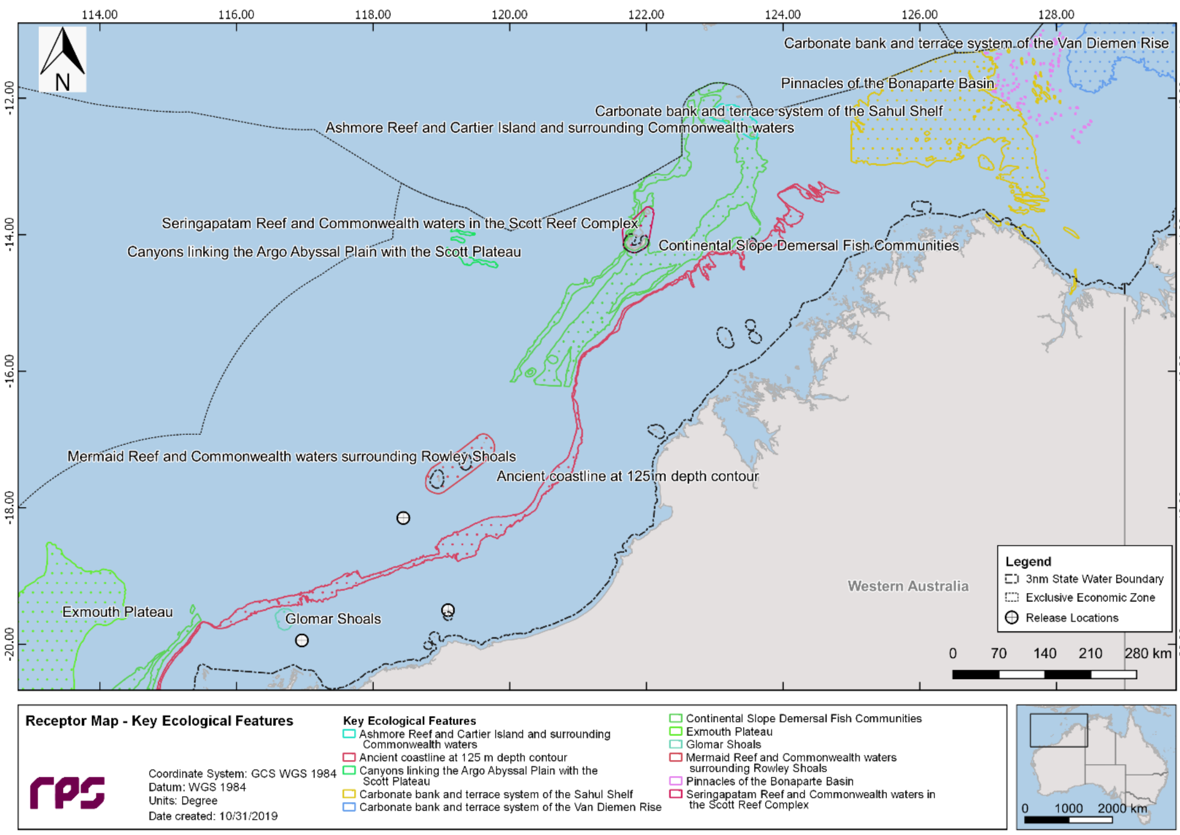


Figure 8.5 Receptor map of Key Ecological Features (KEF) (1 of 2).

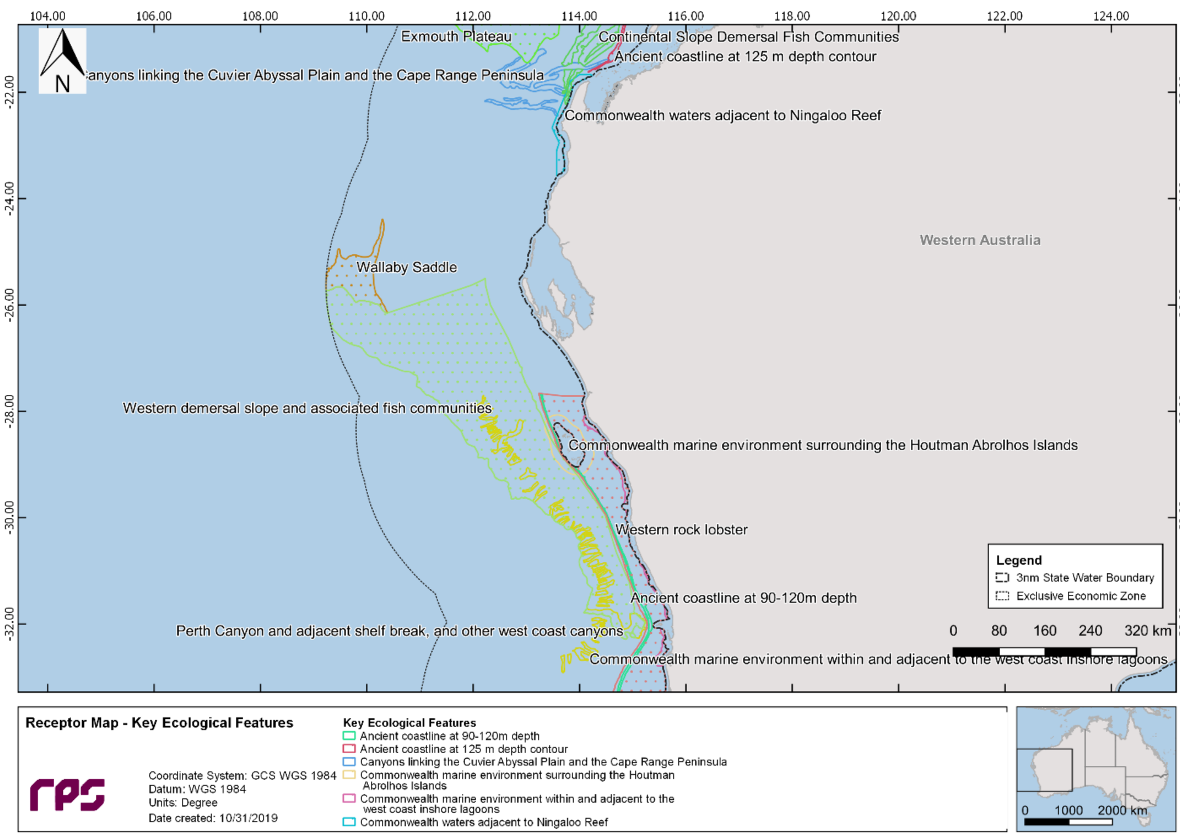


Figure 8.6 Receptor map of Key Ecological Features (KEF) (2 of 2).

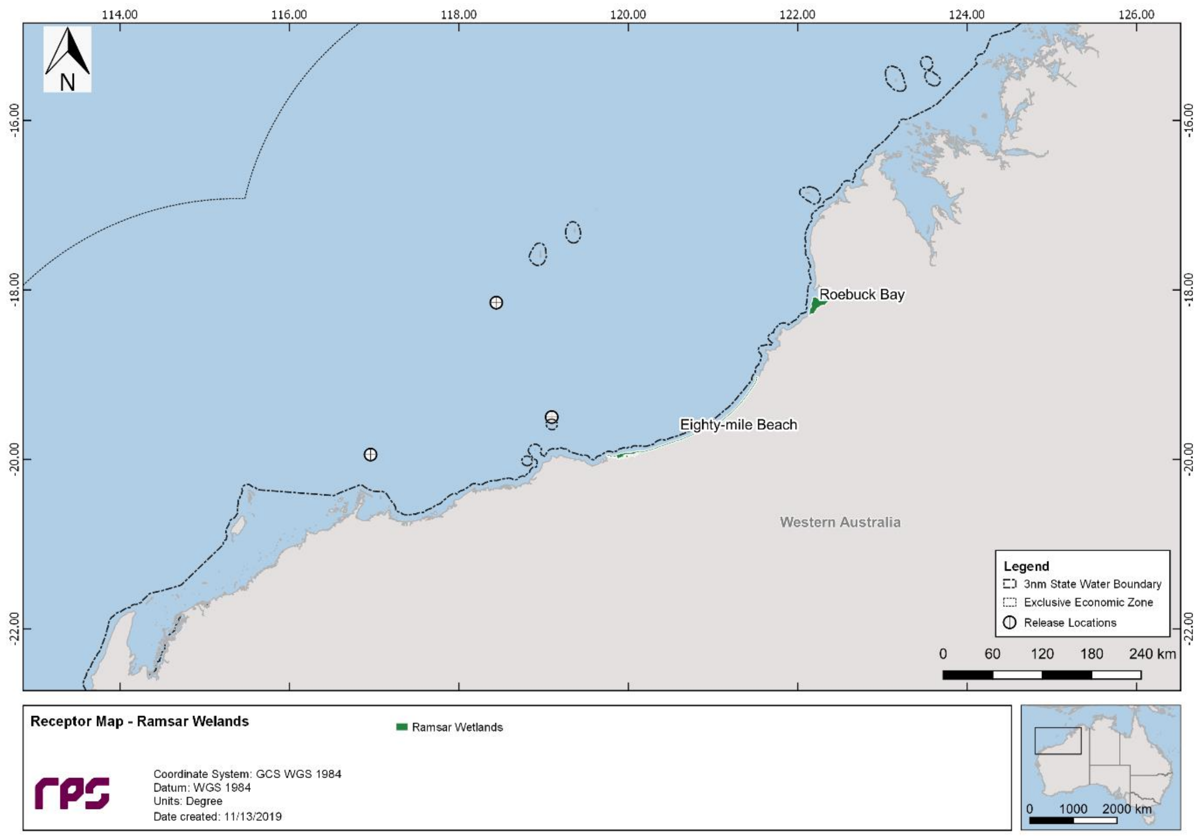


Figure 8.7 Receptor map for RAMSAR wetlands.

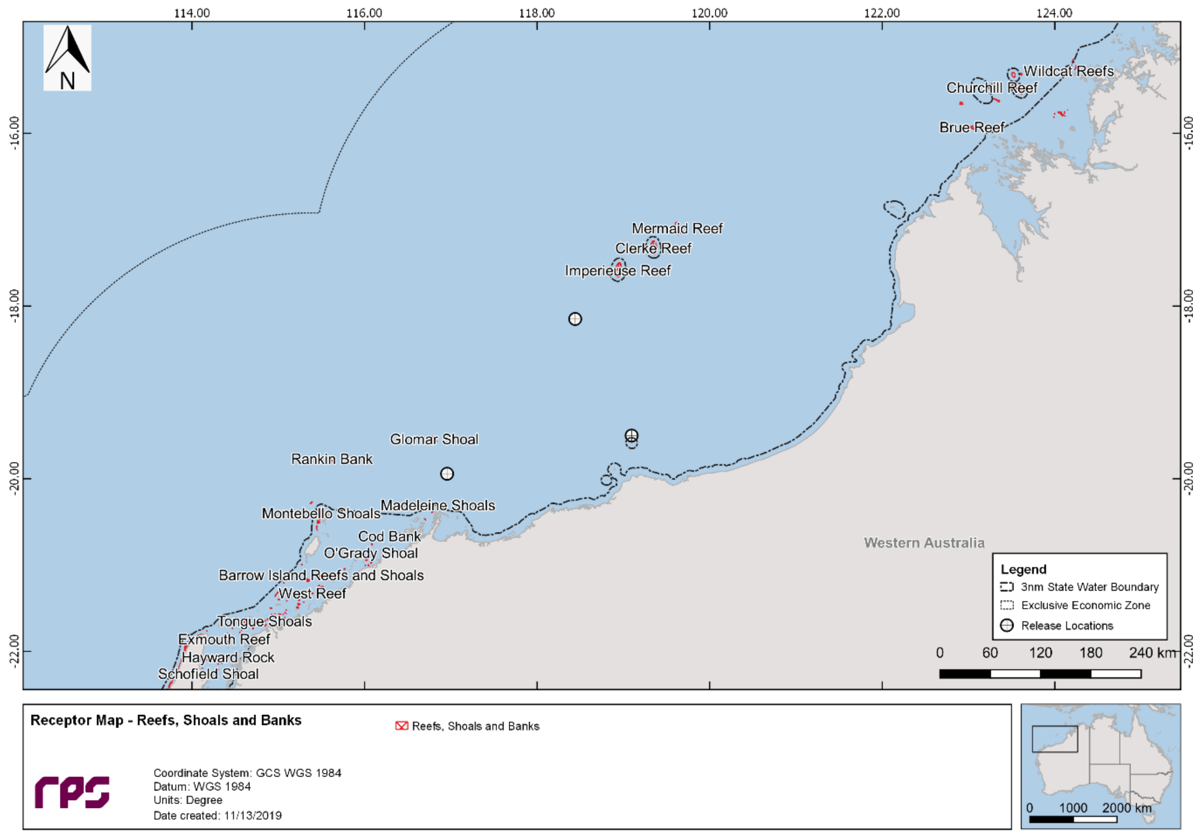


Figure 8.8 Receptor map for Reefs, Shoals and Banks.

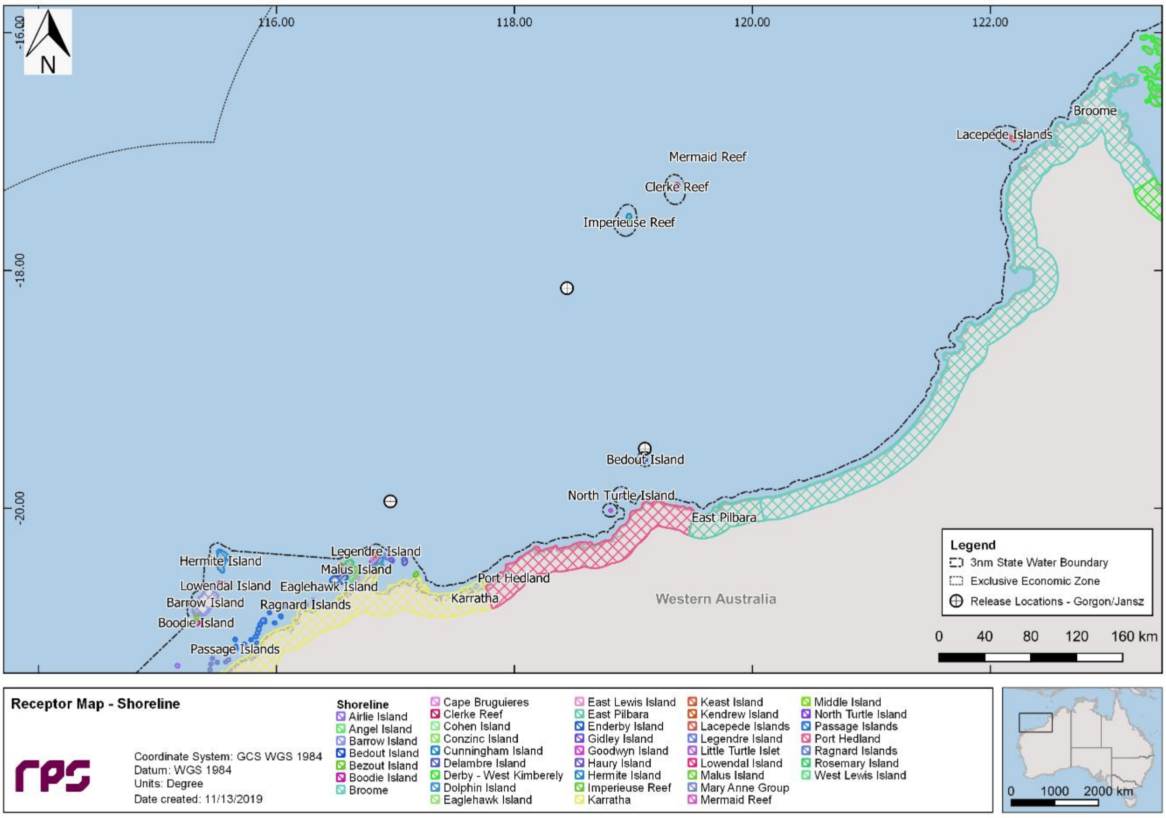


Figure 8.9 Receptor map for the Shoreline.

9 RESULTS - VESSEL FUEL TANK RUPTURE – 1,062 M^3 SURFACE RELEASE OF MDO AT THREE RELEASE SITES

This scenario examined a 1,062 m^3 surface release of MDO over 6 hours resulting from a hypothetical vessel fuel tank rupture during annual conditions. Due to the extent of the Operational Area, three release sites were modelled individually to assess the risk and potential exposure from the proposed operations. A total of 300 spill trajectories (i.e. 100 per release site) were simulated and each was tracked for a period of 40 days. The stochastic results were reviewed (Section 9.1) and it was identified shoreline contact above the low threshold (10 g/m^2) was only predicted for Release Site 2.

9.1 Stochastic Analysis Results

9.1.1 Sea Surface Exposure

Table 9.1 summarises the maximum zones of sea surface exposure for the three release sites modelled. The maximum distance from a release site to low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥50 g/m^2) exposure levels were 115.0 km west-northwest (Release Site 3), 66.4 km south-southwest (Release Site 3) and 19 km west-northwest (Release Site 1), respectively.

Table 9.2 summarises the potential sea surface exposure to individual receptors. At Release Site 1, the Pilbara (offshore) Integrated Marine and Coastal Regionalisation of Australia (IMCRA) was the only receptor predicted to be exposed to the low threshold concentration with a probability of 74% and a predicted minimum time of exposure of 1 hour. At Release Site 2, Eighty Mile Beach Australian Marine Park (AMP), Roebourne Interim Biogeographic Regionalisation for Australia (IBRA) and Western Australia State Waters were all predicted to be exposed at the low threshold concentration with probabilities ranging from 3% to 100% and minimum times before exposure ranging from 1 hour to 11 hours. Only the Northwest Shelf IMCRA was predicted to be exposed to sea surface oil above the low threshold concentration at Release Site 3 with a probability of 5% and predicted minimum time of 20 hours before exposure.

Note, Release Site 2 is situated approximately 115 m north of the border of Eighty Mile Beach AMP.

Figure 9.1 to Figure 9.3 show the zones of potential sea surface exposure above the low (1-10 g/m^2), moderate (10-50 g/m^2) and high (≥50 g/m^2) sea surface exposure thresholds, for Release Site 1, 2 and 3, respectively.

Figure 9.4 shows the zones of oil exposure on the sea surface produced by overlaying the results from all 300 simulations for Release Sites 1, 2 and 3 during annual conditions.

Table 9.1 Maximum distances from each release site to zones of potential oil exposure on the sea surface for each threshold. Results were calculated from 100 spill trajectories (per site) during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Release site	Distance and direction	Zones of potential sea surface exposure		
		Low (1-10 g/m²)	Moderate (10-50 g/m²)	High (>50 g/m²)
1	Maximum distance from release site (km)	35.7	20.1	12.4
	Maximum distance from release site (km) (99th percentile)	31.2	18.1	12.0
	Direction	Southeast	West-Northwest	West-Northwest
2	Maximum distance from release site (km)	28.5	23.5	19.0
	Maximum distance from release site (km) (99th percentile)	26.9	22.1	18.3
	Direction	Northwest	Northwest	West-Northwest
3	Maximum distance from release site (km)	115.0	66.4	18.5
	Maximum distance from release site (km) (99th percentile)	106.1	53.8	17.3
	Direction	West-Northwest	South-Southwest	West-Southwest

Table 9.2 Summary of the potential sea surface exposure to sensitive receptors for each release site. Results were calculated from 100 spill trajectories (per site) during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Release Site	Receptor		Probability of oil exposure on the sea surface (%)			Minimum time before oil exposure on the sea surface (hours)		
			Low	Moderate	High	Low	Moderate	High
1	IMCRA	Pilbara (offshore)	74	52	25	1	1	1
2	AMP	Eighty Mile Beach	100	100	100	1	1	1
	IBRA	Roebourne	3	1	-	11	12	-
	State Waters	Western Australia State Waters	35	15	5	4	6	8
3	IMCRA	Northwest Shelf	5	2	-	20	20	-

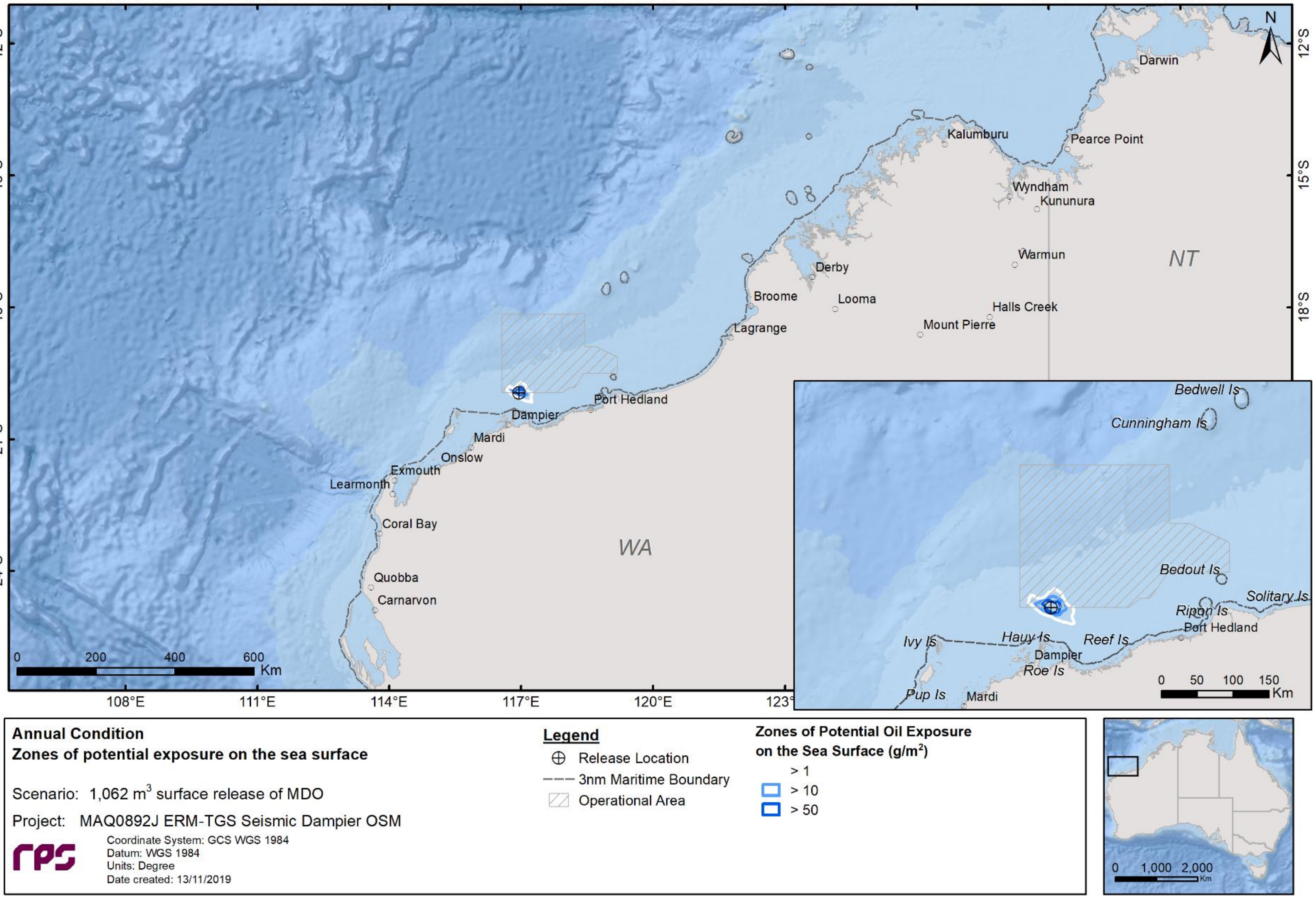


Figure 9.1 **Zones of potential oil exposure on the sea surface, resulting from a 1,062 m³ surface release of MDO over 6 hours at Release Site 1 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.**

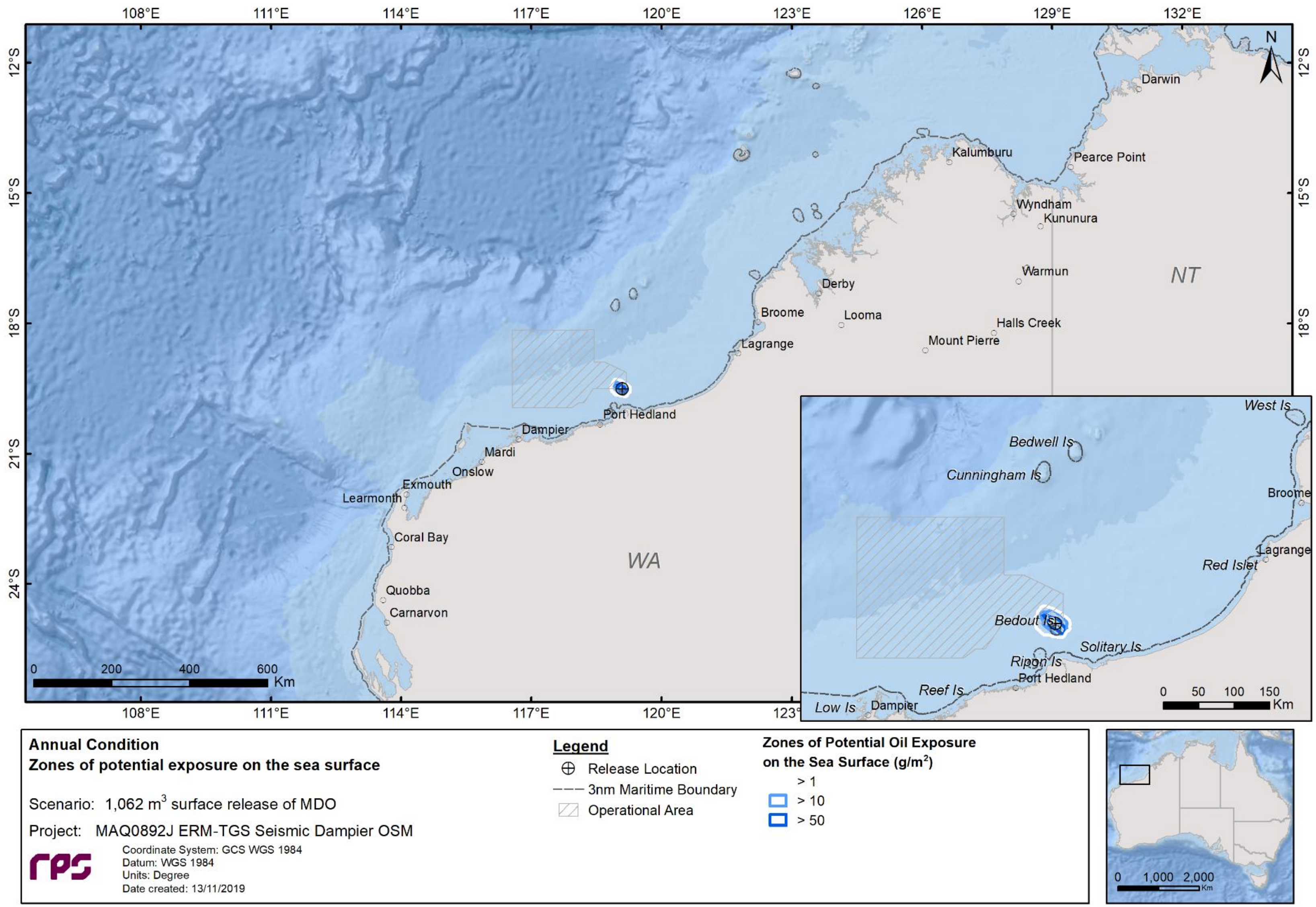


Figure 9.2 Zones of potential oil exposure on the sea surface, resulting from a 1,062 m³ surface release of MDO over 6 hours at Release Site 2 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

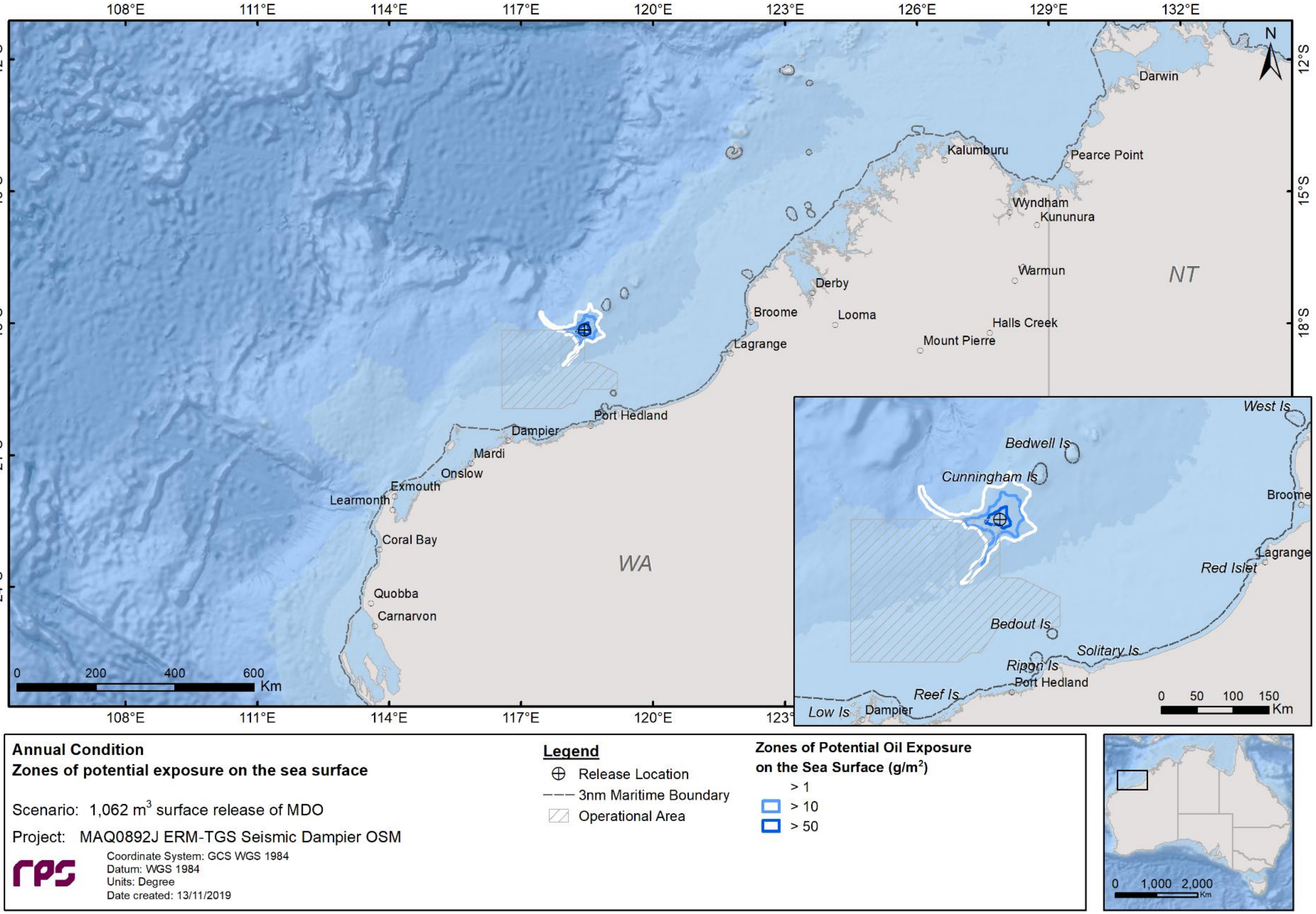


Figure 9.3 Zones of potential oil exposure on the sea surface, resulting from a 1,062 m³ surface release of MDO over 6 hours at Release Site 3 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

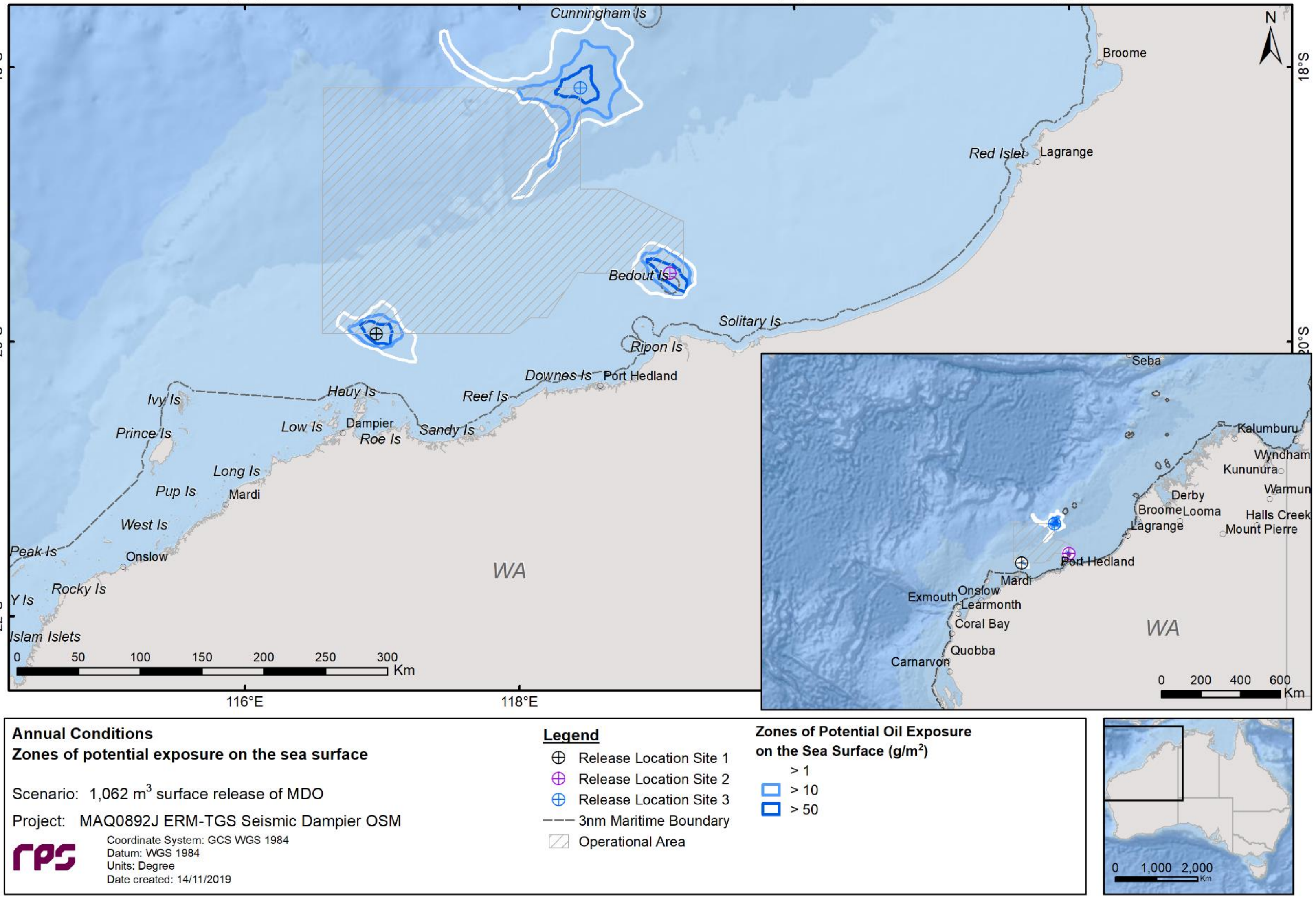


Figure 9.4 Zones of oil exposure on the sea surface produced by overlaying the results from all 300 simulations for Release Sites 1, 2 and 3 during annual conditions. Each simulation is based on a 1,062 m³ surface release of MDO over 6 hours, tracked for 40 days.

9.1.2 Shoreline Contact

Table 9.3 presents a summary of the predicted shoreline contact. For Release Site 2 the probability of contact to any shoreline at, or above, the low threshold (10–100 g/m^2) was 7% while the minimum time before oil contact was approximately 8 hours and the maximum volume of oil ashore was 72.3 m^3. No shoreline contact was predicted for spills originating at Release Site 1 and Release Site 3.

Table 9.4 summarises the shoreline contact to individual receptors assessed. Only Bedout Island was predicted to be contacted by oil at and above the low threshold, occurring from Release Site 2, with a maximum length above the moderate and high threshold of 3 km and 2 km, respectively. No shoreline contact was predicted for spills originating from Release Sites 1 and 3. The maximum potential shoreline loading above the low, moderate and high shoreline thresholds for Release Site 2 are presented in Figure 9.5.

Note, Release Site 2 is situated approximately 9.3 km North of Bedout Island.

Table 9.3 Summary of oil contact across all shorelines. Results were calculated from 100 spill trajectories (per site) during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Shoreline Statistics	Release Site 1	Release Site 2	Release Site 3
Probability of contact to any shoreline (%)	-	7	-
Absolute minimum time for visible oil to shore (hours)	-	8	-
Maximum volume of hydrocarbons ashore (m^3)	-	72.3	-
Average volume of hydrocarbons ashore (m^3)	-	10.7	-
Maximum length of the shoreline at **10 g/m^2** (km)	-	3.0	-
Average shoreline length at **10 g/m^2** (km)	-	1.7	-
Maximum length of the shoreline at **100 g/m^2** (km)	-	3.0	-
Average shoreline length at **100 g/m^2** (km)	-	1.8	-
Maximum length of the shoreline at **1,000 g/m^2** (km)	-	2.0	-
Average shoreline length at **1,000 g/m^2** (km)	-	-	-

Table 9.4 Summary of oil contact to individual shoreline receptors. Results were calculated from 100 spill trajectories (per site) during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Site	Shoreline Receptor	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (hours)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
		Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Bedout Island	7	4	1	8	12	12	349.6	3303.8	10.7	72.3	1.7	1.8	-	3.0	3.0	2.0
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

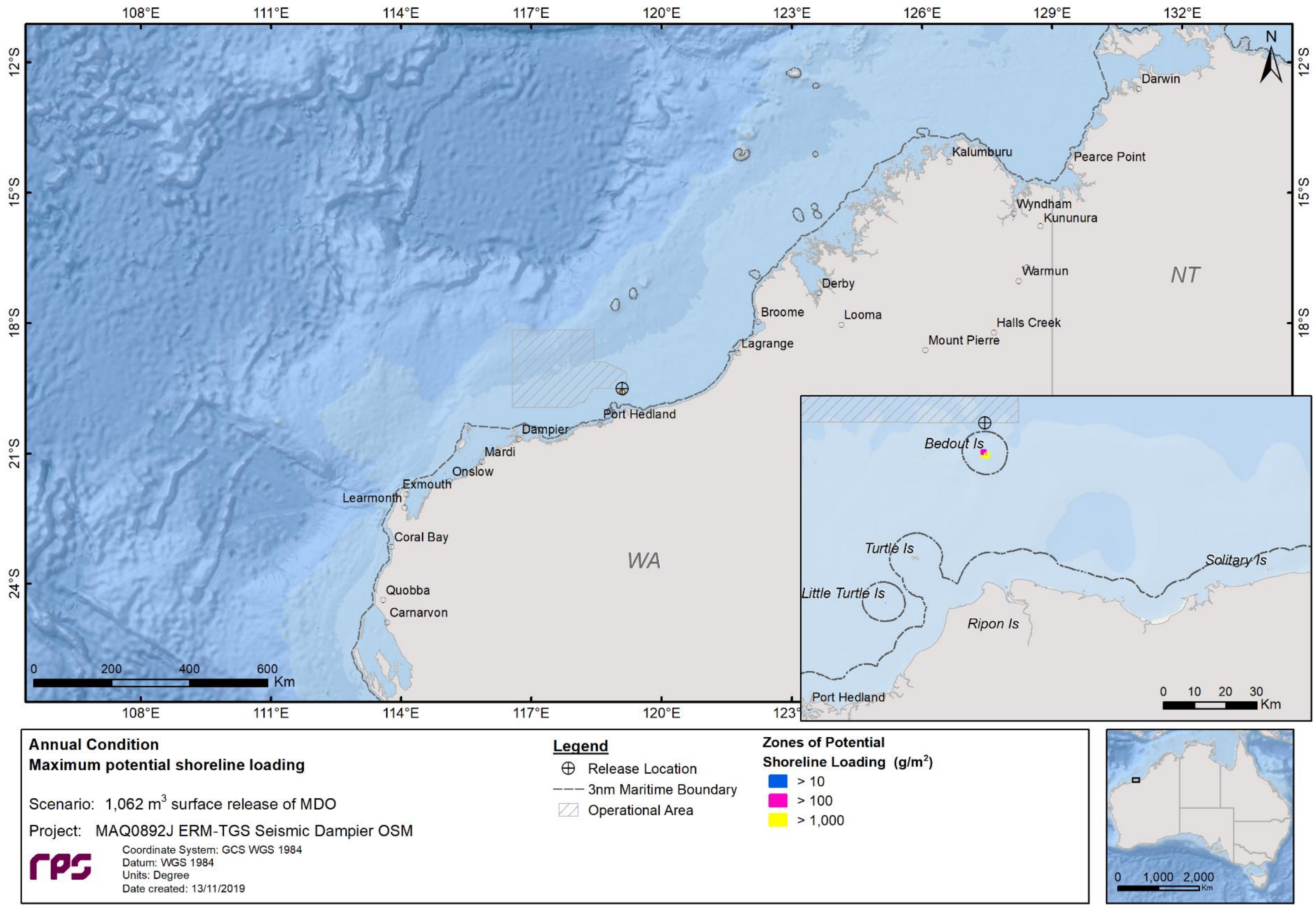


Figure 9.5 Maximum potential shoreline loading for the low (≥ 10 g/m^2), moderate (≥ 100 g/m^2) and high (≥ 1,000 g/m^2) thresholds, resulting from a 1,062 m³ surface release of MDO over 6 hours at Release Site 2 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

9.1.3 Water Column Exposure

9.1.3.1 Dissolved Hydrocarbons

Table 9.5 and Table 9.6 summarise the maximum dissolved hydrocarbon exposure (over 1 hour) and probability of exposure for the low (10-50 ppb), moderate (50-400 ppb) and high (≥400 ppb) exposure thresholds to individual receptors in the 0-10 m and 10-20 m depth layers, for each release site modelled.

In the surface layer (0-10 m), the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 1% for Montebello Australian Marine Park (AMP), Ancient coastline at 125 m depth contour, Continental Slope Demersal Fish Communities and Glomar Shoals KEFs to 27% for the Pilbara (offshore) IMCRA at Release Site 1. Additionally, the Pilbara (offshore) IMCRA was the only receptor predicted to be exposed at the moderate threshold concentration at Release Site 1 with a probability of 8%. At Release Site 2, the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 5% for Roebourne IBRA and Northwest Shelf IMCRA to 66% for Eighty Mile Beach AMP. Only the Eighty Mile Beach AMP and Western Australia State Waters were predicted to be exposed to dissolved hydrocarbons at the moderate threshold concentration with probabilities of 1% and 27%. At Release Site 3, the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 1% for the Ancient coastline at 125 m depth contour KEF to 3% for the Northwest Shelf IMCRA. No receptors were predicted to be exposed at the moderate or high dissolved hydrocarbon exposure thresholds for Release Site 3, while no receptors were predicted to be exposed at the high hydrocarbon exposure threshold for Release Site 1 and 2.

In the 10-20 m layer, the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 1% for Montebello AMP, Continental Slope Demersal Fish Communities and Glomar Shoals KEFs to 3% for the Pilbara (offshore) IMCRA. At Release Site 2, the predicted probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 2% for Roebourne IBRA and Northwest Shelf IMCRA to 6% for Eighty Mile Beach AMP. While at Release Site 3, the probability of exposure to dissolved hydrocarbons at the low threshold concentration ranged from 1% for the Argo-Rowley Terrace AMP and the Ancient coastline at 125 m depth contour KEF to 3% for the Northwest Shelf IMCRA. Only the Eighty Mile Beach AMP was predicted to be exposed at the moderate dissolved hydrocarbon threshold concentration with a probability of 1% exposure originating from Release Site 2. No receptors were predicted to be exposed at the high dissolved hydrocarbon exposure threshold.

Figure 9.6 to Figure 9.11 illustrate the zones of potential dissolved hydrocarbon exposure (over 1 hour) in the 0-10 m, 10-20 m depth layers, for each release site assessed.

Figure 9.12 shows the zones of dissolved hydrocarbon exposure produced by overlaying the results from all 300 simulations originating from Release Sites 1, 2 and 3, during annual conditions.

Table 9.5 Maximum dissolved hydrocarbon exposure levels (over 1 hour) and probability of exposure for each threshold to individual receptors in the 0–10 m depth layer, for each release site. Results were calculated from 100 spill trajectories (per site) during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Release Site	Receptor		Maximum dissolved hydrocarbon exposure level over 1 hour (ppb)	Probability of dissolved hydrocarbon exposure for each threshold (%)		
				Low	Moderate	High
1	AMP	Montebello	25	1	-	-
	IMCRA	Pilbara (offshore)	116	27	8	-
	KEF	Ancient coastline at 125 m depth contour	19	1	-	-
		Continental Slope Demersal Fish Communities	23	1	-	-
		Glomar Shoals	17	1	-	-
2	AMP	Eighty Mile Beach	238	66	27	-
	IBRA	Roebourne	36	5	-	-
	IMCRA	Northwest Shelf	43	5	-	-
	State Waters	Western Australia State Waters	95	24	1	-
3	AMP	Argo-Rowley Terrace	28	2	-	-
	IMCRA	Northwest Shelf	45	3	-	-
	KEF	Ancient coastline at 125 m depth contour	25	1	-	-

Table 9.6 Maximum dissolved hydrocarbon exposure levels (over 1 hour) and probability of exposure for each threshold to individual receptors in the 10–20 m depth layer, for each release site. Results were calculated from 100 spill trajectories (per site) during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Release Site	Receptor		Maximum dissolved hydrocarbon exposure level over 1 hour (ppb)	Probability of dissolved hydrocarbon exposure for each threshold (%)		
				Low	Moderate	High
1	AMP	Montebello	15	1	-	-
	IMCRA	Pilbara (offshore)	27	3	-	-
	KEF	Continental Slope Demersal Fish Communities	19	1	-	-
		Glomar Shoals	13	1	-	-
2	AMP	Eighty Mile Beach	65	6	1	-
	IBRA	Roebourne	26	2	-	-
	IMCRA	Northwest Shelf	24	2	-	-
	State Waters	Western Australia State Waters	49	3	-	-
3	AMP	Argo-Rowley Terrace	25	1	-	-
	IMCRA	Northwest Shelf	45	3	-	-
	KEF	Ancient coastline at 125 m depth contour	17	1	-	-

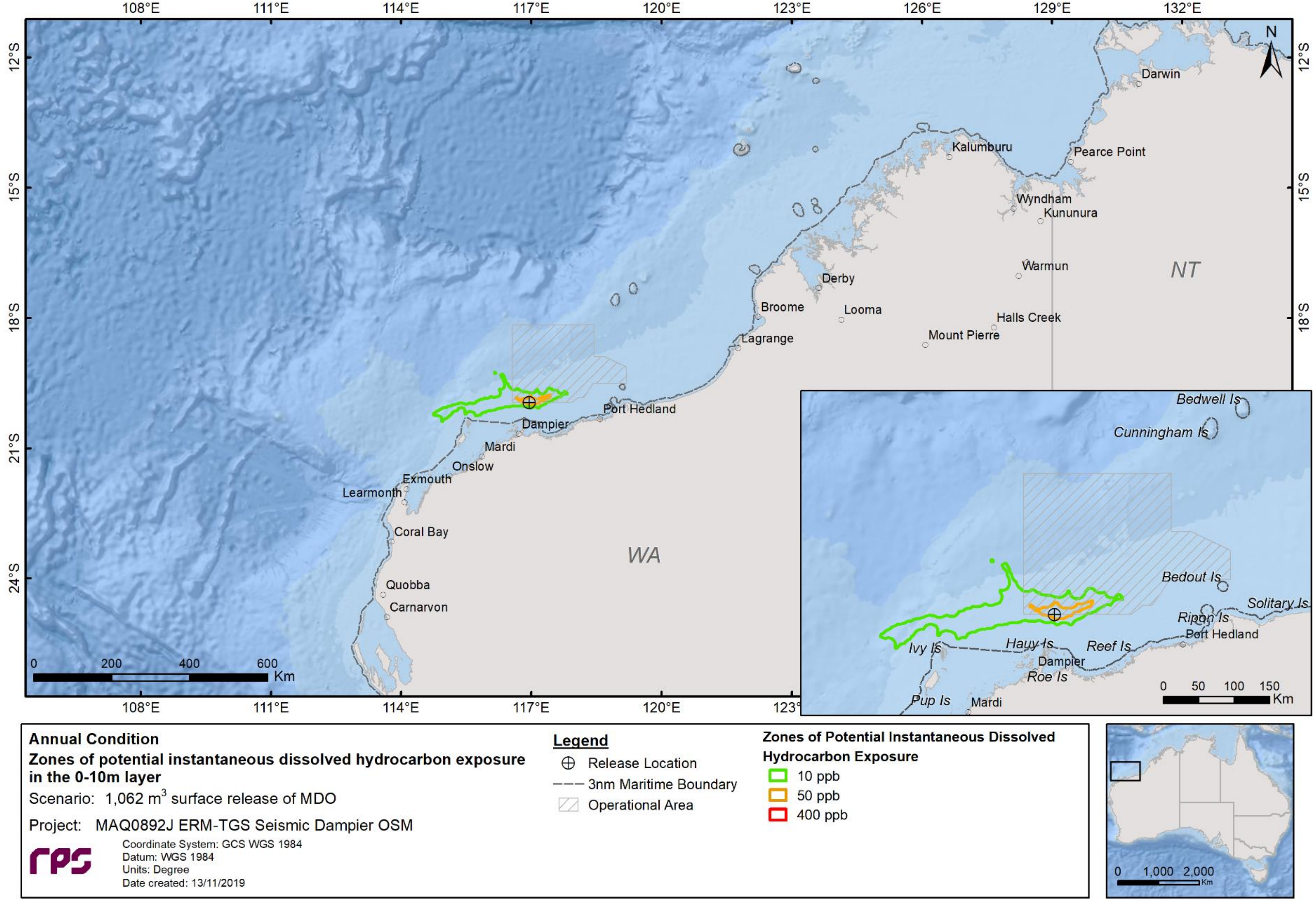


Figure 9.6 **Zones of potential dissolved hydrocarbon exposure (over 1 hour) at 0–10 m below the sea surface in the event of a 1,062 m^3 of surface release of MDO over 6 hours, at Release Site 1 (tracked for 40 days). The results were calculated from 100 spill trajectories during annual conditions.**

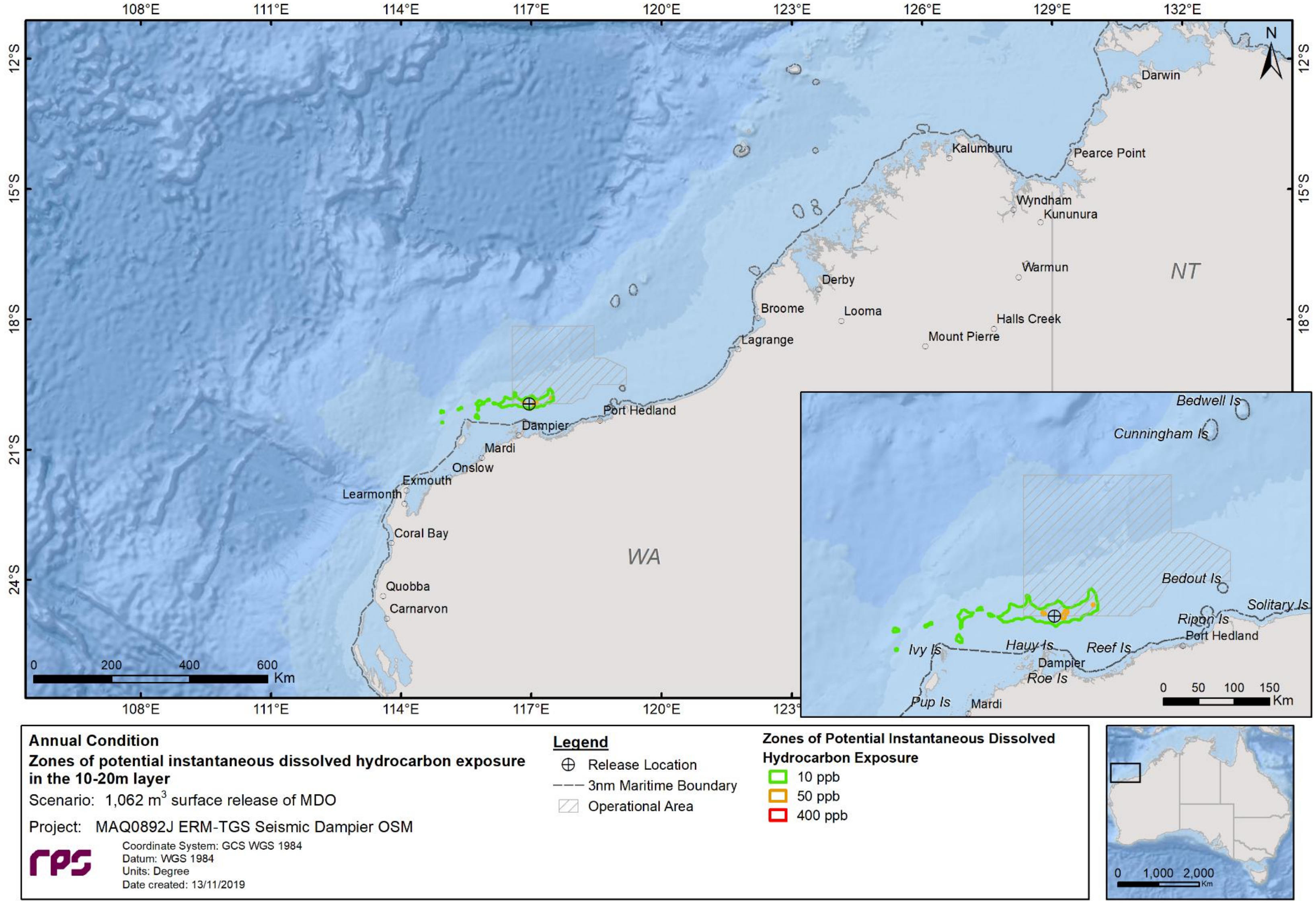


Figure 9.7 Zones of potential dissolved hydrocarbon exposure (over 1 hour) at 10–20 m below the sea surface in the event of a 1,062 m^3 of surface release of MDO over 6 hours, at Release Site 1 (tracked for 40 days). The results were calculated from 100 spill trajectories during annual conditions.

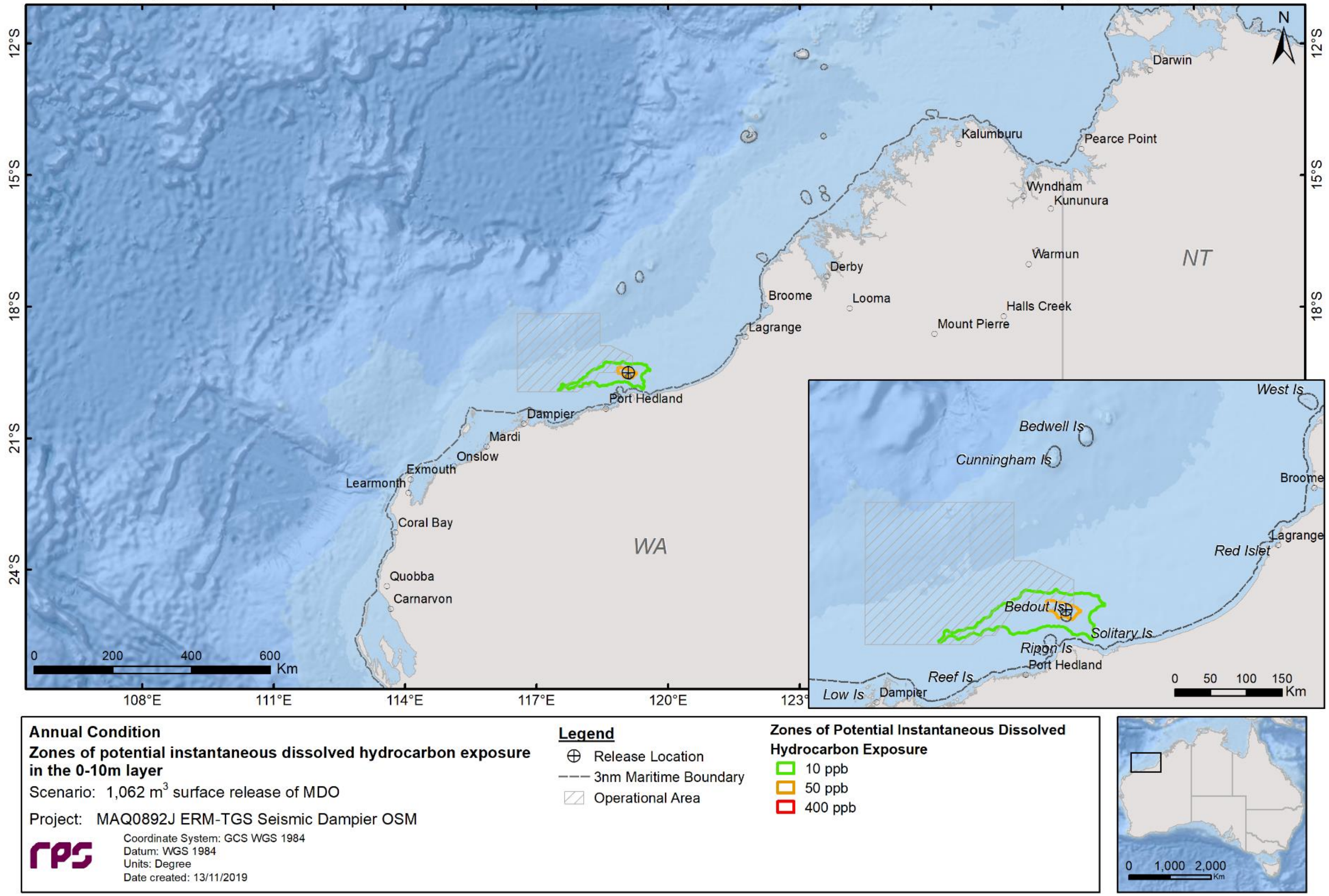


Figure 9.8 Zones of potential dissolved hydrocarbon exposure (over 1 hour) at 0–10 m below the sea surface in the event of a 1,062 m^3 of surface release of MDO over 6 hours, at Release Site 2 (tracked for 40 days). The results were calculated from 100 spill trajectories during annual conditions.

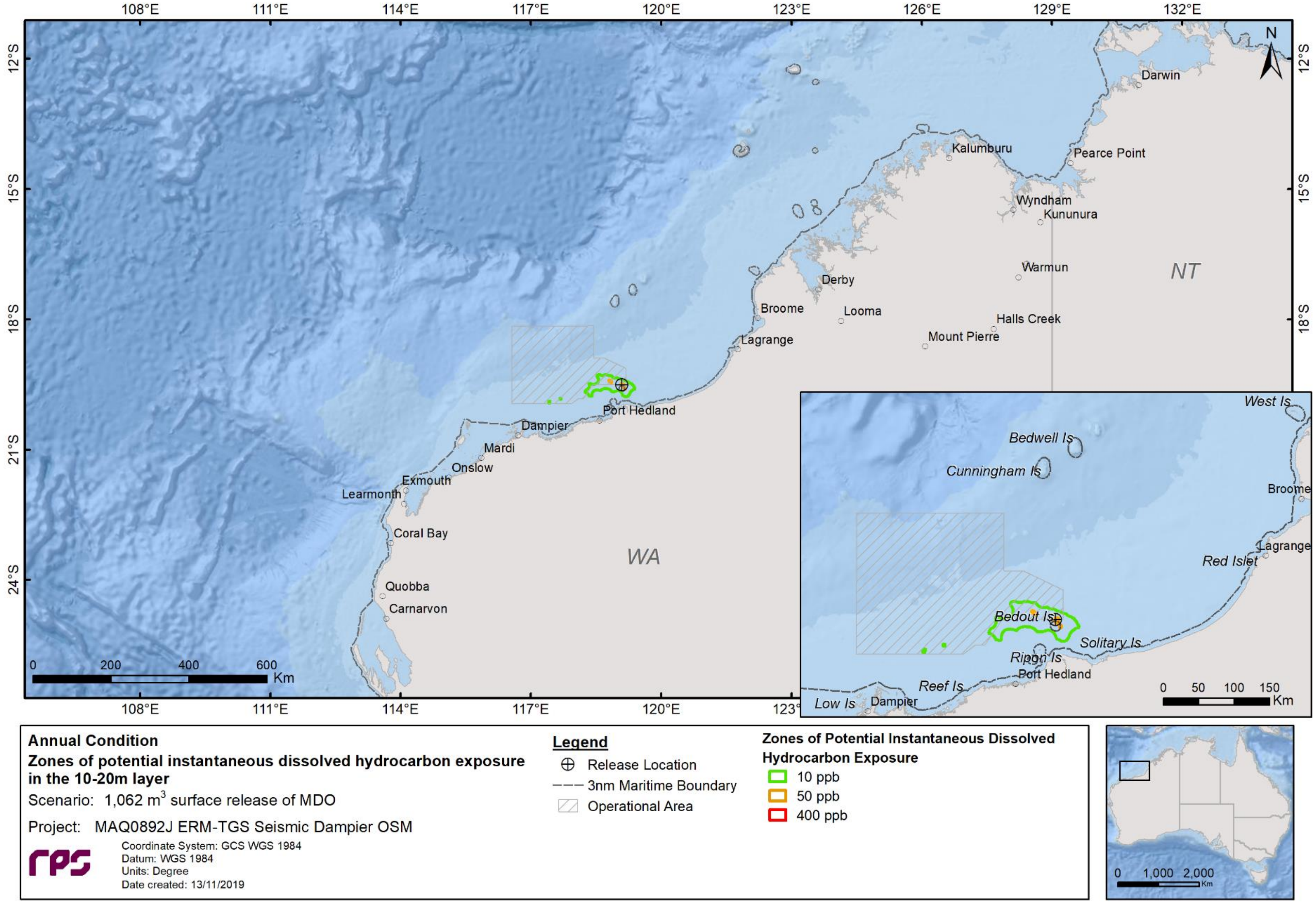


Figure 9.9 Zones of potential dissolved hydrocarbon exposure (over 1 hour) at 10–20 m below the sea surface in the event of a 1,062 m^3 of surface release of MDO over 6 hours, at Release Site 2 (tracked for 40 days). The results were calculated from 100 spill trajectories during annual conditions.

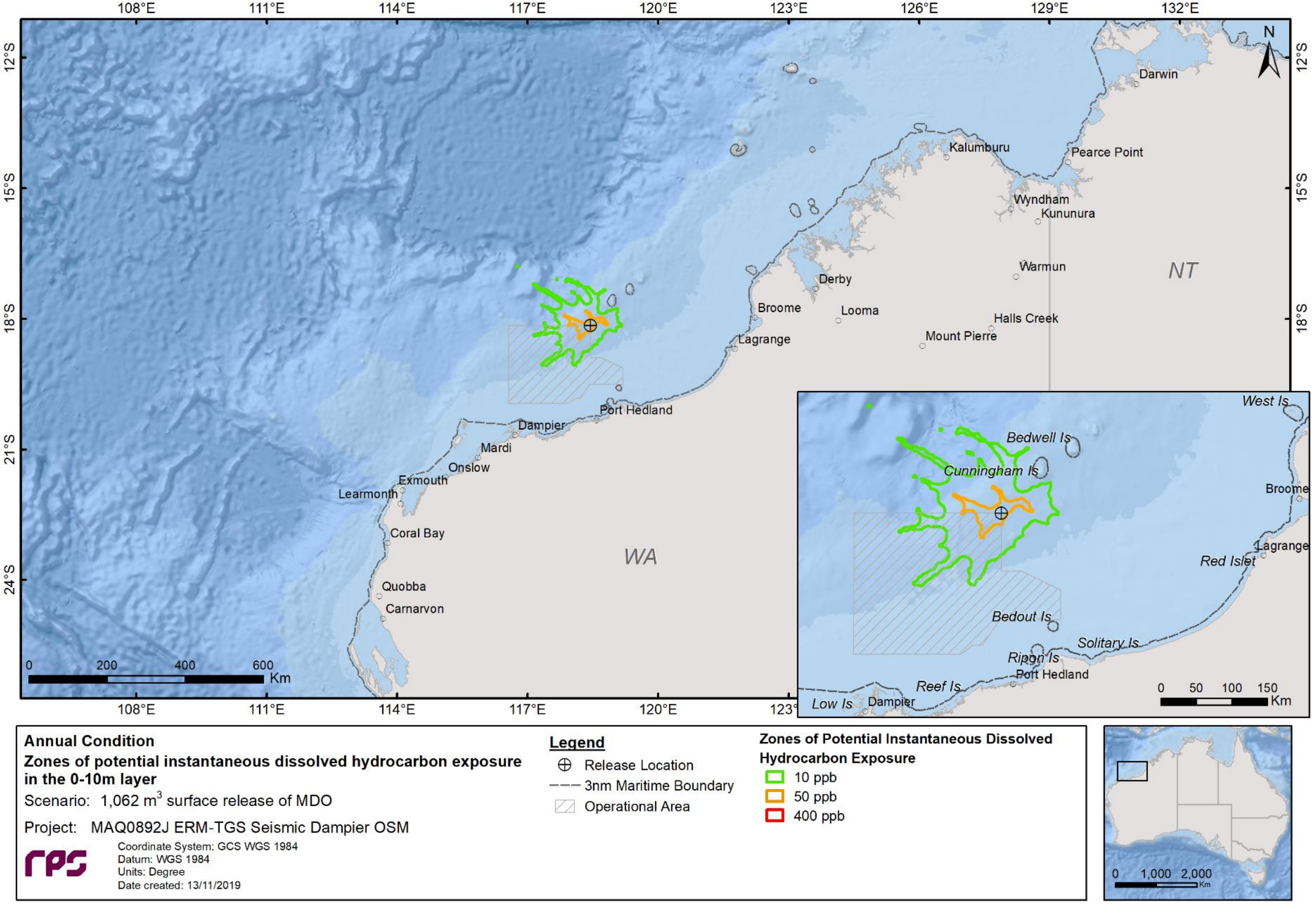


Figure 9.10 Zones of potential dissolved hydrocarbon exposure (over 1 hour) at 0–10 m below the sea surface in the event of a 1,062 m^3 of surface release of MDO over 6 hours, at Release Site 3 (tracked for 40 days). The results were calculated from 100 spill trajectories during annual conditions.

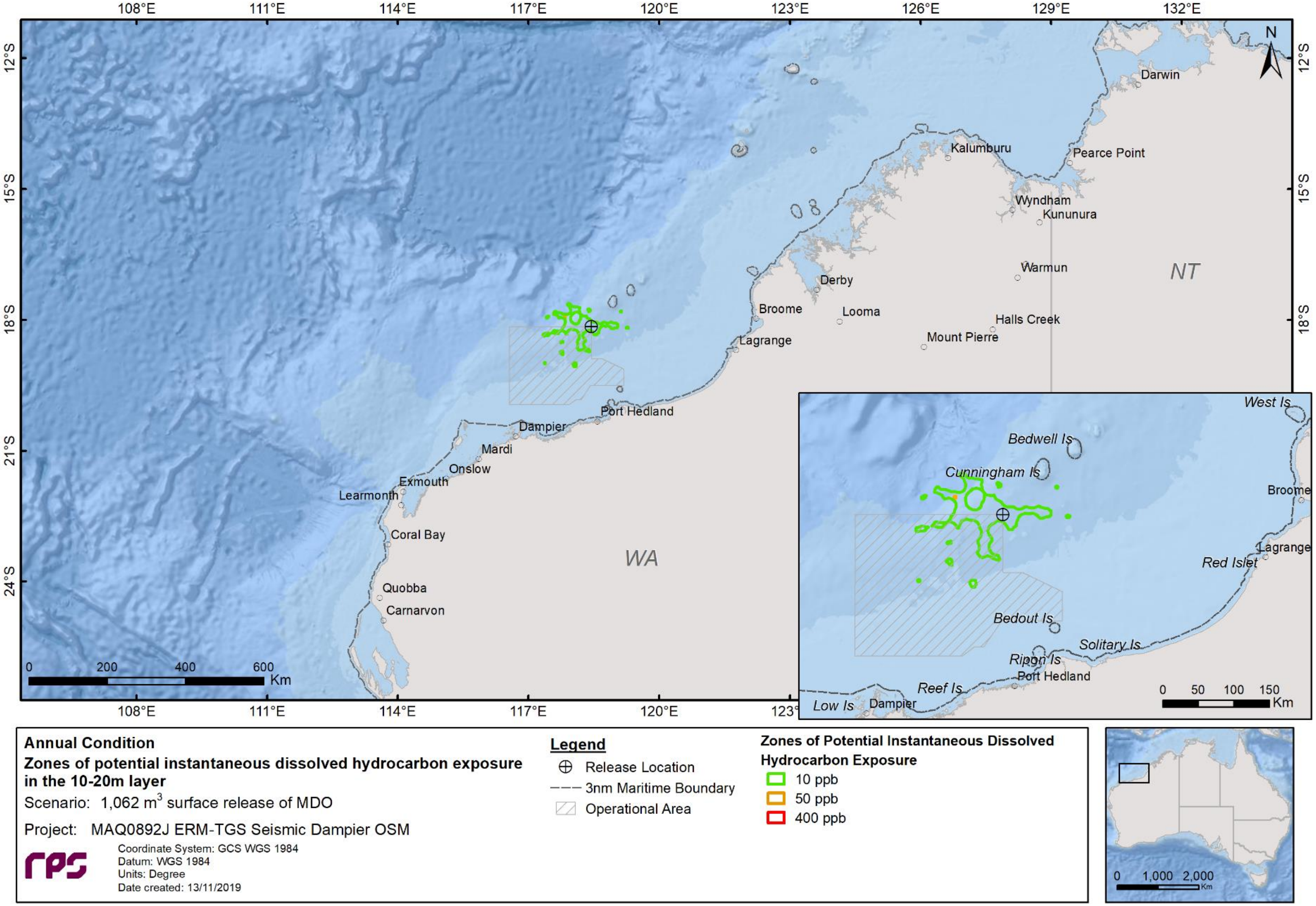


Figure 9.11 Zones of potential dissolved hydrocarbon exposure (over 1 hour) at 10–20 m below the sea surface in the event of a 1,062 m^3 of surface release of MDO over 6 hours, at Release Site 3 (tracked for 40 days). The results were calculated from 100 spill trajectories during annual conditions.

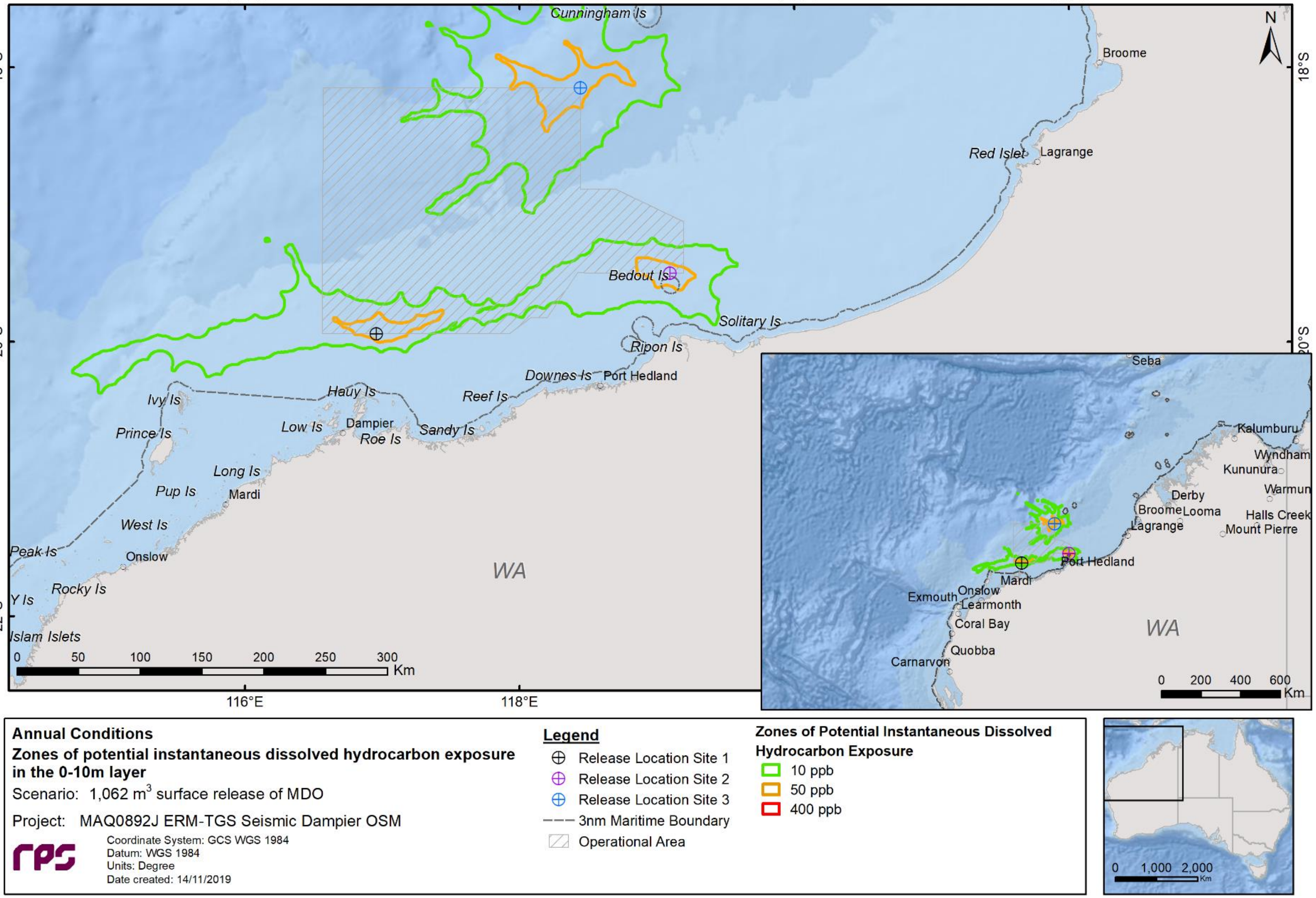


Figure 9.12 Zones of dissolved hydrocarbon exposure (over 1 hour), in the 0 – 10 m layer produced by overlaying the results from all 300 simulations for Release Sites 1, 2 and 3 during annual conditions. Each simulation is based on a 1,062 m³ surface release of MDO over 6 hours, tracked for 40 days.

9.1.3.2 Entrained Hydrocarbons

Table 9.7 and Table 9.8 summarise the maximum entrained hydrocarbon exposure levels (over 1 hour) and probability of exposure for the low (10-100 ppb) and high (≥100 ppb) thresholds to individual receptors in the 0–10 m and 10-20 m depth layer at, or above the exposure thresholds for each release site assessed.

In the surface layer (0-10 m), the Argo-Rowley Terrace, Eighty Mile Beach, Gascoyne and Montebello AMPs were all predicted to be exposed to entrained hydrocarbons at the low threshold concentration at each Release Site with probabilities ranging from 1% (multiple receptors) to 100% (Eighty Mile Beach, Release Site 2). Additionally, the Ancient coastline at 125 m depth contour, Continental Slope Demersal Fish Communities, Exmouth Plateau and Glomar Shoals KEFs as well as Glomar Shoal, Rankin Bank RSBs and Western Australia State Waters all were predicted to be exposed to entrained hydrocarbons at the low threshold concentration at each Release Site with probabilities ranging from 2% (Glomar Shoal and Rankin Bank RSBs, Release Site 3) to 84% (Western Australia State Waters, Release Site 2). A number of receptors were predicted to be exposed at the high entrained hydrocarbon threshold concentration with probabilities ranging from 1% (multiple receptors) to 97% (Eighty Mile Beach, Release Site 2).

In the 10-20 m layer, the Pilbara (offshore) IMCRA was the only receptor predicted to be exposed at the low entrained hydrocarbon threshold concentration for Release Site 1 with a probability of 1%. While at Release Site 2, the only receptor predicted to be exposed at the low entrained hydrocarbon threshold concentration was Eighty Mile Beach AMP with a probability of 1%. No receptors were predicted to be exposed at the low and high entrained hydrocarbon threshold concentration for Release Site 3 while no receptors were predicted to be exposed at the high exposure threshold for Release Site 1 and 2.

Figure 9.13 to Figure 9.18 illustrate the zones of potential entrained hydrocarbon exposure over 1-hour duration in the 0-10 m and 10-20 m depth layers, for release site assessed.

Figure 9.19 shows the zones of entrained hydrocarbon exposure produced by overlaying the results from all 300 simulations for Release Sites 1, 2 and 3 during annual conditions.

Table 9.7 Maximum entrained hydrocarbon exposure levels (over 1 hour) and probability of exposure for each threshold to individual receptors in the 0–10 m depth layer, for all Release Sites. Results were calculated from 100 spill trajectories during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Release Site		Receptor	Maximum entrained hydrocarbon exposure level over 1 hour (ppb)	Probability of entrained hydrocarbon exposure for each threshold (%)	
				Low	High
1	AMP	Argo-Rowley Terrace	12	1	-
		Carnarvon Canyon	18	1	-
		Dampier	13	1	-
		Eighty Mile Beach	50	4	-
		Gascoyne	87	15	-
		Montebello	424	30	10
		Ningaloo	62	2	-
	IBRA	Cape Range	83	2	-
		Roebourne	41	2	-
	IMCRA	Eighty Mile Beach	17	1	-
		Ningaloo	67	7	-
		Pilbara (nearshore)	13	1	-
		Pilbara (offshore)	12,419	78	70
		Zuytdorp	24	1	-
	KEF	Ancient coastline at 125 m depth contour	512	38	9
		Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	87	11	-
		Commonwealth waters adjacent to Ningaloo Reef	62	2	-
		Continental Slope Demersal Fish Communities	387	32	6
		Exmouth Plateau	122	11	1
		Glomar Shoals	1,337	43	19
		Western demersal slope and associated fish communities	17	1	-
	MMA	Barrow Island	138	2	1
	MP	Barrow Island	45	2	-
		Montebello Islands	151	3	1
		Ningaloo	20	1	-
	RSB	Glomar Shoal	361	25	6
		Montebello Shoals	101	2	1
		Rankin Bank	251	33	4
	State Waters	Western Australia State Waters	151	3	1
2	AMP	Argo-Rowley Terrace	35	3	-
		Eighty Mile Beach	16,680	100	97
		Gascoyne	26	1	-

		Montebello	155	8	1
		Roebuck	25	1	-
	IBRA	Pindanland	25	1	-
		Roebourne	2,116	54	33
	IMCRA	Canning	34	5	-
		Eighty Mile Beach	218	12	2
		Northwest Shelf	1,400	47	33
		Pilbara (nearshore)	179	6	1
	KEF	Ancient coastline at 125 m depth contour	176	20	2
		Continental Slope Demersal Fish Communities	125	10	1
		Exmouth Plateau	34	7	-
		Glomar Shoals	186	18	2
	MP	Eighty Mile Beach	23	3	-
	RAMSAR	Roebuck Bay	25	1	-
	RSB	Glomar Shoal	67	16	-
		Rankin Bank	38	11	-
	State Waters	Western Australia State Waters	4,953	84	72
3	AMP	Argo-Rowley Terrace	833	22	8
		Eighty Mile Beach	16	1	-
		Gascoyne	39	1	-
		Kimberley	13	1	-
		Mermaid Reef	38	2	-
		Montebello	16	1	-
	EEZ	Indonesian Exclusive Economic Zone	50	1	-
	IMCRA	Northwest Shelf	2,598	28	14
		Pilbara (offshore)	33	3	-
	KEF	Ancient coastline at 125 m depth contour	663	15	2
		Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	29	2	-
		Continental Slope Demersal Fish Communities	50	8	-
		Exmouth Plateau	74	6	-
		Glomar Shoals	22	3	-
		Mermaid Reef and Commonwealth waters surrounding Rowley Shoals	727	19	6
	MP	Rowley Shoals	358	16	4
	RSB	Clerke Reef	206	5	1
		Glomar Shoal	14	2	-
		Imperieuse Reef	270	12	4
		Mermaid Reef	36	2	-
		Rankin Bank	21	2	-
	State Waters	Western Australia State Waters	358	16	4

Table 9.8 Maximum entrained hydrocarbon exposure levels (over 1 hour) and probability of exposure for each threshold to individual receptors in the 10–20 m depth layer, for all Release Sites. Results were calculated from 100 spill trajectories during annual conditions and each simulation was based on a hypothetical 1,062 m³ surface release of MDO over 6 hours (tracked for 40 days).

Release Site	Receptor		Maximum entrained hydrocarbon exposure level over 1 hour (ppb)	Probability of entrained hydrocarbon exposure for each threshold (%)	
				Low	High
1	IMCRA	Pilbara (offshore)	13	1	-
2	AMP	Eighty Mile Beach	11	1	-
3	-	-	-	-	-

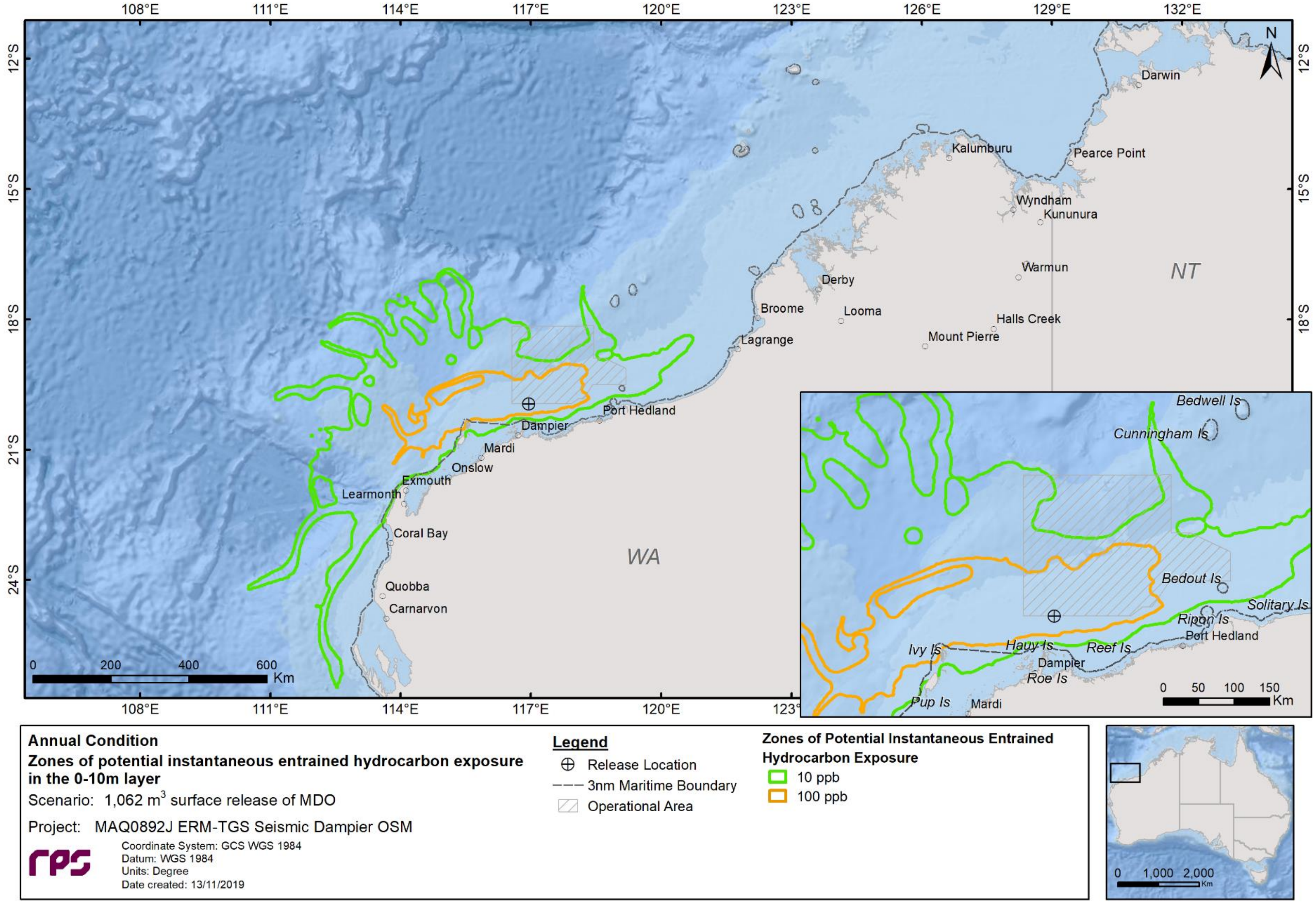


Figure 9.13 Zones of potential entrained hydrocarbon exposure (over 1 hour) in the 0-10 m layer, resulting from a 1,062 m³ surface release of MDO over 6 hours, at Release Site 1 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

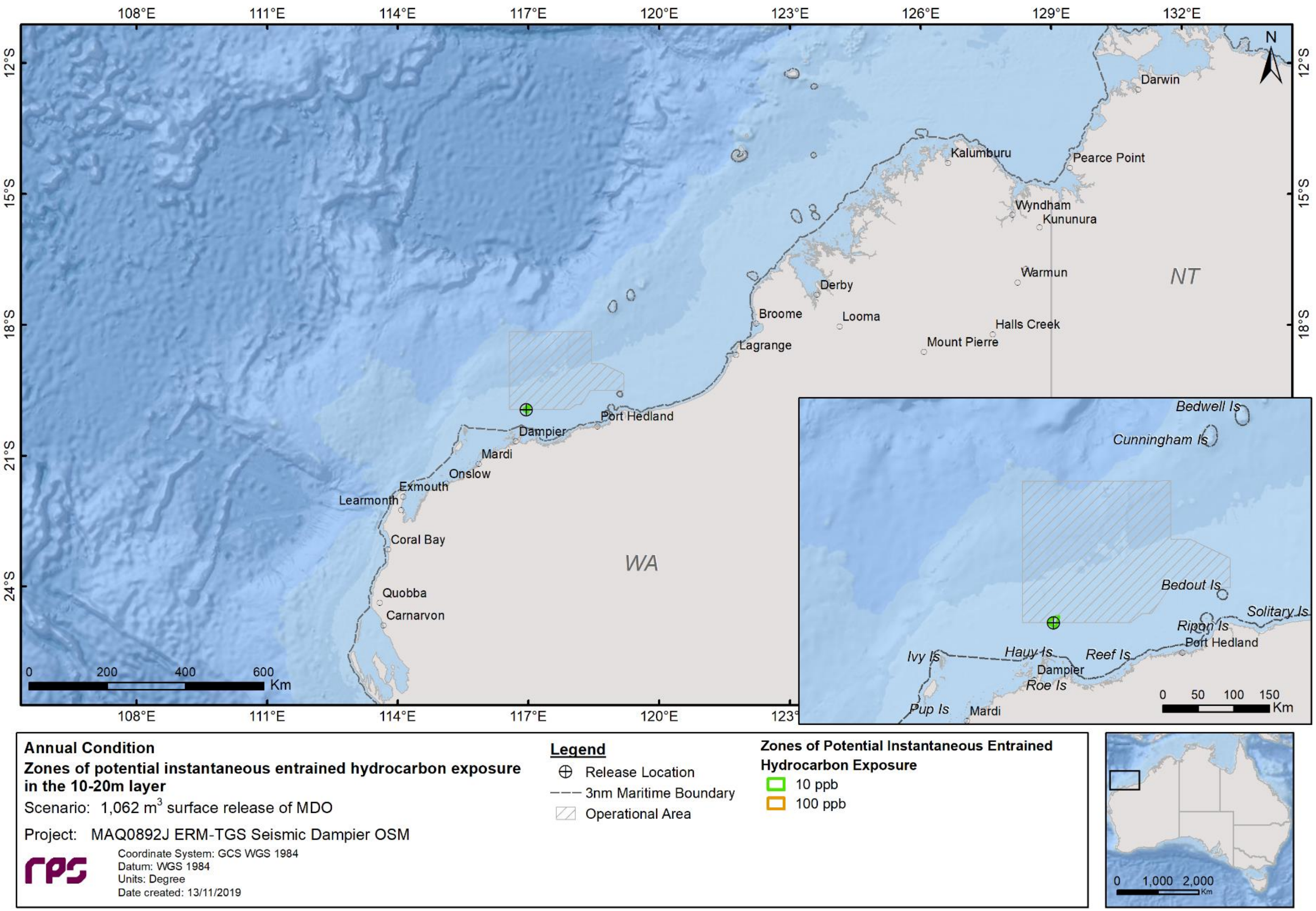


Figure 9.14 **Zones of potential entrained hydrocarbon exposure (over 1 hour) in the 10-20 m layer, resulting from a 1,062 m³ surface release of MDO over 6 hours, at Release Site 1 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.**

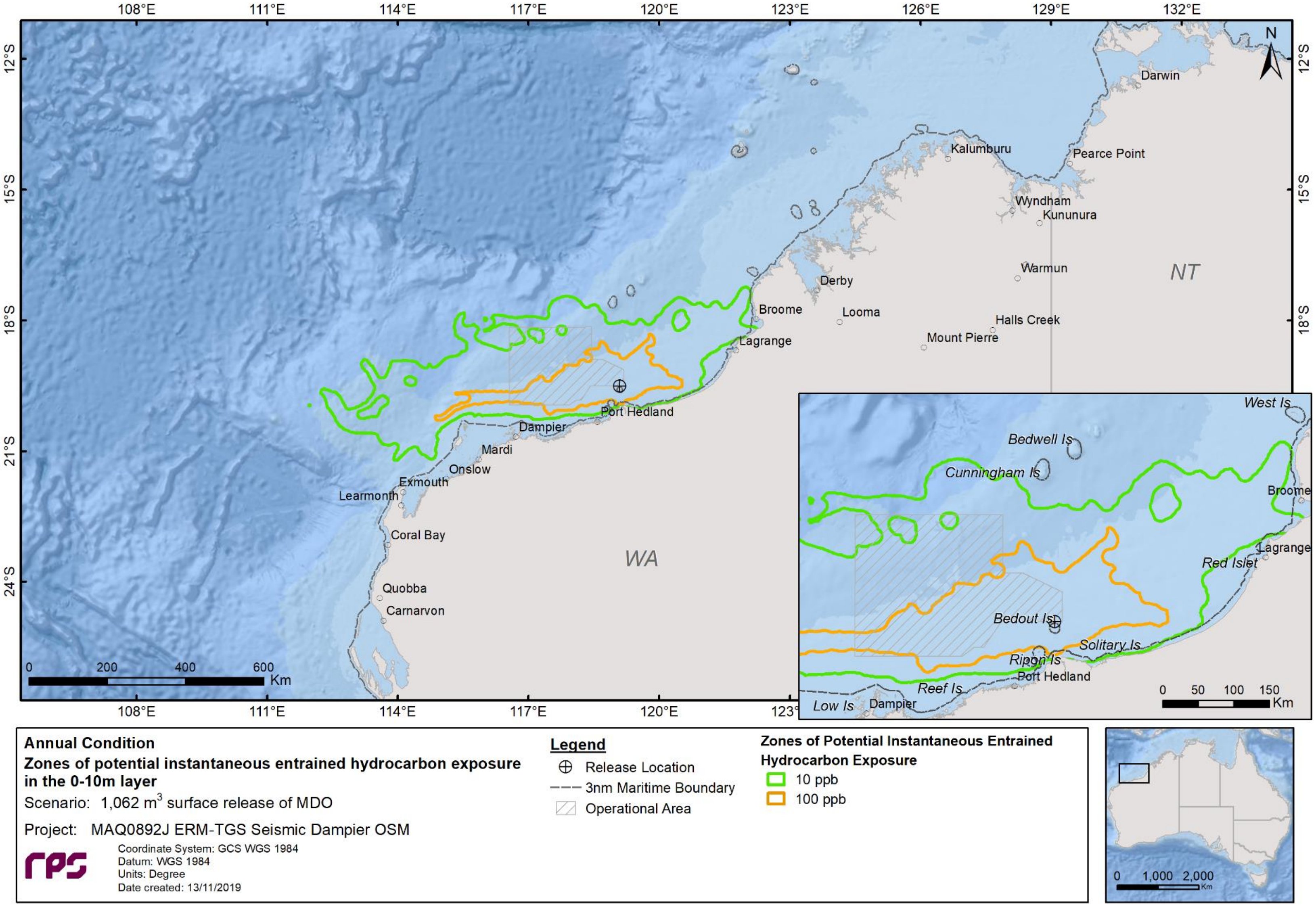


Figure 9.15 Zones of potential entrained hydrocarbon exposure (over 1 hour) in the 0-10 m layer, resulting from a 1,062 m³ surface release of MDO over 6 hours, at Release Site 2 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

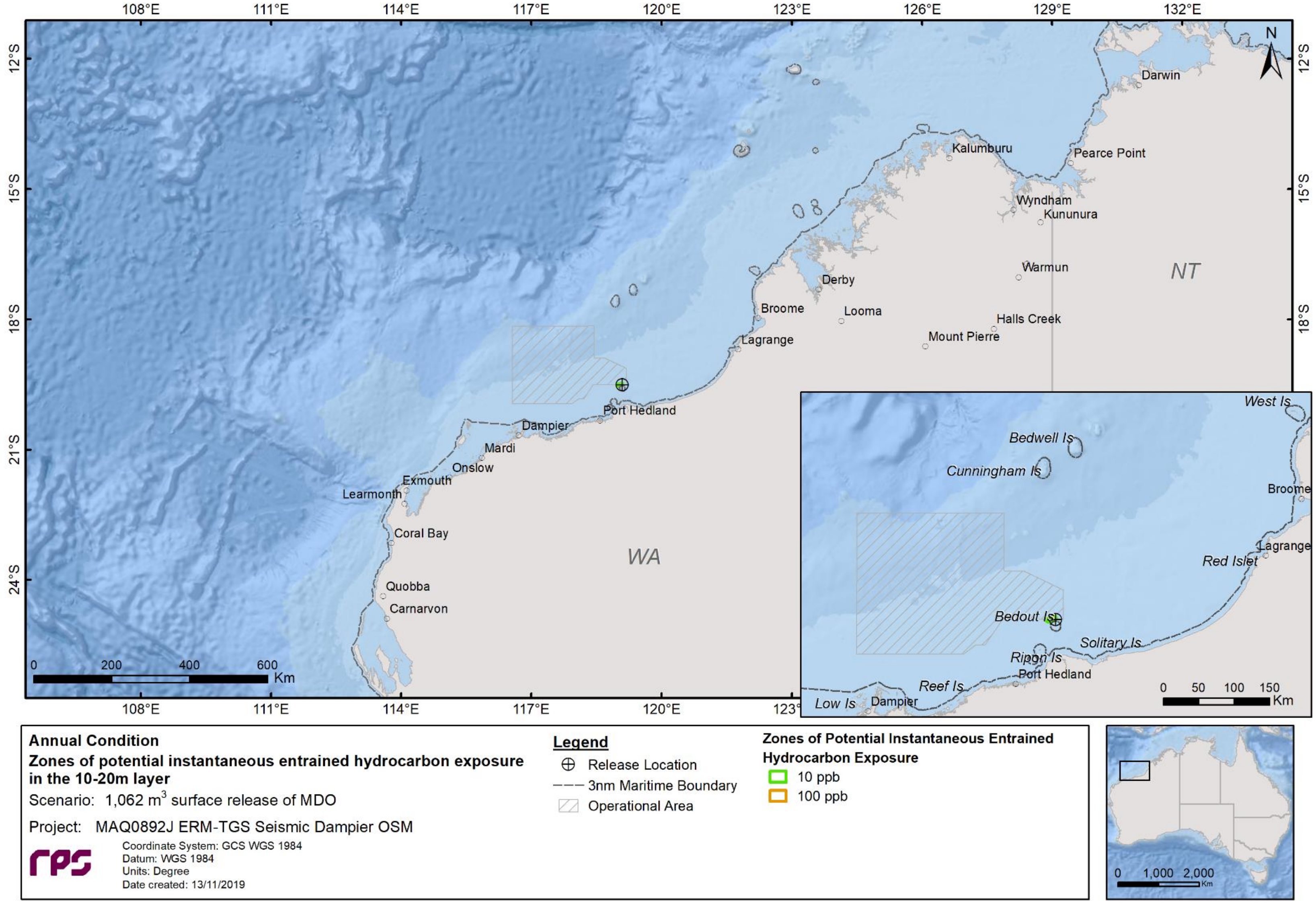


Figure 9.16 **Zones of potential entrained hydrocarbon exposure (over 1 hour) in the 10-20 m layer, resulting from a 1,062 m³ surface release of MDO over 6 hours, at Release Site 2 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.**

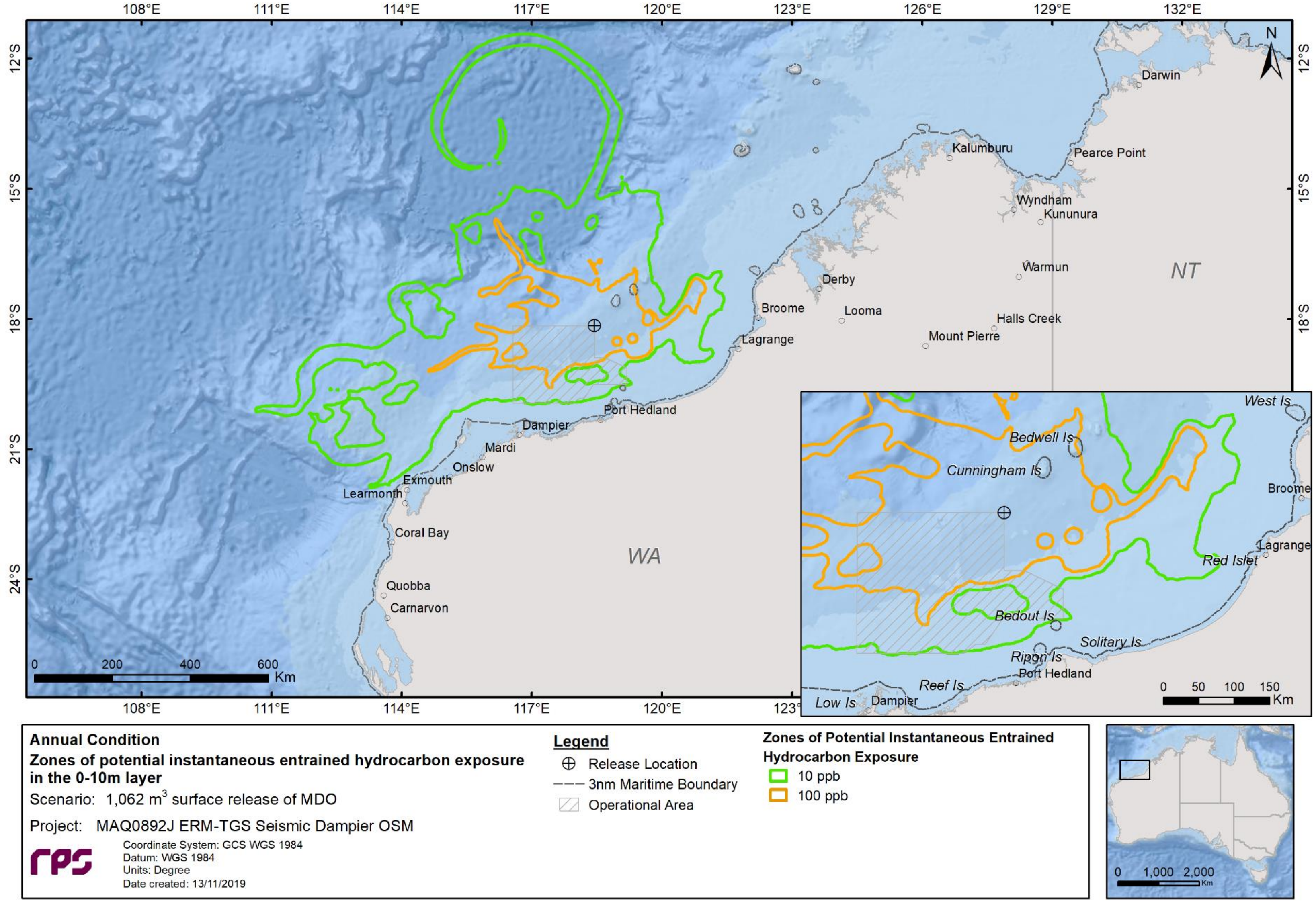


Figure 9.17 Zones of potential entrained hydrocarbon exposure (over 1 hour) in the 0-10 m layer, resulting from a 1,062 m³ surface release of MDO over 6 hours, at Release Site 3 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

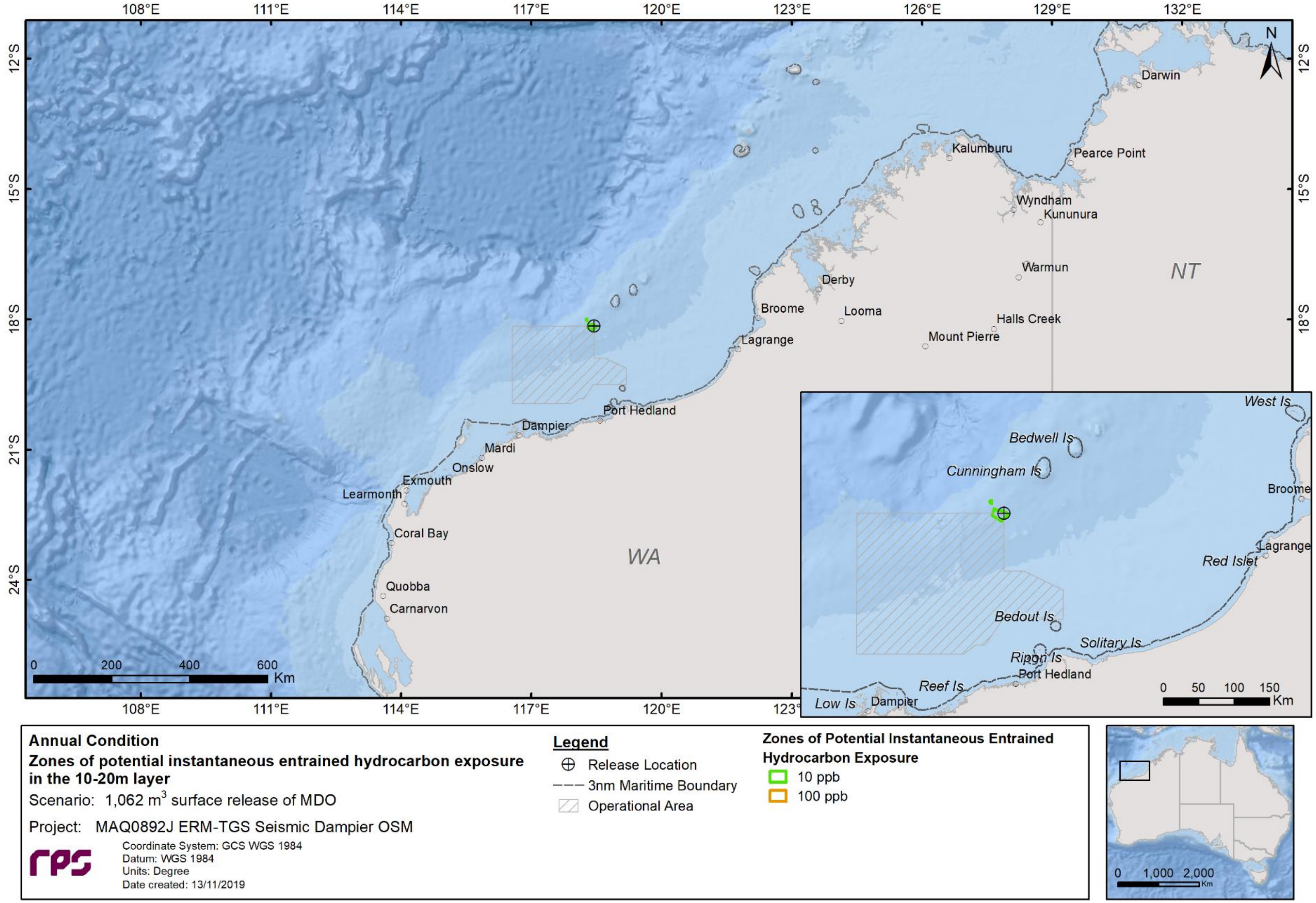


Figure 9.18 Zones of potential entrained hydrocarbon exposure (over 1 hour) in the 10-20 m layer, resulting from a 1,062 m³ surface release of MDO over 6 hours, at Release Site 3 (tracked for 40 days). Results were calculated from 100 spill trajectories during annual conditions.

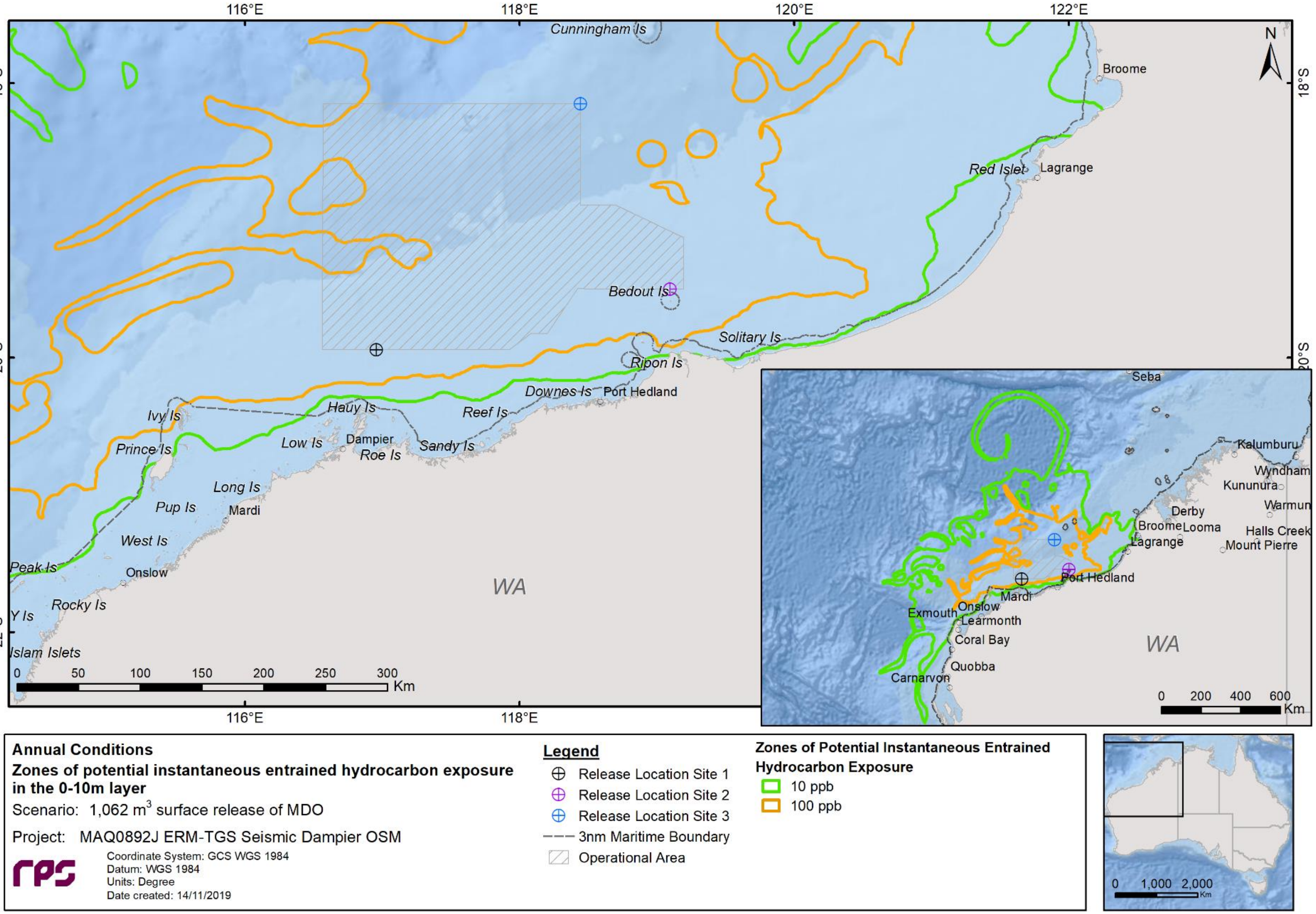


Figure 9.19 Zones of entrained hydrocarbon exposure (over 1 hour), in the 0 – 10 m layer produced by overlaying the results from all 300 simulations for Release Sites 1, 2 and 3 during annual conditions. Each simulation is based on a 1,062 m³ surface release of MDO over 6 hours, tracked for 40 days.

9.2 Deterministic Analysis

The stochastic modelling results were assessed, and the "worst case" deterministic run that resulted in the largest swept area of oil on the sea surface above 1 g/m^2 (visible sea surface oil) across all 300 simulations was identified and presented in the following section.

9.2.1 Deterministic Case: Largest Sea Surface Swept Area above 1 g/m^2

The deterministic trajectory that resulted in the largest sea surface oil swept area above 1 g/m^2 (low exposure threshold) was identified as run number 21 and originated from Release Site 3. This spill trajectory commenced at 4 am on the 27th of May 2016.

Time series maps of the potential zones of exposure from sea surface oil (swept area) at 1 day, 2 days, 3 days and 5 days following the commencement of the spill are presented in Figure 9.20 and Figure 9.21. Figure 9.22 and Figure 9.23 illustrate the potential zones of the sea surface exposure and instantaneous entrained hydrocarbons over the entire simulation, respectively. For this case, the released hydrocarbons initially headed to the northeast of Release Site 3 before swinging around to the west and then south until they dissipated to levels below the lowest reporting threshold by approximately day-8 into simulation.

Figure 9.24 displays the time series of the area of visible oil (1 g/m^2) on the sea surface over the 40-day simulation. The maximum area of coverage by surface hydrocarbons exceeding high exposure zones (>50 g/m^2) was predicted to occur 6 hours into the simulation and covered approximately 5.9 km^2. Note, no zones of high exposure (>50 g/m^2) remained on the sea surface after 18 hours. The maximum area of coverage by surface hydrocarbons exceeding moderate exposures (10 g/m^2) was predicted to occur between 6 hours and 1.5 days following the spill start and covered approximately 16 km^2. After 2.75 days, as a result of evaporation and dispersion, no actionable surface hydrocarbons (exceeding the moderate (10 g/m^2) remained. The maximum area of coverage of visible oil on the sea surface was predicted to occur between day 2.5 and 3.5 and covered approximately 50 km^2. No shoreline contact above the low threshold was predicted for this simulation. No visible surface hydrocarbons (1 g/m^2) remained after 8.75 days after the release.

Figure 9.25 presents the fates and weathering graph for the corresponding single spill trajectory. At the conclusion of the simulation period, approximately 924 m^3 (87.1%) spilled oil was lost to the atmosphere through evaporation. Approximately 69 m^3 (6.5%) of the oil was predicted to have decayed, while approximately 66 m^3 (6.2%) remained within the water column and 2 m^3 (0.2%) on the sea surface.

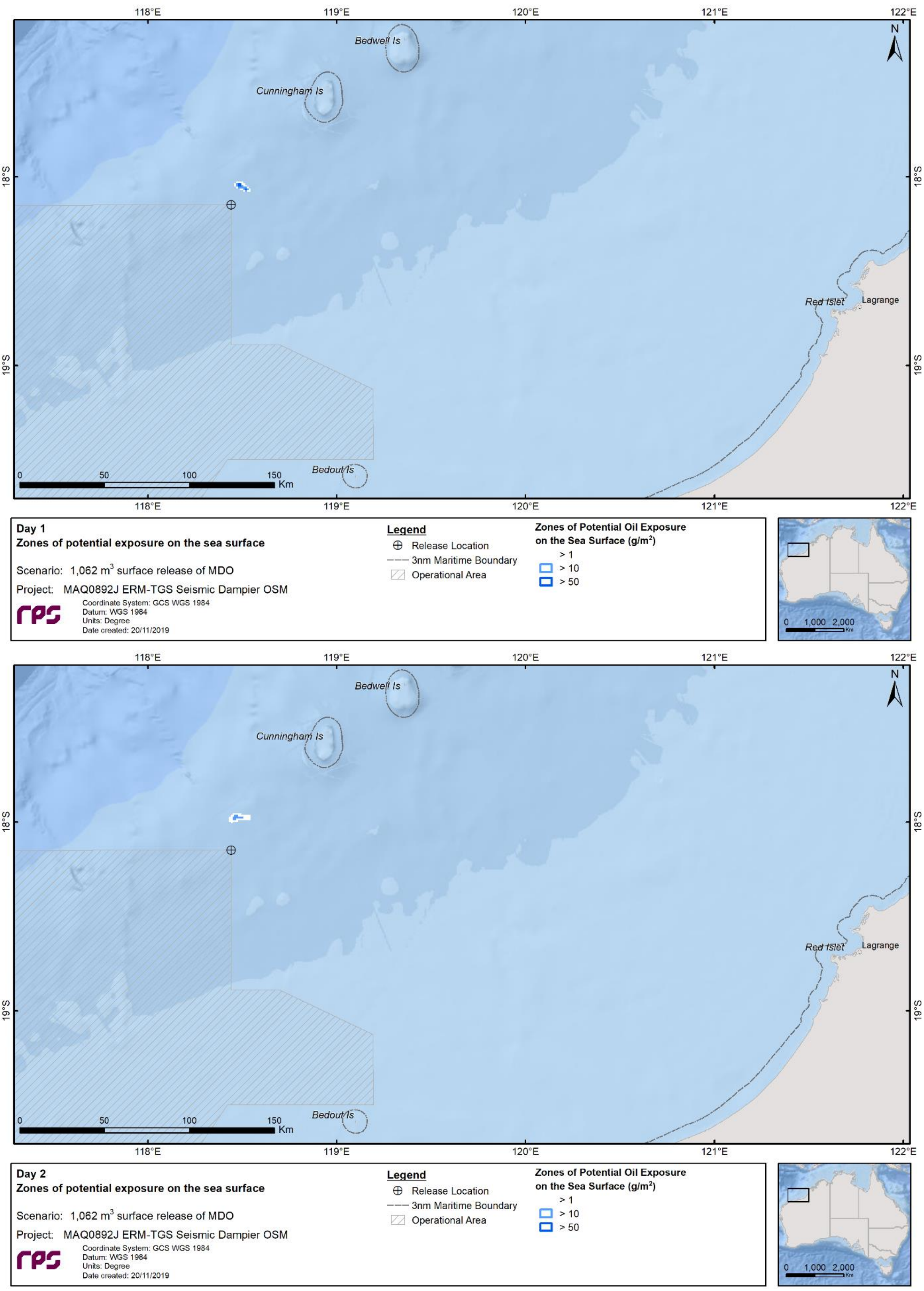
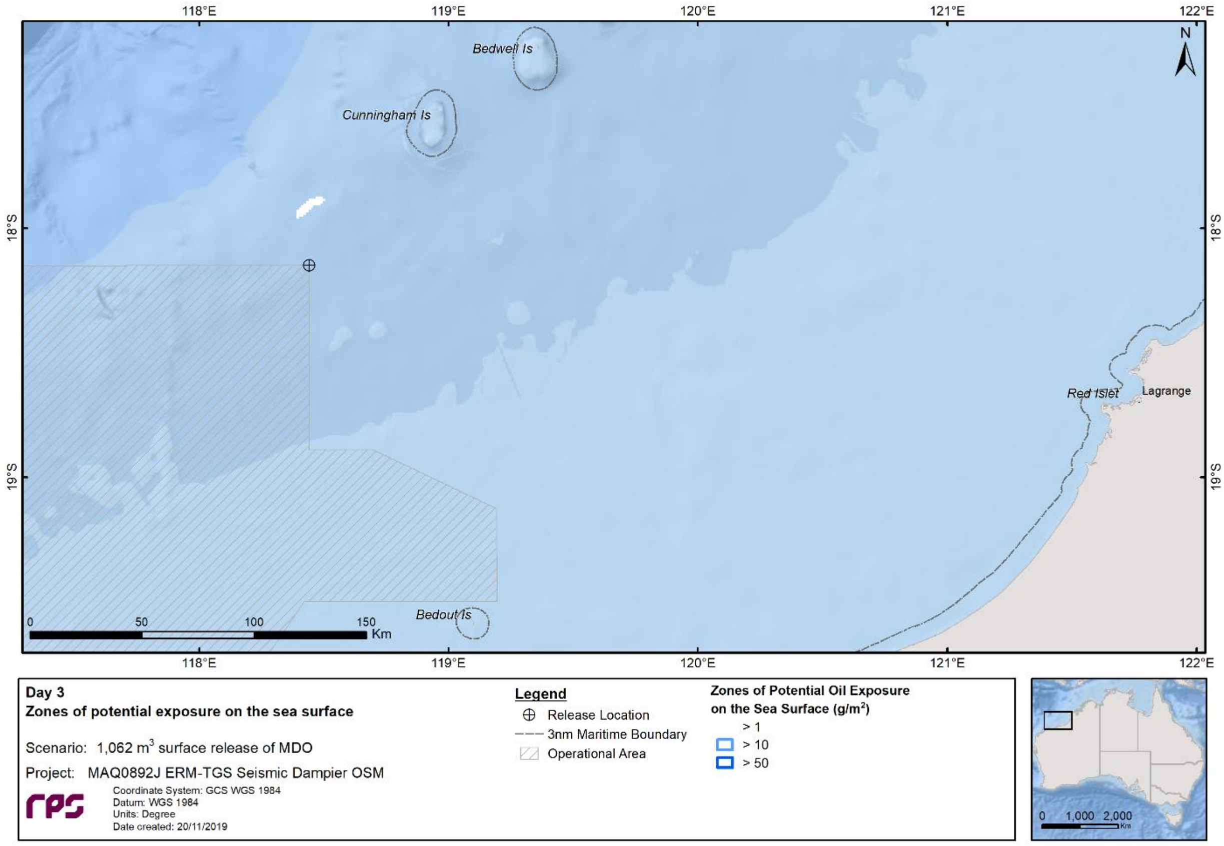


Figure 9.20 Zones of potential exposure on the sea surface and shoreline at day 1 (upper image) and day 2 (lower image) into simulation, for the trajectory with the largest swept area of oil on the sea surface above 1 g/m^2. Results are based on a 1,062 m³ surface release of MDO over 6 hours at Release Site, tracked for 40 days, 8 pm 7th of November 2008.



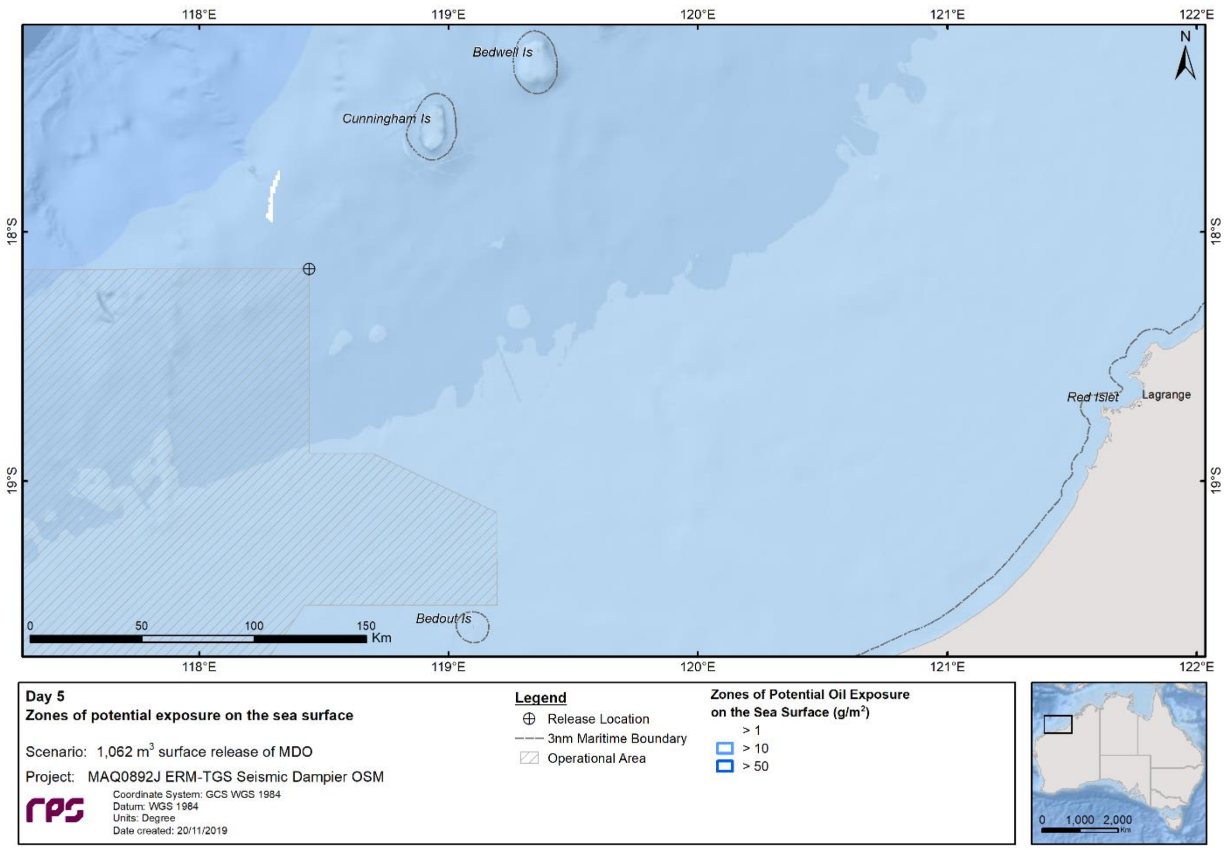


Figure 9.21 Zones of potential exposure on the sea surface and shoreline at day 3 (upper image) and day 5 (lower image) into simulation, for the trajectory with the largest swept area of oil on the sea surface above 1 g/m^2. Results are based on a 1,062 m^3 surface release of MDO over 6 hours at Release Site, tracked for 40 days, 8 pm 7th of November 2008.

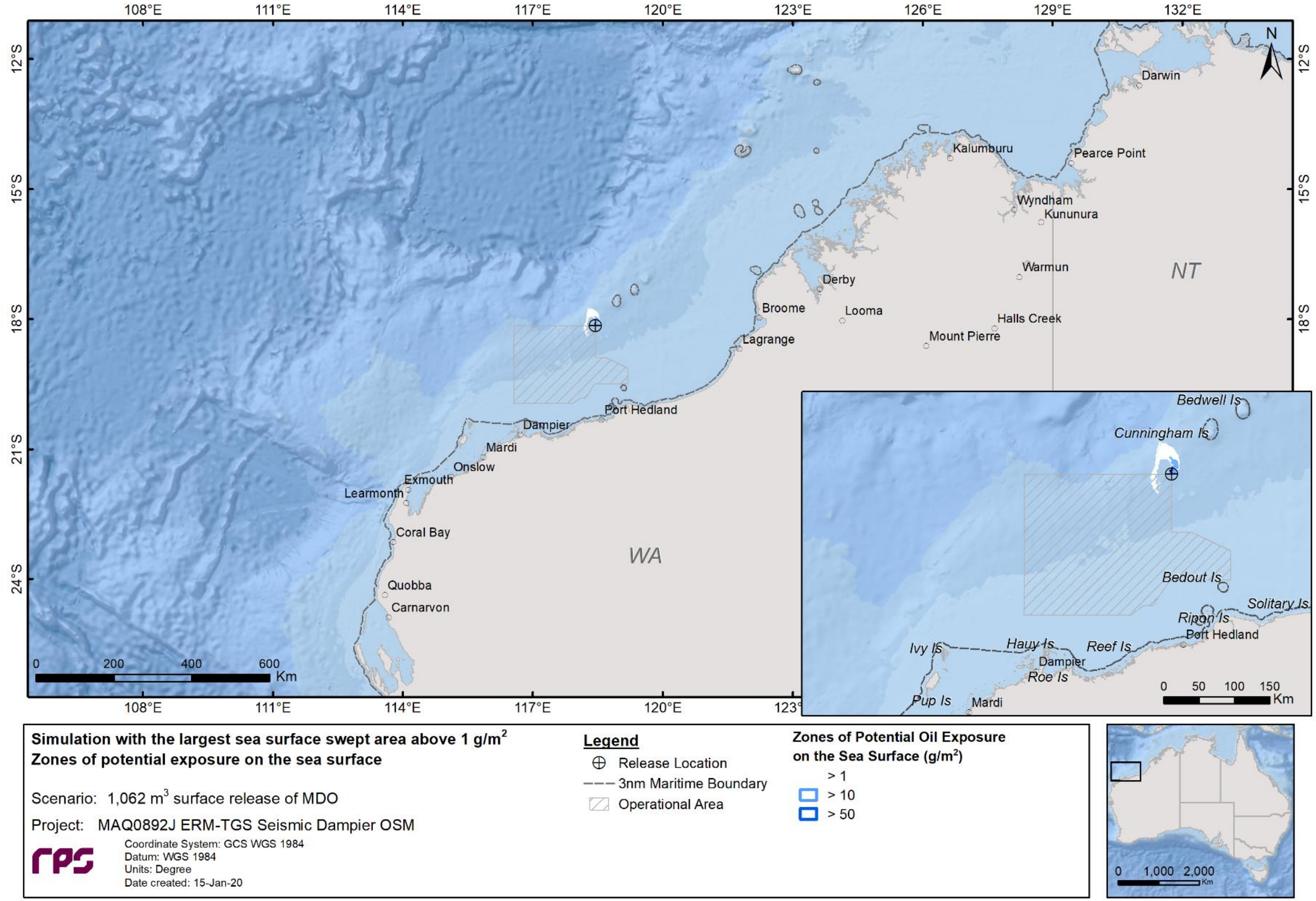


Figure 9.22 Zones of potential exposure on the sea surface (over the entire simulation), for the trajectory with the largest swept area of oil on the sea surface above 1 g/m². Results are based on a 1,062 m³ surface release of MDO over 6 hours at Release Site, tracked for 40 days, 8 pm 7th of November 2008.

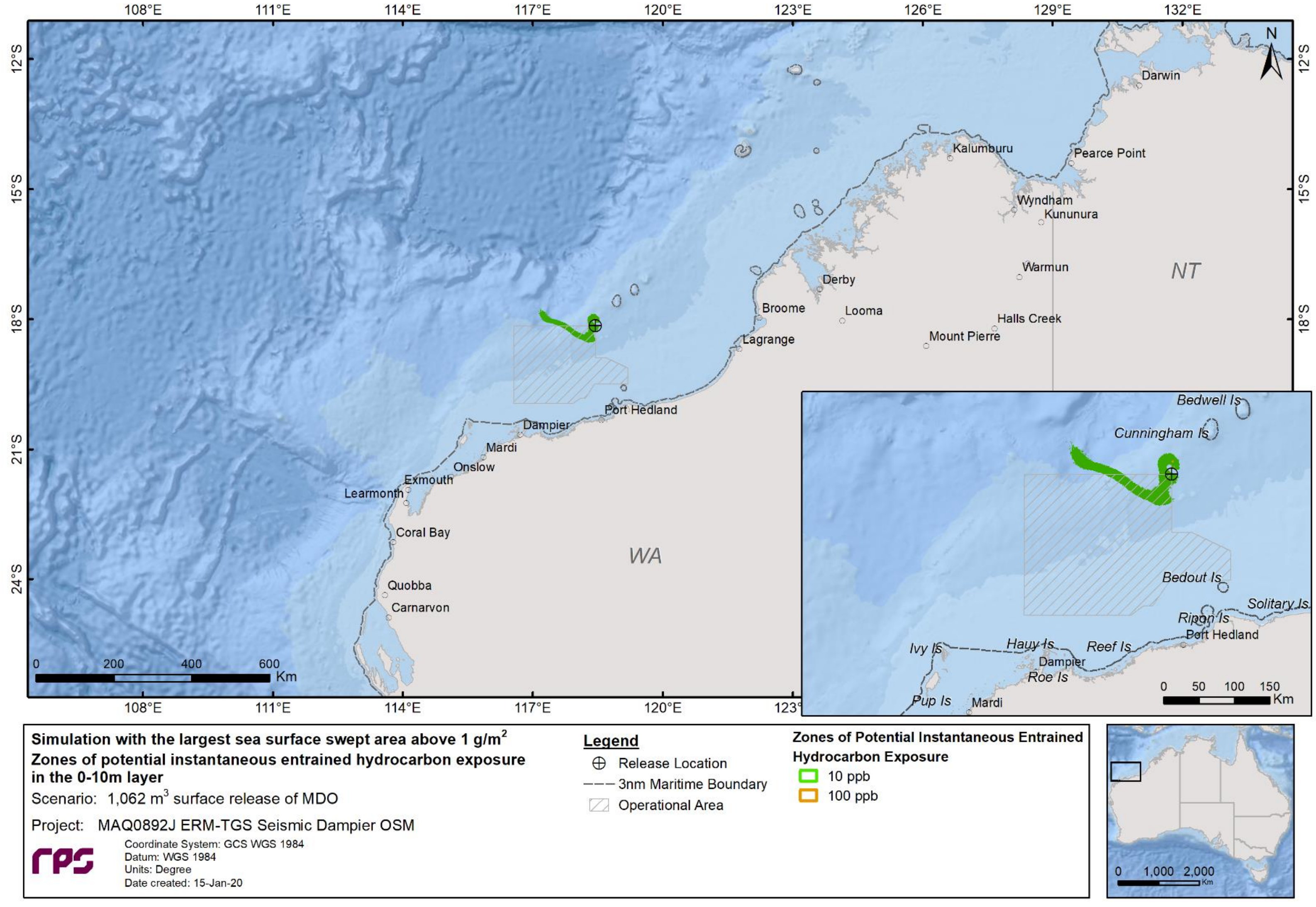


Figure 9.23 Zones of potential instantaneous entrained hydrocarbon exposure (over the entire simulation), for the trajectory with the largest oil volume ashore. Results are based on a 1,062 m³ surface release of MDO over 6 hours at Release Site, tracked for 40 days, 8 pm 7th of November 2008.

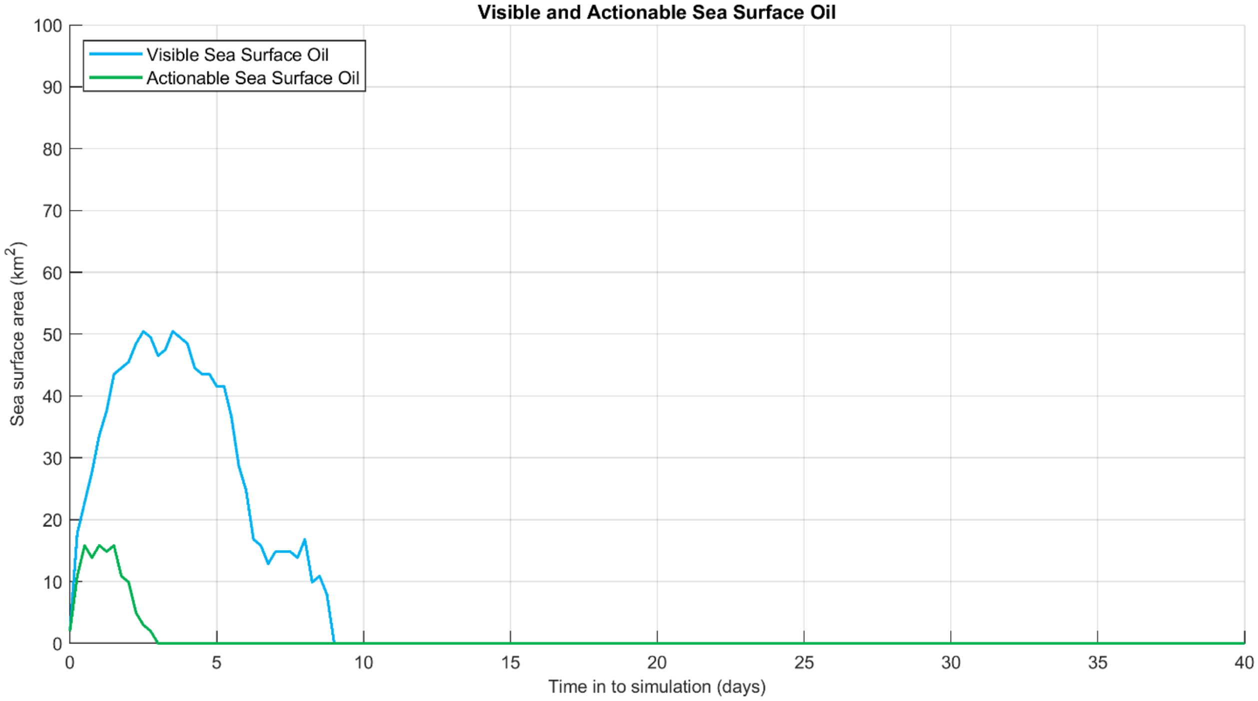


Figure 9.24 Time series of the area of visible (1 g/m²) on the sea surface for the trajectory with the largest sea surface swept area above 1 g/m². Results are based on a 1,062 m³ surface release of MDO over 6 hours at Release Site 3, tracked for 40 days, 4 am 27th of May 2016.

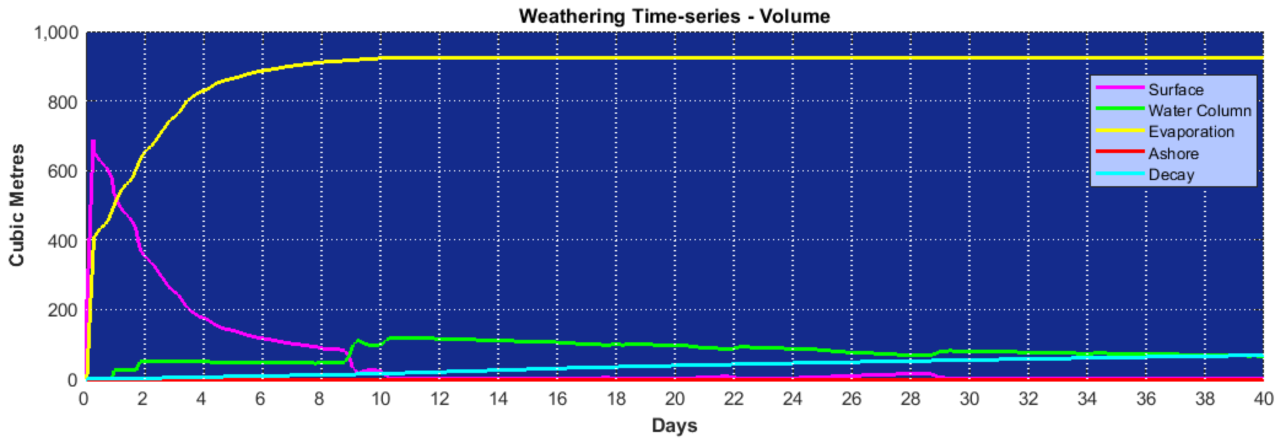


Figure 9.25 Predicted weathering and fates graph for the single spill trajectory with the largest oil volume ashore. Results are based on a 1,062 m³ surface release of MDO over 6 hours at Release Site 3, tracked for 40 days, 4 am 27th of May 2016.

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APPENDIX H TGS FISHERIES COMPENSATION PROCESS

TGS Fisheries Compensation Process - Australia

TGS-NOPEC Geophysical Company Pty Ltd (TGS) implements a range of management strategies to prevent or minimise the potential impact experienced by fishery licence holders and vessel crews during a seismic survey. These management strategies include:

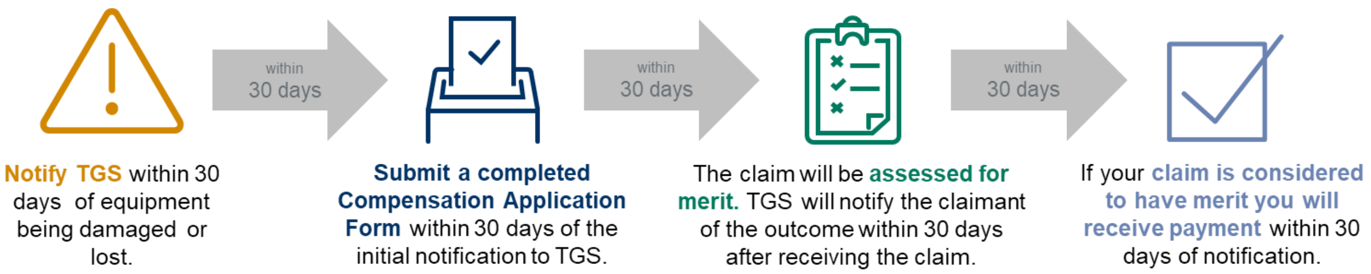
- providing a reasonable period of advance notice to fishery licence holders of the planned commencement date and location of survey activities;
- providing fishery licence holders with details of survey vessels, including radio and satellite phone contact details, to facilitate on-the-water communications;
- providing fishery licence holders with the opportunity to receive, or for their nominated shore base personnel and vessel crews to receive daily updates on survey activities and location during the survey; and
- maintaining open communications with fishery licence holders and/or vessels during the survey.

However, TGS recognises that in some instances compensation may be an appropriate management response.

TGS will consider compensation claims from fishery licence holders and vessel crews (i.e. the claimant) on a case-by-case basis, and in the following circumstances:

- where fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of TGS survey operations in Australia; and
- a temporary loss of fish catch due to damaged or lost fishing equipment as a direct result of TGS survey operations in Australia.

Compensation Claim Process



Claimants are required to notify TGS within 30 days of the equipment being damaged or lost to the marine environment in order to eligible for any compensation under this plan. A completed Compensation Claim Application Form (refer to Attachment A) must be sent to TGS at the address specified below within 30 days of the notification

TGS will, in consultation with the claimant, engage an independent third-party to review the compensation claim. Each claim will be assessed to determine the merit of the claim. In assessing the merit of the claim, consideration will be given to the circumstances giving rise to the claim, including whether the circumstances could have reasonably been avoided. In assessing compensation for temporary loss of catch, evidence must be provided and this may include information including, but not limited to, income via the form of tax returns and catch data.

TGS will determine and communicate the outcome of the claim to the claimant, or request clarification / additional information from the claimant, as soon as practicable and within 30 days after receiving the claim.

If the claim is considered valid and assessed to have merit, payment will be made directly to the claimant within 30 days of the claim determination.

It should be noted that compensation claims received from licence holders in any other circumstance other than those outlined above will not be assessed. TGS will not accept a claim, if the claim covers the same time, area, fishing activity and equipment made in another claim for a seismic survey not operated by TGS.

Please notify TGS of an alleged loss of equipment or damage to equipment at the following address: Capreolus2.Stakeholders@tgs.com.

Please submit a completed Compensation Claim Application Form (refer to attachment A) to the following address: Capreolus2.Stakeholders@tgs.com.

Attachment A: Compensation Claim Application Form

Applicants Details

Registered entity name:		
Registered commercial fishing licence number/reference:		
Applicant's details:	**Name:**	
	Email:	
	Phone No.	
	Address:	
Vessel details:	**Name:**	
	Call sign:	
	IMO No.	
	MMSI	
	Vessel type:	
Vessel owner's details (if different than above):	**Name:**	
	Email:	
	Phone No.	
	Address:	

Incident Report

Please fill in the relevant part/s below if:

- your fishing equipment has been damaged, damaged beyond repair or lost to the marine environment as a direct result of TGS survey operations in Australia, please fill in **Part A**; and/or
- you have experienced a temporary loss of fish catch due to damaged or lost fishing equipment as a direct result of TGS survey operations in Australia, please fill in **Part B**.

PART A - Damaged or Lost Equipment

1. Location, date and time of the incident:

Location: ________________________________

Date: ________________________________

Time ________________________________

N.B. If the date and time of the incident occurring is not known, the applicant should provide the location, date and time that equipment was deployed, and the location, date and time that the damage or loss was discovered.

2. List the equipment damaged or lost to the marine environment. When was the equipment purchased?

Equipment item	Damaged or lost	Date of purchase

3. Provide a summary of the incident (e.g. vessel position, equipment position, equipment depths, fishing operations, weather conditions etc.). Please attach any photo evidence.

4. Are you familiar with earlier damages or lost equipment in this location?

____

____

____

____

5. Please circle your response:

Were you / the fishing vessel crew aware of the location of the seismic survey vessel?	**Yes / No**
Did you register for daily look-ahead reports?	**Yes / No**
Did you receive daily look-ahead reports?	**Yes / No**

6. Did you inform the seismic survey vessel of the location of fishing operations or in-situ fishing equipment?

____

____

____

____

7. Provide costs for the equipment to be repaired or replaced. Please attach supporting evidence, for example, a quote or a receipt.

Equipment item	Cost

PART B - Loss of Fish Catch due to Damaged or Lost Equipment

1. Please circle your response:

   Did you have to abort fishing? If yes, please explain below why fishing was aborted and the duration. **Yes / No**

   ____

   ____

   ____

   ____

2. When did fishing recommence?

   ____

   ____

   ____

   ____

3. Did the damage or loss of equipment result in a temporary loss of fish catch? If yes, please provide the following details:

Species Name	Anticipated loss of catch per fish species (reduced kilograms)	Market price per reduced kilograms at the time the catch would have been sold

Please attach:

1. Catch and disposal records recorded by the vessel for the trip during which the damage or loss occurred; and
2. Monthly catch and disposal records for the vessel for the last 2 years, including the month of the trip during which the damage or loss occurred.

4. Provide details on the value of loss of catch due to damaged or lost fishing equipment.

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